The Welfare Effects of Environmental Conservation Policy: Evidence from Ecuador

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Statement of Originality

I declare that the work outlined in this thesis has not been previously submitted for the requirements of a degree or diploma at any other university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself. I also declare that that this thesis is an original piece of research and has been written solely by me. Any help and assistance that I have received in my research work and in the preparation of the thesis itself have been appropriately acknowledged.

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Abstract

The welfare effects of environmental conservation policy are ambiguous and debated. In particular, there is contention surrounding the effects that common conservation policy tools, such as the establishment of protected areas, have on the welfare of those living nearby. While simple theoretical analyses have suggested that a negative relationship exists between conservation and economic welfare, recent empirical investigations have identified a number of cases where a positive relationship may exist. Divergence between theoretical and empirical results has led to the development of a new theoretical model to explain the relationship between conservation and welfare. The model suggests that a U-shaped relationship exists between conservation effort and optimal welfare, based on the trade-off between the opportunity costs of conservation and the benefits it generates. The model's hypotheses were found to be consistent with empirical evidence in Nepal. This thesis will build on the growing literature investigating the welfare implications of conservation policy, using data from Ecuador to replicate testing of the U-shaped hypothesis. Furthermore, it will extend the literature by incorporating data on Ecuador's Payments for Ecosystems Services (PES) program to empirically test the local welfare effects of a broader set of conservation policies in the context of the U-shaped theoretical model.

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Chapter 1 Introduction

It is well known that the welfare of humanity and the survival of the human race is closely dependent on the health of the natural environment and the range of ecosystems that provide essential support for life (Tisdell, 2005). As the number of species in existence declines and the global human population continues to expand, the importance and value of these vital ecosystems to humankind are likely to rise substantially. One such important biological resource is the remaining unmodified land and forested area left on the Earth. Despite the slowdown in the rate of deforestation and land use change globally in recent years (FAO, 2016), the need to conserve the remaining areas of unmodified land and critically important forested land is ever growing as the human population continues to expand on its path to 9.8 billion people by 2050 (United Nations, 2017). Forests are important predominantly because of the various life-sustaining ecosystem services they provide. These services influence human welfare on local, regional and global scales (Millenium Ecosystem Assessment, 2005; Watson *et al.*, 2018), as well as providing homes to approximately 75% of the world's terrestrial plant and animal life (FAO, 2015, 2016).

Forests provide important regulating services, such as regulating the global climate system by sequestering a significant amount of carbon dioxide (Pan *et al.*, 2011). Reforestation and avoiding deforestation are also seen by many as a low-cost climate mitigation option (Kindermann *et al.*, 2008; Busch & Engelmann, 2017). Furthermore, forests regulate local and regional climate systems and watersheds, which in turn regulates the impacts of droughts and floods (Deo *et al.*, 2009; Sheil & Murdiyarso, 2009). Forests also support agriculture and primary production through the regulation and transport of nutrients and sediments (D'Odorico *et al.*, 2010). Additionally as the majority of terrestrial biodiversity is found in forests, halting deforestation is vital to achieving the reversal of the global biodiversity crisis (Pimm *et al.*, 2014; FAO, 2016). Forests also play a critical role in sustaining the welfare of the world's poorest people, providing products such as food, fresh water and fuel wood. It is estimated 90% of the world's poor depend on forest products for at least a portion of their income (World Bank, 2001; FAO, 2016).

However, due to the high degree of overlap between poverty and tropical forests, there is also a need to balance the goals of conservation with the socioeconomic development goals and the alleviation of poverty for the individuals and communities living in and around conservation areas (Sachs *et al.*, 2009; Barrett *et al.*, 2011). There has long been concern from poverty advocates about the effects of conservation policy on the worlds poorest. Advocates of poverty reduction argue that because conservation policies restrict land-use choices, such as converting land to agriculture, such policies constrain economic development opportunities and can potentially lead to poverty "traps" (Adams *et al.*, 2004; Barrett *et al.*, 2011). As natural resource extraction, and in particular agriculture, often represents the dominant form of income for the word's poorest, some thus argue that the goals of conservation and poverty alleviation are conflicting and cannot be achieved simultaneously (Sanderson & Redford, 2003).

There are two commonly used conservation policies: the establishment of protected areas by national governments, which has been the dominant approach to conserving land and biodiversity historically (Millenium Ecosystem Assessment, 2005; Pullin *et al.*, 2013), and the newly developed Payments for Ecosystem Services (PES) conservation policy tool (IPCC, 2013; Sims & Alix-Garcia, 2017). Protected areas are a form of command-and-control policy instrument aimed at prohibiting activities that alter the natural environment, such as agriculture and natural resource extraction. PES schemes on the other hand are a form of incentive-based conservation policy, aiming to conserve land by altering the incentives faced by agents and ultimately compensating landowners for avoiding ecosystem degradation (Jack *et al.*, 2008). Following the Wunder (2005) definition, a PES contract is a "voluntary transaction in which a well-defined environmental service is 'bought' by a buyer from a provider if and only if the provider continuously secures the provision of that service." PES schemes are therefore defined by their voluntary, conditional and private good nature, whilst protected areas are essentially the public provision of conservation to fix a market failure (Dixon & Sherman, 1991).

While the environmental effectiveness of these policies has been studied in depth, the potential socioeconomic effects of these policies have received little attention. Thus definitive conclusions cannot be reached when consulting the academic literature. On one side, the few theoretical analyses exploring the local welfare impacts of protected areas tend to suggest that a negative relationship exists between protected area conservation and local welfare, whilst the theoretical literatures modelling PES schemes suggests there is potential for a positive relationship between conservation and welfare. However, these outcomes are conditional on the design of the scheme. The empirical literature studying the socioeconomic effects of both conservation policies, on the other hand, display a wide range of divergent results. While some early studies suggest that protected area conservation has had no effect on local economic welfare, recent developments in the methodology used when evaluating the socioeconomic effects of protected areas have highlighted conditions under which a positive relationship exists between protected areas and local economic welfare. Authors of these studies suggest that land protection can in fact have positive effects on human welfare if the opportunity cost of conservation is less than the benefit generated by alternative uses of the land (Sims, 2010; Ferraro & Hanauer, 2011; Ferraro *et al.*, 2011; Yergeau *et al.*, 2017). Conversely, of the few rigorous ex-post evaluations of PES schemes, the empirical literature is mostly in line with theoretical expectations: that PES programs will have insignificant or modest effects on local welfare.

Recognising the divergence in results between the theoretical and empirical literatures on protected areas, Yergeau *et al* (2017) sought to reconcile the difference and build a theoretical model explaining the relationship between conservation and welfare based on the consistent empirical findings emerging in the field. The authors maintain that the reason for the divergence in results is because theoretical models do not account for the development of an alternative sector on conserved land, particularly in the case of protected area-based conservation schemes. The authors thus develop a two-sector model that allows for the development of an alternative sector on conserved land, and show that the relationship between conservation and welfare is U-shaped, based on the trade off between the benefits generated by conservation policies and the alternative industry that develops on conserved land, versus the opportunity costs of conservation based on the potential returns from extractive uses of the land. The authors also theorised that an ecotourism industry was a strong candidate for the alternative sector that may develop on conserved land and generate economic benefits for those living in and around conservation areas. After testing their model on data from Nepal, the authors found promising empirical evidence consistent with their theoretical predictions; there appeared to be a U-shaped relationship between conservation and welfare in Nepal, and the development of an ecotourism industry in Nepal seemed to be a significant mechanism through which conservation policy influenced welfare. The authors conclude that when protected areas are combined with a well-developed ecotourism industry, conservation can indeed be positively related to local economic welfare.

This thesis will seek to replicate the empirical testing of the theoretical model developed by Yergeau *et al* (2017) in order to determine whether the results from their original study apply in different contexts and countries. Furthermore, this thesis will extend Yergeau *et al's* analysis by employing data on Ecuador's payments for ecosystem services program, the Socio Bosque Program, to evaluate the socioeconomic effects of this conservation policy as well as test the generality of the theoretical model. It is well recognised in the theoretical literature on PES programs that for the program to be welfare-enhancing, the incentives associated with the scheme must be greater than the opportunity costs of private land conservation, otherwise landowners will not enrol. This is a similar theoretical prediction to that of Yergeau *et al (*2017) with respect to the development of an alternative industry on protected land, and thus it is relevant to test whether the welfare effects of PES programs follow similar theoretical predictions. Thus, this thesis will also provide a test of the comparative effects of protected area conservation policy and payments for ecosystem services policy. Results from this thesis, outlined in Chapter 4 are promising. Empirical evidence from Ecuador is consistent with Yergeau *et al's* U-shaped hypothesis on the relationship between conservation and welfare, and the Socio Bosque program appear to have had significant positive welfare effects on average, even in its early years.

The remainder of this thesis will proceed as follows. Chapter 2 provides a comprehensive review of the theoretical and empirical literature on the local welfare effects of the two conservation policies of interest in this study: protected areas and payments for ecosystem services schemes. Chapter 3 outlines the data and methodology employed in this thesis, including an overview of Yergeau *et al's* theoretical model and it's hypotheses, an overview of the data sources and the empirical estimation procedure to be undertaken, as well as an overview of Ecuador and a justification for why it is a prime candidate to study the welfare effects of conservation policy. Chapter 4 presents the main results from empirical testing of the main hypotheses of interest and some of their implications. Finally, Chapter 5 will discuss the implications of the results of this study in a broader context as well as some of the limitations of the study.

Chapter 2 Literature Review

This chapter will provide a detailed survey of the academic literature concerning the local welfare effects of environmental conservation policy, splitting up the literature discussion between the two conservation policies of interest to this study. It will begin firstly with a review of the literature analysing the local welfare effects of protected areas, followed by payments for ecosystem services, from a theoretical perspective, before briefly highlighting theoretical analyses of other policies contained in the literature. Subsequently, this chapter will provide a review of the empirical literatures concerning the evaluation of the impacts that the two dominant conservation policies have had on local economic welfare separately, including a discussion of the Yergeau *et al* (2017) paper, as well as a review of the few studies that have comparatively analysed the effects of both policies together. Finally, this chapter will conclude with a discussion of the main gaps in the literature and describe how this thesis aims to generate knowledge to fill these gaps.

2.1 Theoretical Literature

There are two broad themes in the theoretical literature concerning the relationship between conservation and welfare. On the one hand, theoretical papers analysing the effects protected areas have on local economic welfare often arrive at negative conclusions, suggesting that a direct negative relationship exists between conservation and welfare. Explicitly, these papers suggest that increases in conservation effort will lead directly to decreases in local welfare. This finding however is based on fairly restrictive and strong assumptions. On the other hand, the theoretical literature covering the effects that payments for ecosystem services programs can have on local welfare suggest that, under certain conditions, these conservation schemes may in fact lead to improvements in local living standards.

2.1.1 Protected Areas

There are very few papers that explicitly analyse theoretically the relationship between protected areas and local welfare. Ultimately, the theoretical literature covering the relationship between protected areas and local economic welfare broadly arrives at the conclusion that a negative relationship exists between conservation and welfare (Angelsen, 2010). While these papers keep their definition of conservation general, they are essentially analysing the effects of protected areas, predominantly because of the assumptions made about the way in which conservation affects land use choices, as well as the author's interchangeable use of the terms "conservation" and "protected areas". These papers typically use a von Thünen framework to model the welfare effects of conservation policy (Yergeau *et al.*, 2017), as well as making the strong assumption that the establishment of protected areas places a binding restriction on land use options.

The von Thünen model is a model of land use that describes how market forces and spatial dynamics influence the use of different types of land. The set up for the model assumes that land is allocated to the use that yields the highest rent, and the rents of various land uses are determined by their location to the nearest city or major market (Angelsen, 2007). Changes in the rent generated by different uses of the land therefore become the key to explaining changes in land uses and cover. When using this framework to model the socioeconomic effects of protected areas, authors are comparing the rents generated from forested land and the rents generated from agricultural or other extractive activities (Angelsen, 2010). When combining the von Thünen assumption of optimal land allocation with the assumption that conservation places a binding restriction on land use, authors tend to find that conservation policy negatively affects local economic welfare, as they are essentially assuming that no rent can be generated from forested land (Yergeau *et al.*, 2017).

Robalino (2007) employs such an approach in attempting to analyse the effect of conservation on welfare. Using the von Thünen framework, he sets up a two-sector model, consisting of an agricultural sector and a manufacturing sector, to analyse the impact that protected areas have on equilibrium rents and real wages. Employing the assumption that the emergence of protected land implies constraints on that land resources, Robalino finds that protected areas can have important distributional effects through their influence on changing the relative returns to land and labour. The model predicts that protected areas will lead to an increase in aggregate agricultural rents, combined with a decrease in real wages due to higher agricultural prices. Therefore, landowners are on average no worse off, but workers and the landless suffer as a result of the establishment of protected areas. Therefore overall, the effect of protected area conservation policy on local economic welfare is found to be negative.

Robinson *et al*. (2008) and Robinson & Lokina (2011) built a model incorporating spatial and temporal aspects of resource extraction by people living nearby forests, and used this model to examine the effects of establishing strictly protected areas on local's utility. Local people's utility is influenced by availability of forest resources and the distance cost associated with traveling to and from a renewable resource-harvesting site, i.e. a forest. Solving their model, the author's results suggest that after the establishment of protected areas, villagers must travel further to access forest resources, increasing their distance costs and therefore leading to a decrease in utility and welfare. The authors suggest that permitting villagers to collect sustainable amounts of forest products for free, or a small fee, can help with both the success of the conservation area as well as sustaining local livelihoods.

In each of these expositions, the authors have essentially assumed that no benefits can be derived from conserved land, since protected areas place a binding restriction on land use. As Sims (2010) highlight, the assumption that protecting land leads to a binding constraint on land use that does not generate any local-level benefits means that diminishing marginal returns to fixed land cause a decrease in total rent. Therefore protection causes workers to relocate, increasing labour supply and decreasing real wages. Overall, the effect of protected areas on welfare is negative. However, this result follows from the binding land constraint assumption, which is a very strong assumption. Relaxing this assumption may in fact lead to entirely different conclusions. Several reviews on the social and economic impacts of protected areas have highlighted that this assumption may be unrealistic. Coad *et al* (2008), Dixon & Sherman (1991) & Wunder (2001) all recognise the potential for ecotourism to develop as an alternative productive industry on protected land, providing employment opportunities and a flow of economic benefits that offsets some of or all of the opportunity costs of protected area conservation. These reviews also highlight the potential for payments for ecosystem services programs to both conserve land and improve the living standards of those living in and around conservation areas. Intuitively, a well-designed PES program will provide incentives that offset the opportunity costs of conservation in order to encourage private agents to enrol in the program, potentially contributing to aggregate welfare increases for people living around such conservation areas.

2.1.2 Payments for Ecosystem Services

While the few papers analysing the effects of conservation via protected areas on local economic welfare suggest that a negative causal relationship exists, the literature examining the effects of PES arrives at the opposite conclusion. The key result identified in the literature is the significant relationship between the positive-welfare potential of PES schemes and the low agricultural potential of land being considered for conservation. More generally, these papers highlight that for conservation to be welfare improving, the benefits from conservation policy, such as PES compensation, must be greater than the opportunity cost of the land being conserved. This is an important result and one that the empirical literature on the welfare effects of protected areas has recently recognised. Furthermore, these papers highlight the importance of secure property rights over the land in capturing the private benefits generated by PES mechanisms.

Wang, Poe & Wolf (2017) analyse the potential success of PES programs with respect to the distribution of wealth between buyers and sellers of ecosystem services in a Coasian transaction framework of bargaining. Starting from neoclassical utility foundations, the authors set up a model of aggregate demand and aggregate supply of ecosystem services as a function of income, wealth and utility. The buyers of ecosystem services in this model are assumed to be urban residents, whilst the suppliers are private rural landowners. Solving their model, the authors find that PES schemes will be more successful when the wealth disparity between buyers and sellers is higher, with the wealth distribution skewed towards the buyers. This is because higher income populations tend to express higher willingness to pay and lower income populations express a lower willingness to accept. This leads to more contracts signed and thus a more successful program, but importantly also suggests that welfare gains from PES programs are enhanced by wealth disparities between buyers and sellers. Furthermore, the authors recognise that wealth disparities are greater when the agricultural productivity of the land being considered is low, leading to lower agricultural rents. Their model ultimately suggests that PES schemes may not only be environmentally effective and economically viable, but socially progressive as well by reducing wealth disparities, both within countries and across countries.

Zilberman, Lipper & McCarthy (2008) undertake a similar analysis to determine how PES payments impact the livelihoods of the poor. The authors also construct an aggregate demand and supply model built from neoclassical foundations to measure the demand and supply of environmental services compared to agricultural goods when a PES scheme is introduced. Using this model, they evaluate the effects of a PES scheme on three groups of poor; the urban poor, the landless poor and poor landholders. Their conclusion rests on the assumption that a landowner will join a PES program if doing so generates more income than the rent they could generate from agricultural production. They find that when ecosystem service supply and agricultural productivity are negatively correlated, and the poor own lands of low agricultural quality, then PES programs can have significant positive impacts on the livelihoods of poor landholders. For the urban and landless poor, the effect that PES schemes have on their livelihoods depends on how it affects the price of agricultural products and wages. But the key finding is that, assuming poor landowners have secure property rights over their land, and their land is of low agricultural potential, then PES is likely to be highly beneficial for local livelihoods.

Pagiola, Arcenas & Platais (2005) similarly explore how payments for ecosystem services may help to reduce poverty. They suggest that payments for ecosystem programs can be both socioeconomically and environmentally effective when the program is well designed and local conditions are favourable. The impact depends on how many participants in the program are poor, their ability of the poor to participate, and the amounts paid to each participant. For land owning participants in the program, the overall impact of the program on their livelihoods depends on the difference between the amount of incentive payments and the opportunity cost of enrolling in the program and conserving land. For nonparticipants, such as farm workers and people dependent on non-timber forest products collection, the impact on their welfare depends on local conditions. For farm workers, their welfare impacts depend on the relative labour needs of PES-promoted practices compared to traditional practices and other employment opportunities. For people dependent on non-timber forest product collection, their welfare impacts depend on the nature of traditional and PES-promoted practices, i.e. whether PES programs will lead to greater restrictions on land access when compared to traditional practices. The authors also highlight that negative effects can occur when property rights are insecure or if PES programs encourage less labour-intensive practices, leading to a fall in wages for poor rural workers.

2.1.3 Other literature

An alternative paper analysing the socioeconomic effects of conservation is one by Anthon *et al*. (2008), which examines the effects of taxing marketed forest products as a means to conserve forested area. The authors develop and solve a theoretical model that suggests a trade-off exists between using taxation as conservation policy and poverty alleviation. Furthermore, despite intuitive belief, the authors suggest that taxing forest products may even lead to increases efforts in forest resource utilisation, as the burden for such taxation often falls on very poor households who don't have many options for labour utilisation. But importantly, as producers of forest products are often the very poor, taxing their use of forest products leads to declines in the income of the poorest people living around forests. Assuming no economic benefits flow from the use of taxation as conservation policy, taxing forest resources will therefore have negative effects on the welfare of those living in and around conserved forests.

2.2 Empirical Literature

There are a large number of empirical analyses examining the impacts of conservation policy on local welfare. However, the majority of empirical studies are qualitative in nature, focused on judgements and discussing issues such as justice and rights, rather than quantitatively analysing the socioeconomic impact of conservation policy (Tumusiime & Vedeld, 2015). Furthermore, of the quantitative empirical studies, only few studies use appropriate methodologies and study designs to properly isolate the cause and effect mechanism between conservation policy and economic welfare. Early studies often use sub-optimal proxies for economic welfare and don't employ appropriate methodology to control for the non-random assignment of conservation areas (Andam *et al.*, 2010).

The empirical literatures on both conservation policies of interest arrive at similar conclusions; under certain conditions, conservation policy can in fact have positive effects on local welfare. There are substantially fewer rigorous evaluations of the effects of payments for ecosystem services programs on poverty and welfare, likely because it has only recently began to be implemented.

2.2.1 Protected Areas

While the theoretical literature analysing the effect of protected areas on economic welfare generally predicts a pessimistic outcome, the empirical literature is much more diverse.

A number of studies into the effect of protected areas found either no significant impact of protected areas on local economic welfare, or small negative impacts. Early studies such as those by Duffy-Deno (1998) and Lewis *et al*. (2002) & (2003) each evaluated the effect of protected areas on local economic welfare in specific regions of the United States. Duffy-Deno (1998) attempts to determine whether local economies are adversely affected by the designation of protected areas in the intermountain western US using a disequilibrium model of population and employment growth, and finds no evidence for an adverse effect on population-density or employment, using a sample of 250 nonurban counties. Lewis *et al*. (2002) & (2003) similarly seek to quantify the effect that public conservation lands have on both employment growth and wages in the Northern Forest Region of the US. Using a model of simultaneous employment and net migration growth, the authors find that the existence of public conservation lands has no significant effect on employment or wage growth rates.

Later studies such as Bandoyopadhyay & Tembo (2009) Clements *et al*. (2014), Tumusiime & Vedeld (2015) and Miranda *et al*. (2016) analysing the effects of protected areas on local economic welfare reach similar findings. Bandoyopadhyay & Tembo (2009) analyse how game management areas in Zambia affect the economic welfare of household living in around such areas. They find that the impacts are large for active participants in natural resource management and others living in conservation areas, but the gains are unevenly distributed. Only four areas were found to show significant benefits generally, while the poor in all areas were not found to benefit even when participating.

Similarly, Clements *et al*. (2014) finds no evidence that protected areas exacerbated local poverty or reduced agricultural harvests in an analysis of two protected areas in Cambodia, with the significant benefits generated by conservation accruing to a select group of households. Miranda *et al* (2016) find that while protected areas reduced deforestation in the Peruvian Amazon, they had no robust effect on poverty using matching techniques, which the authors suspect is due to the fact that the majority of protected areas evaluated had low ecotourism potential.

On the other hand Tumusiime & Vedeld (2015) analyse the effect of a strict protected area on household livelihoods in South-Western Uganda, finding negative welfare effects associated with protected areas. The authors suggest that proximity to protected areas is associated with lower income and restricted access to resources. Overall, average households accrued a net annual loss of 12.5% of total incomes.

However, some of these studies have been criticised for using questionable methodologies that do not appropriately isolate the causal effect on protected area assignment on the socioeconomic variables (Andam *et al.*, 2010). Particularly, some of the studies fail to control for the non-random assignment of protected areas, as well as often using sub-optimal proxy's for socioeconomic welfare (Andam *et al.*, 2010). Controlling for the non-random assignment of protected areas in particular is crucial, as protected areas are often established on land of low agricultural potential (Millenium Ecosystem Assessment, 2005), a fact that theoretical analyses of PES schemes also recognises. Failing to control for the covariates that determine both the establishment of protected areas and lands of low agricultural potential, and therefore conventional economic development potential, leads to unfavourable assessments of the welfare effects of protected areas.

Recognising these limitations of earlier studies, a number of later studies have employed appropriate methodologies developed by Ferraro (2008) to correctly isolate the causal effect of protected areas on local economic welfare. When controlling for the geographic covariates of conservation and welfare potential, as well as common socio-demographic variables that determine welfare, these studies often find strong positive effects of protected areas on local welfare, particularly where poverty is higher. Ferraro (2008) suggests that a credible study on the welfare effects of conservation policy must include the following elements:

- Objectively measurable indicators of human welfare at an appropriate scale of analysis.
- Observations of the relevant indicators before and after the establishment of conservation. If no pre-establishment observations are available, use some other control for the initial state and trend of social welfare.
- Observations of the relevant indictors from both treated units and control units.

- Observations of pre-establishment characteristics that affect both where conservation areas are located and how the selected indicators of human welfare change over time.

Studies by Andam *et al* (2010), Sims (2010), Ferraro & Hanaeur (2011), Ferraro *et al*. (2011), Canavire-Bacarreza & Hanauer (2013) and Robalino & Villalobos-Fiatt (2015) all found positive socioeconomic impacts associated with protected areas in Costa Rica, Thailand and Bolivia after controlling for the covariates of conservation and poverty, common determinants of welfare and using primary data objectively measuring economic welfare, such as expenditure data or asset-based poverty data. Furthermore, Canavire-Bacarreza & Hanauer (2013) were the only authors in this group to find that when including geographic controls, the positive effect that protected area conservation had on poverty was less than without the controls. The main geographic controls identified as being highly correlated with the location of conservation areas and human welfare are slope, elevation and distance from a major city (Ferraro *et al.*, 2011). Slope and elevation of the land are highly correlated with agricultural potential; the steeper slopes are, or the higher the ground is from sea level, the less the land is suited to agriculture and therefore the lower the opportunity costs of protection. Likewise, distance from a major city is highly correlated with low economic development. Thus, these studies show that the use of appropriate geographic controls is important to properly isolate the effect of the establishment of protected areas.

The key necessary condition developed from these studies for a positive conservation-welfare relationship in the context of protected areas is that the opportunity cost of conservation, i.e. the return to agricultural land, must be less than the benefit generated by alternative uses of the land (Sims, 2010; Ferraro & Hanauer, 2011; Ferraro *et al.*, 2011; Sims & Alix-Garcia, 2017; Yergeau *et al.*, 2017). Another key result arising from these papers was the identification of ecotourism as a potential channel through which protected areas may positively influence economic welfare (Ferraro & Hanauer, 2014), thereby relaxing the assumption employed in the theoretical literature that conservation places a binding restriction on land use choice.

2.2.2 Recent Literature Developments

Developments in the empirical literature evaluating the welfare impacts of protected area conservation motivated Yergeau *et al* (2017) to develop a theoretical model to explain the overall relationship between conservation and welfare, based on empirical findings, and ultimately reconcile the gap between theoretical and empirical literatures. The authors develop a two-sector model made up of an extractive sector and an environmental sector. Conservation exogenously constrains production in the extractive sector as in Robalino (2007). However, unlike Robalino (2007), conservation also allows for the development of an alternative industry. This is the first model of the welfare effects of conservation policy that allows an alternative, income-generating sector to develop due to conservation. Their model suggests that a U-shaped relationship exists between conservation and welfare, based on the trade-off between the opportunity costs of conservation and the economic benefits generated from conservation policies. When conservation effort is low, there is a negative relationship between conservation and welfare. After a certain level of conservation effort however, the relationship becomes positive. The model will be discussed in greater depth in Chapter 3. Yergeau *et al* (2017) tested their new theoretical model using data from Nepal, with results consistent with their U-shaped relationship hypothesis. Their study however only studied protected areas, and they suggest that ecotourism in protected areas was the dominant mechanism through which conservation policy positively influenced local economic welfare in Nepal.

2.2.3 Payments for Ecosystem Services

There are substantially fewer evaluations of the local welfare effects of PES schemes, most likely because it is a relatively new policy and there are far less operating PES schemes than protected areas. Furthermore, while the theoretical literature analysing the effects of PES schemes highlighted the potential for significant positive welfare benefits, rigorous empirical analyses have so far concluded that PES have had positive but mostly insignificant impacts on local livelihoods (Liu & Kontoleon, 2018). For the most part, evaluations of payments for ecosystem services programs have focused on how participation in a program influences the living standards of ecosystem service providers, or those who own the land. Very few studies focus on the local welfare effects of payments for ecosystem services conservation policy.

Robalino *et al* (2014) evaluate the local effects that Costa Rica's national payments for ecosystem services had on poverty and socioeconomic outcomes between 2007 and 2009. They recognise the fact that PES programs can potentially address poverty concerns by alleviating poverty amongst poor landowners through the use of conditional cash transfers. However, the authors also recognise that payments for ecosystem services might also affect individuals who do not directly receive payments in places where contracts are implemented. One hypothesis is that the conservation of land will reduce employment in the agricultural sector for non-landowners, leading to increases in poverty. On the other hand, forest conservation could increase employment related to tourist activities and therefore reduce poverty. The authors find that when controlling for individual and locality characteristics that affect location decisions, the effect of PES on poverty outcomes at a national level is not statistically different from zero, or of very low magnitude. They suggest that this result implies that PES programs may have heterogeneous effects on poverty based on geographic characteristics. To test this, the authors split the sample according to slope of terrain. They find that PES contract coverage and welfare are positively related in high-sloped terrains, and negatively related in low slope terrains. This implies that the incentives associated with the program were not enough to offset the opportunity costs of conservation in low-sloped areas, but were enough to offset opportunity costs in high-sloped areas. Overall, they conclude that Costa Rica's payments for ecosystem services program had no effect on poverty. To my knowledge, this is the only study of its type that evaluates the local welfare effects of payments for ecosystem services nationally.

There is a range of studies however that evaluates the effects of payments for ecosystem services programs on the welfare of ecosystem service providers. A meta-analysis of 27 rigorous causal statistical studies covering the effects of 15 PES programmes on the livelihoods of suppliers of ecosystem services in the developing world was recently conducted by Liu & Kontoleon (2018). This is the first robust quantitative synthesis of available empirical evidence on the livelihood impacts of PES schemes, using only studies that evaluate the impact of PES schemes using statistical techniques that control for confounding variables. Overall, the authors find that PES programs have only had modest positive effects on local livelihoods. They also highlight however that some institutional characteristics are highly correlated with positive livelihood impacts; that payments are high, there is a high degree of voluntary participation, transaction costs are low, and landowners have access to alternative income sources. Thus the authors argue that PES schemes possessing these characteristics will be more beneficial socioeconomically.

Some of the peer-reviewed, robust ex-post evaluations of PES schemes around the world include those by Uchida *et al*. (2007), Hegde & Bull (2011) and Alix-Garcia *et al*. (2015). All studies find small or insignificant, but positive socioeconomic effects associated with PES schemes in Costa Rica, Mexico, China and Mozambique.

2.2.4 Combined Comparative Analyses

To date there are very few rigorous comparative analyses of the effects of protected areas and PES schemes on local welfare. One such study by Clements & Milner-Gulland (2015) measures the impacts on both forest cover and human well-being of three PES programs situated in two protected areas in Northern Cambodia, using a panel of intervention villages and matched controls. They find that both PES and protected areas reduced deforestation rates significantly, while only the two high paying PES programs had significant positive welfare impacts.

Sims & Alix-Garcia (2017) on the other hand provide the first national-scale comparison of the two land conservation instruments across both environmental and social outcomes in Mexico. They find that the PES scheme was more socioeconomically effective, leading to a 10-12% decrease in poverty, while protected areas were more environmentally effective but had no statistically significant impact on poverty. On average, localities with conservation policies in place showed improvements across all poverty indicators. They also split up protected areas into their separate IUCN designations, and PES payments into the major PES goals; hydrological services, biodiversity conservation and carbon capture and storage. They find trade-offs between environmental effectiveness and poverty alleviation, suggesting that not one single park or PES designation can achieve the best environmental and socioeconomic outcomes simultaneously. However they suggest that to aid the achievement of both goals, conservation policies should be well funded, well enforced and clearly zoned, while allowing for some continued local resource extraction. Furthermore, they identify the role of ecotourism in protected areas as a mechanism that positively influences local welfare.

2.2.5 Literature Conclusions and Implications

While traditional theory suggests that conservation policies will yield negative welfare outcomes for local communities, recent developments in empirical evaluation has contributed to a change in understanding about how conservation policy may impact local welfare. Newly developed theory by Yergeau *et al* (2017) summarises these empirical developments and states the necessary condition for a welfare-positive relationship: that the opportunity cost of land conservation must be less than the benefit generated by alternative uses of the land. Such alternative uses have been identified as the establishment of a productive industry, such as ecotourism, on protected land, or the implementation of payments for ecosystem services schemes to compensate landowners for avoiding land clearing. In the case of PES programs, it is also important that landholders have secure property rights over their land in order to ensure the success of the program both environmentally and socioeconomically (Zilberman *et al.*, 2008; Angelsen, 2010).

Further investigation into the welfare effects of conservation is undoubtedly needed. This thesis will contribute to the literature in two ways. Firstly, it will be the first known empirical replication of the empirical component Yergeau *et al* (2017) study in a different context, applying their newly developed theory on the causal relationship between conservation and welfare using data from Ecuador. Secondly, it will extend the Yergeau *et al* (2017) study by not only evaluating the effects of protected areas, but also incorporating data on Ecuador's PES scheme, the Programma Socio Bosque, thus providing a nation-wide evaluation of the relative effects of protected areas versus PES schemes in the context of Yergeau's theoretical model.

As empirical evidence on PES schemes have displayed small but positive livelihood effects, and the theoretical literature on PES programs highlighted both the positive welfare potential of PES and that the benefit from PES must be greater than the opportunity cost of

PES enrolment, it is a reasonable assumption that similar effects should be observed between the two policy instruments.

This thesis will also have important implications for conservation work and poverty alleviation efforts. If it is found that conservation policies have had a positive effect on local welfare in Ecuador, then my thesis will contribute to the growing evidence supporting the idea that conservation and poverty alleviation are not necessarily conflicting goals. Furthermore, it may also give support to the use of protected areas and PES policies as effective development policies in areas that have low levels of agricultural potential. And ultimately, even if it is found that protected areas and PES schemes have had no significant effect on socioeconomic welfare, the use of the policies could still be Pareto efficiency improving, due to the significant and highly beneficial regional and global ecosystem services provided by forests to people around the world (Tisdell, 2005; Barrett *et al.*, 2011).

Chapter 3 Data and Methodology

This chapter begins first by introducing and explaining the theoretical model formulated by Yergeau *et al* (2017) and the econometric procedure to be used to test the hypotheses of this model. Secondly, this chapter will give an overview of the primary data sources collected and used in this thesis to test the theoretical predictions of Yergeau *et al's* (2017) model. Finally, this chapter will briefly describe the Ecuadorian context for the study and why Ecuador serves as a strong case study to evaluate the welfare effects of conservation policy.

3.1 Yergeau et al's U-Shaped Hypothesis

3.1.1 The model

The following is a brief description of the model developed and set out in Yergeau *et al's* paper. The full derivation and explanation of the model is reported in Appendix A. The model is a static two-sector model, made up of an extractive (x) and an environmental (v) sector. The extractive sector comprises any activities whose production leads to an alteration or degradation of the natural environment, such as agricultural activities, timber harvesting and the harvesting of other non-timber forest products. The extractive sector produces an extractive good. The environmental sector on the other hand is an alternative sector that develops because of the conservation of land, and produces an environmental good. The environmental sector therefore becomes the mechanism through which conservation can influence welfare. It is assumed that the mechanism is market-based and therefore the environmental good is private. Production in the extractive sector has a negative effect on the environmental sector through the alteration of the natural environment on which the environmental sector is dependent. In turn, the environmental good is produced out of environmental quality. In Yergeau *et al's* theoretical set up, one local agent allocates their time between the extractive and environmental sectors. The agent derives their welfare from cash income that they earn from allocating time in either sector. It is assumed for the sake of simplicity that there is a one to one relationship between income and consumption. Finally, a central planner aims to maximise social welfare by determining the allocation of labour between the two sectors and thus the quantities of the extractive good and the environmental good to be produced.

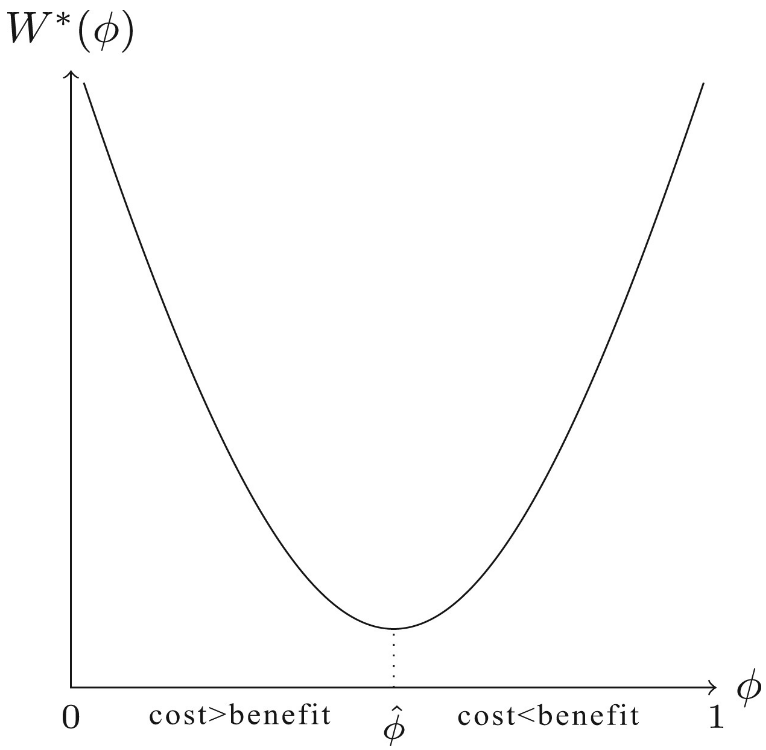
3.1.2 Conservation and optimal welfare

The primary hypothesis of Yergeau *et al*'s model is outlined in Proposition 1, which describes how optimal welfare varies according to the value of ϕ, a parameter measuring conservation effort.

Proposition 1. Optimal welfare, $W^*(\phi)$, and conservation, ϕ, exhibit a U-shaped relationship.

Proof of proposition 1 is reported in Appendix A. Proposition 1 states that when ϕ is low, an increase in ϕ will lead initially to a decrease in welfare, at a decreasing rate. After a certain value of ϕ, increases in ϕ will start to generate increases in welfare, at an increasing rate. What this means is that when conservation efforts are low, the environmental sector does not have much opportunity to develop compared to the already established extractive industry, and thus intuitively losses from the extractive sector are more important than productivity gains in the environmental sector. The opportunity cost of conservation is thus higher than the benefits generated by conservation, leading to decreasing welfare effects of conservation initially. However, as conservation effort, ϕ, gets stronger, the environmental sector is able to develop more and generate greater benefits, which in turn lowers the rate at which welfare decreases. Finally, after some level of conservation effort, benefits from the environmental sector begin to outweigh the opportunity cost of conservation, and the relationship between conservation and welfare shifts from negative to positive. The turning point at which this occurs is interpreted as the point at which the opportunity cost of conservation is equal to the benefit generated by conservation, at which point landowners and other stakeholders are indifferent between conserving and not conserving land. Figure 3.1 displays the graphical relationship between conservation and optimal welfare.

Figure 3.1: Theorised relationship between conservation and welfare



Source: *Yergeau et al (2017).*

3.1.3 Mechanisms

Yergeau *et al* (2017) hypothesised that certain productive activities on conserved land would produce an environmental good, which provides the mechanism through which conservation positively affects economic welfare. In their model, they assumed that the good was private, and thus conservation would only affect economic welfare through market channels. In their study, Yergeau *et al* (2017) hypothesised that the development of an ecotourism industry would produce the environmental good through which conservation positively affected welfare, a theoretical result that was deemed to be empirically valid. However, they also highlighted the potential of other market-based conservation mechanisms, such as payment for ecosystem schemes and integrated conservation and development programs (ICDPs), to enable a welfare-positive relationship. As they kept the definition of the environmental good general amongst private market-based mechanisms, an important extension of their study is to test whether other market-based mechanisms, such as PES and ICDPs schemes had similar effects in moderating the relationship between conservation and welfare.

3.2 Econometric Procedure

3.2.1 Testing the U-Shaped Hypothesis:

To test the hypothesis that there is a U-shaped relationship between conservation and optimal welfare, an econometric procedure must be used that specifies a non-linear functional form. As per the procedure carried out by Yergeau *et al* (2017), this thesis will test the U-shaped hypothesis by using standard OLS regression, but including squares and cubes of the variable of interest, the proportion of land under conservation, to decide whether a non-linear relationship exists, and if so, whether this relationship resembles the U-shaped model hypothesised.

The main equation of interest to test the U-shaped hypothesis is equation 3.1.

$$exp_{ij} = \beta_0 + \beta_1 cons_j + \beta_2 cons_j^{sq} + \beta_3 cons_j^{cu} + \beta_4 farm_{ij} + \beta_5 H_{ij} + \beta_6 G_j + \varepsilon_{ij}. \qquad \textit{Eq 3.1}$$

where exp_{ij} is the per household final annual consumption expenditure of household i in canton j, $cons_j$ is the per canton share of area conserved under either a protected area or a payments for ecosystem services contract, $farm_{ij}$ is income from agricultural activities for household *i* in canton *j*, H_{ij} is a vector of household level controls controlling for the common determinants of differences in expenditure and welfare, G_j is a vector of geographic controls per canton *j* that co-determine the existence of conservation and poverty, and ε_{ij}, a random error term for household *i* in canton *j*. Equation 3.1 specifies a non-linear parametric relationship between household expenditure on one side of the equation, and conservation on the other. Coefficients β_1, β_2 and β_3 would all have to be significant for a non-linear relationship to be observed between welfare and conservation effort.

3.2.2 Testing the ecotourism hypothesis

Yergeau *et al* (2017) also hypothesised that ecotourism is a mechanism that turns the existence of protected areas into a market-based mechanism that positively influences welfare in Ecuador. The first test of this hypothesis is to be conducted by estimating Equation 3.2. Equation 3.2 is made by adding a variable $tour_j$ to Equation 3.1, which measures the number of tourist arrivals to protected areas in canton *j* in 2011.

$$exp_{ij} = \beta_0 + \beta_1 cons_j + \beta_2 cons_j^{sq} + \beta_3 cons_j^{cu} + \beta_4 farm_{ij} + \beta_5 tour_j + \beta_6 H_{ij} + \beta_7 G_j + \varepsilon_{ij}. \qquad \textbf{\textit{Eq 3.2}}$$

This tests the assumption that the relationship between conservation and welfare is conditional on the development of an alternative environmental sector, ecotourism. The coefficient β_5 should be significant and positive to support this hypothesis.

There is potential for reverse causality between tourist arrivals and consumption expenditure, meaning that tourist arrivals could potentially be an endogenous regressor. An instrumental variable two-stage least squares (IV2SLS) regression approach can be used to test for potential reverse causality. This test will use tourist arrivals from 2008 as an instrument for the ecotourism variable. The regressions to be estimated to conduct this test are outlined in Equations 3.3 and 3.4 below.

$$tour_j = \beta_0 + \beta_2 tour08_j + \beta_2 cons_j + \beta_3 cons_j^{sq} + \beta_4 cons_j^{cu} + \beta_5 farm_{ij} + \beta_6 H_{ij} + \beta_7 G_j + \varepsilon_{ij}. \quad Eq\ 3.3$$

Equation 3.3 is the first step in the IV2SLS estimation procedure, involving regressing the ecotourism variable on all explanatory variables of Equation 3.1, plus the instrumental variable $tour08_j$, which measures the number of tourist arrivals to protected areas per canton *j* in 2008. To be a valid instrument, $tour08_j$ must be highly correlated with $tour_j$, but not with exp_{ij}. To test the correlation between the $tour_j$ and $tour08_j$, an F-test should be performed on β_2 in Equation 3.3. Due to the time difference in observations between $tour08_j$ and the dependent variable, it is reasonable to assume that there is no correlation between the instrument and the dependent variable.

Once the validity of the instrument has been tested, IV2SLS estimation can proceed. Fitted values for the dependent variable from equation 3.3 are to be saved and used in Equation 3.4 as $\widehat{tour_j}$ in place of the original ecotourism variable. For the endogeneity concerns of $tour_j$, to be ameliorated, the coefficient β_5 from Equation 3.4 should not be significantly different from that of Equation 3.2.

$$exp_{ij} = \beta_0 + \beta_1 cons_j + \beta_2 cons_j^{sq} + \beta_3 cons_j^{cu} + \beta_4 farm_{ij} + \beta_5 \widehat{tour_j} + \beta_6 H_{ij} + \beta_7 G_j + \varepsilon_{ij}. \quad Eq\ 3.4$$

Finally, to further evaluate the extent to which ecotourism is a mechanism through which conservation affects welfare in Ecuador, Equation 3.5 is to be estimated:

$$exp_{ij} = \beta_0 + \beta_1 PA_j + \beta_2 Tour_j + \beta_3 inter_j + \beta_5 farm_{ij} + \beta_6 H_{ij} + \beta_7 G_j + \varepsilon_{ij} \quad Eq\ 3.5$$

where PA_j is the share of land in canton *j* conserved under only a protected area designation, $Tour_j$ remains the number of tourist arrivals to protected areas in canton *j* and $inter_j$ is an interaction variable between PA_j and $Tour_j$. Estimating this regression tests to see whether there is an interaction effect between the establishment of protected areas and the arrival of tourists in each canton, and the inclusion of the interaction term modifies the interpretation of the coefficients slightly. β_1 now measures the welfare effect of protected area conservation on welfare when there are no tourist arrivals in a canton and β_2 measures the effect of ecotourism on welfare when the protected area share of a canton is equal to zero. β_3 thus captures the effect of the combination of both ecotourism and protected area conservation on welfare. The marginal effect of ecotourism on welfare will be equal to $\beta_1 + \beta_3 Tour_j$, which depends on the level of ecotourism in a given canton.

3.2.3 Testing the PES mechanism and comparing welfare effects

To test whether payments for ecosystem services in Ecuador serve as a mechanism through which conservation can influence welfare, it is simply necessary to estimate the effect that the share of land under a payments for ecosystems services contract has on consumption expenditures. Payments from the Ecuadorian national government are conditional on monitored outcomes and are linked to the amount of land under a conservation contract: intuitively, larger amounts of land conserved result in larger payments for ecosystem services. Therefore the benefit generated by PES schemes, i.e. the environmental good, is directly tied to the amount of land conserved under a PES contract. Thus the share of land conserved under a PES contract should provide a reliable estimate for the overall mechanism effect of PES. To test the PES mechanism, Equation 3.6 is to be estimated.

$$exp_{ij} = \beta_0 + \beta_1 PES_j + \beta_2 farm_{ij} + \beta_3 H_{ij} + \beta_4 G_j + \varepsilon_{ij}. \qquad \textit{Eq 3.6}$$

where PES_j is the proportion of land conserved under a payments for ecosystems services contract in canton *j*.

To contrast and compare the relative welfare effectiveness of protected areas and payments for ecosystem conservation programs Equations 3.7 and 3.8 are to be estimated.

Equation 3.7 directly compares the differences in welfare effects associated with the share of land in an area conserved under either a protected area or a payments for ecosystems services contract, and follows a similar specification to that employed by Sims & Alix-Garcia (2017) in their evaluation of conservation schemes in Mexico. Equation 3.8 extends 3.7 slightly to include the dynamics associated with ecotourism in protected areas in order to compare whether ecotourism is a more effective mechanism than PES schemes.

$$exp_{ij} = \beta_0 + \beta_1 PA_j + \beta_2 PES_j + \beta_3 farm_{ij} + \beta_4 H_{ij} + \beta_5 G_j + \varepsilon_{ij}. \qquad \textit{Eq 3.7}$$

$$exp_{ij} = \beta_0 + \beta_1 PA_j + \beta_2 Tour_j + \beta_3 inter_j + \beta_4 PES_j + \beta_5 farm_{ij} + \beta_6 H_{ij} + \beta_7 G_j + \varepsilon_{ij} \qquad \textit{Eq 3.8}$$

3.3 Data Description

3.3.1 The ENIGHUR (2011-2012) survey data

The National Urban and Rural Household Income and Expenditure Survey (ENIGHUR) is a household budget and living standards survey conducted by the Department of Sociodemographic Statistics (DIES), a department within Ecuador's national statistics institute INEC. The ENIGUR survey has the primary objective of providing a comprehensive view of household budgets in terms of the structure, amount and distribution of income and expenditure of households in both urban and rural areas, including information on the socioeconomic and demographic characteristic of household members as well as the characteristics of housing assets, infrastructure and equipment. INEC uses the information provided by the ENIGHUR survey for a number of reasons, including to measure poverty, update the basis of calculation for the Ecuadorian CPI and to understand the consumption habits of households.

INEC have carried out similar surveys in the past to gain information about household budgets and spending habits. However, previous surveys have focused on predominantly the income and expenditure of households in urban areas, with only one survey of rural households being conducted, and no combined urban and rural household survey, After a change in methodological and informational requirements, INEC extended their coverage of surveys to include urban and rural areas and thus the ENIGHUR 2011-2012 survey is the first countrywide survey on both urban and rural household income and expenditures. Furthermore, the sample area was broadened in order to sample households in both the Amazon and the Insular Region. Sampling, surveying and data collection were carried out over the course of 2011, and the data collated and released in 2012.

The primary data for this thesis is per household final annual consumption expenditures obtained from the ENIGHUR 2011-2012 survey. The sample size obtained in the survey was 40,932 dwellings, distributed in 3,411 sectors, of which 12 houses were selected for each sector. The survey covers all 24 of Ecuador's provinces and it's 221 cantons, the penultimate administrative division. To avoid biasing the results of the study, the sample is restricted to exclude data gathered from households in the Insular Region, or the Galapagos Islands, from the data analysis. 96.7% of the terrestrial land area of the Galapagos islands is reserved for the maintenance of natural ecosystems under the protection of the Galapagos National Park, with only the remaining 3.3% of land area available for human use (Villacis & Carrillo, 2013). Accordingly, tourism is the islands main economic activity, while agricultural activity plays a markedly smaller role in the islands economy. Agricultural expansion however has not only been hindered by geographic factors that reduce potential returns from agriculture; rather the early establishment of the Galapagos National Park and state restrictions on agricultural activity has halted its expansion. Due to it's significant and mostly untouched biological diversity, it is likely that the Galapagos Islands have a high potential for agriculture and thus high opportunity costs from conservation. For these reasons, households residing in the Galapagos Islands region are excluded from the study as these observations will likely bias the results of the study in favour of a positive conservation-welfare relationship. This results in a reduced final dataset of 39012 households.

The ENIGHUR survey also provides household level data measuring per household income from agricultural activities, which is used as a measure of the extractive sector benefit or extractive consumption measure. This is an important variable of interest to this study, as this study is interested in comparing how local households benefit from conservation policy against the benefit associated with traditional extractive industries. Agriculture is the dominant source of extractive sector benefit in developing countries, and thus income from agricultural activities acts as a good proxy for extractive good benefit. Finally, ENIGHUR provides household level data used to control for the common determinants of expenditure and differences in expenditure between households, including the ethnicity, sex, age and education level of the head of the household, the size of the household, and the value of housing and other non-farm assets.

3.3.2 Conservation Data

To obtain a measure of the welfare effects of conservation in Ecuador, a measure of conservation effort is needed. Following the specification of Yergeau *et al* (2017), the proportion of a canton's area that is under a form of conservation is used as a proxy for conservation effort. It is of interest to this study to evaluate both the overall effect of conservation policy on welfare, as well as compare the welfare effects of the two predominant conservation instruments used by the Ecuadorian national government, the establishment of protected areas and the use of payments for ecosystem services.

To obtain data for the variable measuring protected area based conservation, ArcGIS geographic information system software was used as in Yergeau *et al* (2017). The variable was created by mapping the borders of protected areas in Ecuador, then measuring the area of each canton that is designated as protected according to these borders, before calculating the proportion of each cantons land area under protection. To obtain data for the variable measuring the level of conservation effort associated with payments for ecosystem services methods, a similar approach is taken, taking the proportion of each canton's land conserved under a private payment for ecosystem services contract between the national government and individual landowners or collective agreements. This is the same specification that Sims & Alix-Garcia (2017) employed in their study comparing the effects of protected areas and PES schemes in Mexico. This data however was obtained from Krause & Loft's (2013) dataset used to analyse the distribution and equity of benefits associated with Ecuador's PES scheme. Krause & Loft's dataset includes relevant data on the size of agreements, starting date of contract, yearly payments and the location of each contract. Restricting their sample size to include only PES agreements in which payments started before or during 2011, a total of 920 individual PES agreements and 65 community PES agreements signed for private conservation were used for the purpose of the study. Overall a total of 985 agreements, conserving approximately 6549km^2, or 2.3% of the national territory were used to assess the local welfare effects of PES schemes and private conservation in Ecuador.

3.3.3 Tourism Data

To evaluate the effect that ecotourism in protected areas can have on local economic welfare, data measuring the level of ecotourism in Ecuador's protected areas in 2011 is necessary. This data comes from the Ministry of the Environment's 2017 release of tourist visits to continental protected areas, which contains data on monthly tourist arrivals at each of Ecuador's protected areas from 2001-2016. This data is used in conjunction with data on the proportion of land protected to evaluate the extent to which ecotourism is a mechanism through which conservation can positively influence welfare. The data does not contain information on the origin of tourists, only the overall number of arrivals. Thus we can not differentiate between local and foreign tourists. However, overall arrivals is sufficient for the purposes of this thesis to estimate the ecotourism mechanism.

3.3.4 Geographic Control Data

To properly isolate the causal effect of conservation policy on local economic welfare, it is necessary to control for the covariates that co-determine the existence of conservation areas on the one hand, and the high incidence of poverty or low socioeconomic outcomes. It has been demonstrated in the empirical literature that certain geographic features, such as the slope and elevation of the land and the distance of the land to major cities and roads, affect both the likelihood of poverty and poor economic outcomes as well as the probability of conservation of land, meaning that variables controlling for these features should be included in any regression model. However, like Yergeau *et al* (2017), data on the relevant geographic characteristics for Ecuador was not available for use in this study at a sufficiently disaggregated level. This may pose some problems for estimating the underlying causal impacts of conservation policy on local economic welfare.

In order to control for certain geographic characteristics, a similar approach to Yergeau *et al* (2017) is followed, which should provide a relatively good approximation of control for the important geographic covariates. This process involves splitting the country into separate ecological and geographic zones that group cantons together based on similar geographic and ecological characteristics, and using dummy variables to represent each distinct zone. The first set of dummy variables splits the country up along its three distinct ecological zones, the Coast, the Andes and the Amazon, from East to West. For each household, dummy variables are equal to 1 if the canton is is within a particular ecological zone, and 0 if not. The second set of dummy variables splits the country up into 7 distinct planning zones that run approximately from North to South. These planning zones are the first level of administrative planning levels established by the National Secretariat of Planning and Development (SENPLADES) of Ecuador and used to assist in the planning and delivery of public services. They exist alongside the administrative political divisions of

Figure 3.2: Administrative planning zones of Ecuador:

Source: SENPLADES

provinces, cantons and parishes. The planning zones are made up of provinces and are grouped according to cultural and economic proximity, as well as geographic characteristics, which means that the planning areas should isolate some variation in important geographic co-variates. There are 9 planning zones. However, Zone 8 is made up of only three cantons, Guayaquil, Samborondón and Durán, while Zone 9 consists only of the Quito canton. These divisions are made purely due to population and demographic considerations and not due to differences in the geographical characteristics of planning zones they would otherwise belong to. Therefore, I eliminate Zones 8 and 9 and place their relevant cantons into Zone 5 and 2 respectively, leaving just 7 planning zones in total. A map of Ecuador's planning zones is included in Figure 3.2.

The ENIGHUR 2011 dataset also includes data on whether a particular household lives within a rural or urban area. This data is used to create a final geographic control variable to control for differences between households living in urban and rural areas. A full summary of the variables used in the study is included in Table 3.1.

Table 3.1: Summary of Variables

Variable	Description	Source
Dependent variable:		
exp	Per household final annual consumption expenditures	ENIGHUR (2011)
Variables of interest:		
PA	Proportion of canton belonging to a protected area	Authors calculation (ArcGIS)
PES	Proportion of canton covered by a PES contract	Krause & Loft (2013)
Cons	Total proportion of canton under conservation (PA+PES)	Authors calculation
Tour	Tourist arrivals per protected area, per canton	MAE (2017)
Farm	Per household income from agricultural activities	ENIGHUR (2011)
inter	Interaction variable measuring ecotourism mechanism	PA x Tour
Household control variables:		
HHS	Household Size	ENIGHUR (2011)
Ethnicity	Ethnicity of household head	ENIGHUR (2011)
Sex	Sex of household head	ENIGHUR (2011)
Age	Age of household head	ENIGHUR (2011)
Edu	Education of household head	ENIGHUR (2011)
NFA	Value of non-farm assets owned by household	ENIGHUR (2011)
Geographic control variables:		
Region	Country division into 3 geographic regions (Coast, Andes and Amazon)	INEC (2010)
Plan	Country division into 7 planning zones	SENPLADES (2017)
UrbRur	Variable for whether a household resides in an urban or rural area.	ENIGHUR (2011)

3.4 Ecuador

3.4.1 Background

Ecuador is one of the world's 17 mega-diverse countries (Mittermeier *et al.*, 2008; Cuesta *et al.*, 2017), home to a wide range of different species and ecosystems, as well as a significant number of unique endemic species not found anywhere else in the world (Mittermeier *et al.*, 1997). Ecuador is considered to be home to 2 of the world's 34 biodiversity hotspots, in the Tumbes-Chocó-Magdalena Forest and in the Tropical Andes

(MAE, 2011). With a total surface area of approximately 260,000km^2, Ecuador has only about 100,000km^2 of ecologically native forests left (de Koning *et al.*, 2011).

Ecuador can be split into three main geographic regions as per the national statistics institute (INEC, 2010), the Coast, the Andes and the Amazon. The Coast, covering approximately 67,164km^2, is predominantly characterised by large-scale agriculture and urban areas, with only small tracts of native ecosystems such as dry and Chocó-Daren rainforests remaining. The Andes covers approximately 63,808km^2 and is mainly characterised by páramo and cloud forest native ecosystems, with large areas also having been converted to small-scale agriculture and timber plantations. Finally, the Amazon is covered predominantly by tropical rainforest and has a surface area of around 116,606km^2 (Krause & Loft, 2013).

Ecuador has experienced significant changes to its natural habitats and forest cover over the years, predominantly in the coastal areas. Much of the country's coastal ecosystems have already been deforested for agriculture, with approximately only 30% of natural vegetation remaining in the coastal region, while 60% and 88% of natural vegetation remains in the Andean and Amazonian regions respectively (Cuesta *et al.*, 2017). While the annual deforestation rate has been decreasing steadily in recent years (The REDD Countries Database, 2012; MAE, 2015), Ecuador's deforestation rate remains one of the highest when compared to other South American countries (Mosandl *et al.*, 2008), with an annual rate of deforestation of 776km^2 between 2000-2008 (Raes & Mohebalian, 2014).

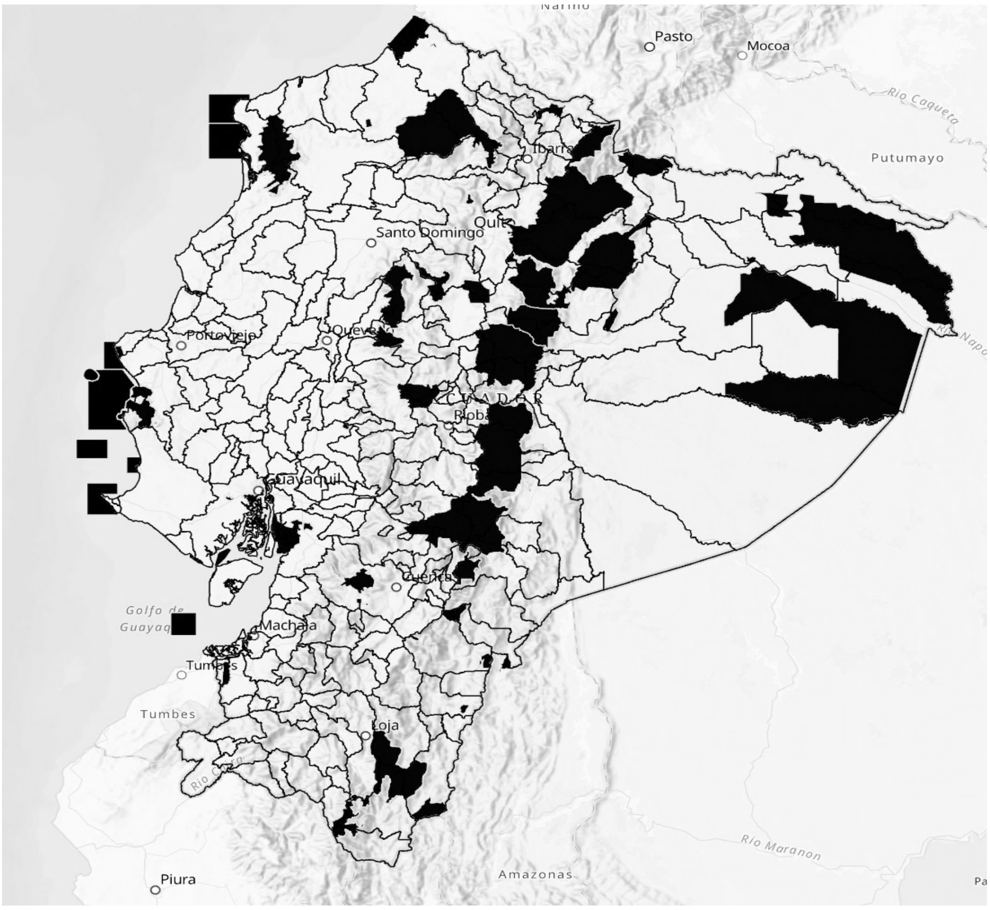
The predominant driver of deforestation and land use change in Ecuador is, like most other developing nations, agriculture (Southgate *et al.*, 1991). The rapidly expanding agricultural frontier is a particular threat to the Ecuadorian Amazon and Sierra regions since these regions have experienced relatively little land use change to present (Mosandl *et* *al.*, 2008). Other threats to Ecuador's biodiversity and natural landscape include those posed by natural resource extraction, a threat particularly problematic to the relatively untouched Western Amazon, much of which resides within Ecuador's national borders (Finer *et al.*, 2008). However with agriculture still constituting the greatest threat to Ecuador's natural landscapes, it is critically important that in order to conserve the important remaining areas of forested land in Ecuador and decrease or even reverse it's high rate of deforestation, Ecuador must alter the incentives associated with the conversion of forests to agricultural land, and increase the reforestation of already degraded land (Mosandl *et al.*, 2008).

Conducting this study on Ecuador is appropriate because of not only the environmental and ecological significance of Ecuador, but also because of the strong environmental conservation approach taken by the Ecuadorian government. Ecuador has a well-developed and extensive protected area network and a newly developed payments for ecosystems scheme, known as the Socio Bosque Program, which cover large amounts of land across it's three mainland geographic areas as well as the entire Galapagos Islands region. Since 2008, the national policy framework of Ecuador has also embedded a significant mandate to halt environmental degradation and land use change (de Koning *et al.*, 2011). Article 74 of the newly written constitution of 2008 gave the state the legal right to manage the environmental services of Ecuador. The National Plan for Good Living (*Plan Nacional para el Buen Vivir*) 2009-2013 contains a number of environmental goals, such as reducing deforestation rates by 30% and decreasing the national ecological footprint to within Ecuador's bio-capacity by 2013, as well as specific policies aiming to protect biodiversity and water sources while promoting climate change mitigation and adaptation (SENPLADES, 2010). Furthermore, the Ecuadorian government aims to achieve these environmental goals alongside achieving a reduction in poverty by 20-25% in urban areas and by 50% in rural areas by 2013 (SENPLADES, 2010), highlighting the dual approach of environmental conservation and poverty alleviation embedded within Ecuador's national development plan. Interestingly, Ecuador is also the first country in the world to guarantee the rights of nature by incorporating these rights in the rewriting of the country's constitution in 2008. These rights of nature give strong legal protections to natural habitats and represents a significant milestone in environmental conservation efforts in the country (Tanasescu, 2013). Ecuador thus represents a good case study to evaluate the welfare effects of environmental conservation policy, given its strong environmental conservation focus alongside its aims to reduce poverty and contribute to country-wide economic development.

3.4.2 Protected Areas

Ecuador has a long history of conservation via the use of protected areas, the traditional method of conserving important ecosystems and biodiversity. Ecuador's protected area network started in 1936 with the introduction of the Galapagos Islands National park to conserve the biologically and ecologically unique Galapagos Islands and it's ecosystems. This was followed by the establishment of the Cotopaxi National Park in 1975 protecting the Cotopaxi volcano and surrounding lands. Today, Ecuador has significant network of protected areas, called the National System of Protected Areas (NSPA). The system covers all four geographic regions, (The Coast, The Andes, The Amazon and the Insular Region) and covers approximately 20% of the national territory when marine reserves are included (MAE, 2016). At present Ecuador has 56 protected areas established under NSPA. However, for the purposes of this study, the number of protected areas included is restricted to include solely terrestrial protected areas established pre-2011. Four marine protected areas are excluded, and another eight protected areas were established after 2011. This leaves a total of 44 terrestrial protected areas established before 2011, covering approximately 57,800km^2 of land. Figure 3.3 displays a map of the protected areas of Ecuador.

Figure 3.3: Protected Areas of Ecuador



While no thorough analysis of the environmental effectiveness of Ecuador's protected areas has been conducted to date, some evidence exists that Ecuador's NSPA has been moderately effective in it's environmental conservation objectives. Van Der Hoek (2017) found that governmentally controlled parks in Ecuador were effective in reducing deforestation using matching techniques, finding that deforestation rates were lower in protected areas than outside of protected, although the difference was quite small.

3.4.2.1 Ecotourism

The United Nations World Tourism Organisation (UNWTO) defines ecotourism as "responsible travel to natural areas that conserves the environment, socially and economically sustains the well-being of local people, and creates knowledge and understanding through interpretation and education of all involved" (CREST, 2017). Ecotourism is a rapidly growing industry in Ecuador, in part due to it's significant biodiversity and unique ecological areas, granting Ecuador a comparative advantage in ecotourism (MAE, 2016). In 2006, less than 500,000 tourists visited protected areas in Ecuador, increasing to 2,000,000 visitors in 2015. 2011 in particular saw the greatest increase in tourists visiting protected areas historically, with an increase in tourist number by approximately 72.9% (MAE, 2016), although the ecotourism industry remained in relative infancy.

3.4.3 Payments for Ecosystem Services

The Socio Bosque Program (SBP) is Ecuador's national payments for ecosystem services scheme that involves direct monetary transfers from the national government to rural families and local and indigenous communities that voluntarily commit to comply with agreed conservation activities (de Koning *et al.*, 2011). The program has experienced rapid growth since it's 2008 inception, and has been highlighted as a promising national conservation agreement scheme from which other national governments can appropriate their own PES schemes. The program was officially established in November 2008, with the first beneficiaries signed up in December 2008. The Ministry of Environment again operates the program.

The program specifically has the dual objectives of achieving both ecosystem conservation and poverty alleviation simultaneously, making Ecuador a good case study to evaluate the local economic welfare effects of PES conservation policy. MAE defines the two overarching goals of the SBP to be the protection of over 36,000km^2 of forests and native ecosystems, thereby protecting important biodiversity as well as reducing greenhouse gas emissions from deforestation, alongside increasing the level of income and human capital of the people living in the poorest rural communities of the country, aiming to enhance the economic development of between 500,000 to 1,500,000 people (de Koning *et al.*, 2011).

From the start of the program in 2008 through til October 2011, the incentives used to encourage participation in the scheme were based on a uniform incentive scale with payments based on the number of hectares of native ecosystems that were protected, with no distinction made between individual or community contracts (Krause & Loft, 2013). When developing the scale, the MAE assumed that opportunity costs would decrease when the area under conservation increased, since access becomes more difficult in larger areas. In October 2011, the MAE revised the incentive scale due to a decrease in the signing up of new participants, implying the original design of incentives was not sufficient to cover the opportunity costs for the desired level of private land conservation set as the program's objective. In particular, new participants in the páramo areas of the Andes were suggested to have higher opportunity costs, as these areas are very fertile and relatively easy to access, thereby having greater potential returns to agriculture and thus requiring greater incentive payments. As a result, payments for collective contracts within páramo areas increased substantially, alongside a doubling of incentives for all individual contracts with less than 20 hectares conserved, highlighting the increased opportunity costs of conserving small areas of land (Krause & Loft, 2013).

Chapter 4 Results

This chapter will report the results from estimating the regressions set out in Section 3.2 and briefly discuss the implications these results have for the hypotheses and the theoretical predictions of Yergeau *et al's* model with respect to Ecuador. It is shown that for Ecuador, there appears to be some empirical evidence of a U-shaped relationship between conservation and welfare, providing further empirical support for the main hypothesis of Yergeau *et al*'s theoretical model. However, it is also found that there is insufficient evidence to suggest protected areas had any significant effect on local welfare, and that ecotourism seems to have mixed effects on welfare. Finally, reported results demonstrate the potent local welfare improving potential of payments for ecosystem services programs. Complete regression output for each estimated regression, including estimated coefficients for all control variables, is reported in Appendix B.

4.1 Do conservation and welfare share a U-shaped relationship?

This section reports the results associated with estimating equation 3.1, which tests the hypothesis that conservation and optimal welfare share a U-shaped relationship, using data from Ecuador. This involves estimating Equation 3.1. Table 4.1 reports the estimated coefficients on relevant variables associated with testing the U-shaped hypothesis.

Table 4.1: Estimated coefficients for variables of interest from Equation 3.1.

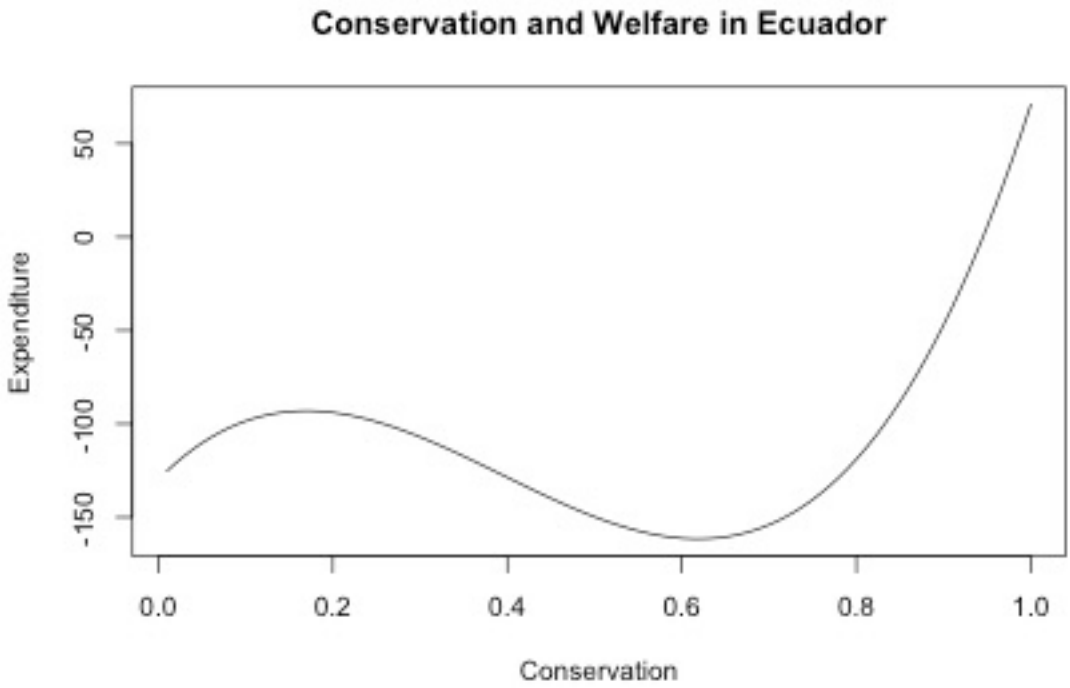
	Equation	
	3.1 (1)	**3.1 (2)**
Dependent variable	$\boldsymbol{exp_{ij}}$	$\boldsymbol{exp_{ij}}$
$\boldsymbol{cons_j}$	477.122*** (95.2883)	412.160*** (95.8911)
$\boldsymbol{cons_j^{sq}}$	-1791.51*** (383.963)	-1564.87*** (386.821)
$\boldsymbol{cons_j^{cu}}$	1515.19*** (356.597)	1354.34*** (358.740)
$\boldsymbol{farm_{ij}}$	0.304191*** (0.0435830)	-7.90771 (19.9555)
Estimation	OLS	OLS
$\mathbf{R^2}$	0.44	0.43
Observations	39012	39012
***1% significance. **5% significance. Robust standard errors in brackets. All regressions include household level controls for household size, sex of head of household, age of household head. level of education of household head, ethnicity of household head, value of non-farm assets owned by household and geographic controls. All household controls are significant at 1%.		

Column 3.1 (1) reports results from estimating equations 3.1 using household income from agricultural activities as the data for the variable $farm_{ij}$, whilst Column 3.1 (2) uses the households share of income from farming instead. This approach was chosen as per Yergeau *et al* (2017) to check for robustness of results amid the possibility of reverse causality between per-household agricultural income and consumption expenditure. No instrument was available to test for potential endogeneity, so instead the household share of income from agricultural activities is used, as it is less likely to be biased by reverse causality (Yergeau *et al.*, 2017).

The coefficients for the extractive good measure, i.e. $farm_{ij}$ for both equations are as expected. For Equation 3.1(1), per-household agricultural income has a positive and significant effect on welfare, whilst for Equation 3.2 (2), an increasing proportion of a household's income derived from agricultural activities is associated with a decrease in welfare. The first result is intuitive: as a household's income from agriculture increases, so too does their consumption expenditure. The second result is also consistent with the fact that in developing countries, poorer households have higher proportions of agriculturally derived income than wealthier households.

The coefficients for all other variables of interest do not change substantially between the two different equation specifications. Therefore, it is safe to assume that the potential reverse causality between farm income and consumption expenditure doesn't affect the relationship between conservation and consumption expenditure. In each equation, the coefficients for the level, square and cube of conservation are all highly significant. This result suggests that a cubic non-linear relationship between conservation and welfare is supported by the data. Furthermore, the coefficients for the levels and cubes of conservation are both positive, whilst the coefficient for the square of conservation is negative. This suggests that the relationship between conservation and welfare has at least two turning points and is not always positive. Initially, conservation effort leads to an increase in welfare, followed by a subsequent decrease as conservation effort increases. However, after some level of conservation effort, the relationship between conservation and welfare turns positive again. This suggests that the empirical evidence from Ecuador may be consistent with Yergeau *et al*'s theoretical prediction of a U-shaped relationship between conservation and welfare. Indeed, plotting the relationship using the estimated coefficients from Equation 3.1(1) confirms the consistency of the theoretical and empirical results. Figure 4.1 displays the plotted relationship using estimated coefficients, yielding a U-like shaped figure that describes the relationship between conservation and welfare in Ecuador. However, it is important to emphasise that the data does not support a purely quadratic U-shaped relationship, and rather a cubic relationship exists between conservation and welfare.

Figure 4.1: Relationship between conservation and welfare in Ecuador



4.2 Does ecotourism serve as a mechanism through which protected areas influence welfare?

This section reports results from testing the hypothesis that ecotourism in protected areas is the mechanism through which protected areas can have positive welfare effects for local peoples in Ecuador. Testing this hypothesis first involves estimating Equation 3.2, as well as Equations 3.3 and 3.4, which test for potential endogeneity, and Equation 3.5, which tests for the interaction between protected area conservation and ecotourism. Table 4.2 contains the estimated coefficients of interest from estimating Equations 3.2, 3.4 and 3.5. Results from estimating Equation 3.3 will be discussed underneath.

Table 4.2: Estimated coefficients for variables of interest from Equations 3.2 - 3.5.

	Equation			
	3.2	**3.4 (1)**	**3.4 (2)**	**3.5**
Dependent variable	exp_{ij}	exp_{ij}	exp_{ij}	exp_{ij}
$cons_j$	371.664*** (98.3764)	378.596*** (99.2715)	316.997*** (99.9213)	- -
$cons_j^{sq}$	-1452.09*** (388.420)	-1474.40*** (390.162)	-1258.62*** (393.189)	- -
$cons_j^{cu}$	1257.81*** (358.163)	1274.73*** (359.067)	1122.14*** (361.314)	- -
$farm_{ij}$	0.304822*** (0.0436229)	0.304781*** (0.0436179)	-7.05044 (19.9536)	0.302738*** (0.0238374)
$tour_j$	0.000736069*** (0.000216184)	0.000687686*** (0.000227869)	0.000664872*** (0.000227642)	0.00168541*** (0.000409690)
PA_j	- -	- -	- -	-17.7816 (31.9692)
$inter_j$	- -	- -	- -	-0.00366762** (0.00176210)
Estimation	OLS	IV2SLS	IV2SLS	OLS
R^2	0.44	0.44	0.43	0.44
Observations	39012	39012	39012	39012
***1% significance. **5% significance. Robust standard errors in brackets. All regressions include household level controls for household size, sex of head of household, age of household head. level of education of household head, ethnicity of household head, value of non-farm assets owned by household and geographic controls. All household controls are significant at 1%.				

The results from estimating Equation 3.2 are reported in column 3.2. Including a variable representing the number of tourist arrivals to protected areas per canton causes only a very small change to the magnitude of the results. The coefficient for $tour_j$ is positive and significant, meaning that tourist arrivals in protected areas in 2011 is correlated with higher levels of expenditure and thus welfare. This lends some empirical support to the hypothesis that ecotourism can positively influence welfare for those living nearby protected areas. The non-linearity of the relationship between conservation and expenditure remains, however the magnitude of each conservation coefficient is now slightly smaller. This suggests that ecotourism has captured some of the overall effect of conservation policy on welfare, lending empirical support to the theoretical prediction that the relationship between conservation and welfare is dependent on the establishment of an alternative environmental sector, i.e. ecotourism.

There is potential for reverse causality between tourist arrivals in 2011 and expenditure, and thus potential for the results to be biased via endogeneity. To check for this potential endogeneity, a two-stage least squares estimation procedure is proposed similar to Yergeau *et al* (2017), using tourist arrivals in 2008 as an instrument for tourist arrivals in 2011. Like the previous section, two different specifications of extractive good income are used, i.e. per household farm income and proportion of income from agricultural activities, when conducting the two stage least squares estimation to test for endogeneity between tourism and consumption expenditure. The results for the two stage least squares estimation using agricultural income are reported in column 3.4 (1), and the results using the proportion of income from farming are reported in column 3.4 (2).

For tourist arrivals in 2008 to be a valid instrument for tourist arrivals in 2011, it must be highly correlated with tourist arrivals in 2011 but uncorrelated with consumption expenditures in 2011. To test for correlation between the instrument and 2011 tourist arrivals, an F-test on the instrument is performed in the first stage of the 2SLS procedure, when estimating Equations 3.3(1) and 3.3(2). The F-statistic for the instrument in Equation 3.3(1) is 8715.73, and for Equation 3.3(2) it is 8717.31. Each statistic has a p-value of 0, and coefficients and F-statistics are relatively unchanged using the two different specifications of farm income. This suggests that across the two specifications, tourist arrivals in 2008 are highly correlated with tourist arrivals in 2011. Furthermore, as the data is on tourist arrivals from three years earlier, it is plausible that the time spans makes it unlikely that there is correlation between the instrument and consumption expenditures in 2011. Therefore, tourist arrivals in 2008 can be safely considered a valid instrument for tourist arrivals in 2011, and the second stage of the 2SLS procedure can be estimated safely. Estimating the second stage involves estimating Equations 3.4(1) and 3.4(2), using the fitted values for tourist arrivals in 2011 saved from estimating the equations in the first stage. Results from the second stage estimation are reported in columns 3.4(1) and 3.4(2) respectively. Coefficient values for all relevant variables remain relatively unchanged, suggesting that any reverse causality concerns are minimal and do not bias the results significantly. These results suggest the empirical evidence on the ecotourism mechanism is relatively robust and thus lends further support to the theoretical prediction that the development of an alternative environmental sector is a condition for a positive relationship between conservation and welfare.

Finally, to further test the extent to which ecotourism moderates the relationship between conservation and welfare, Equation 3.5 is estimated, which tests for interaction effects between tourist arrivals and the per canton protected area share. Results are reported in column 3.5. The results from this estimation are quite unexpected considering the results from estimating the previous equations. The coefficient of PA_j, which now measures the welfare effects of protected area when there is no tourism, is negative but insignificant from zero. Thus we can conclude that when there is no tourism in protected areas, a canton's share of protected land has no statistically significant effect on local welfare. The coefficient of $tour_j$, which now measures tourist arrivals when there is no protection, is positive and has a significant impact on consumption expenditures. However, as the variable is originally measuring the impact on tourist arrivals to protected areas, this result is inconsistent, as without protection, there can be no tourist arrivals to protected areas. Interpretation of this coefficient is therefore meaningless. Finally, and most surprisingly, the coefficient on the interaction term between ecotourism and protected areas is significant and negative. Recall from Section 3.3.2 that the coefficient for $inter_j$ represents the combination of ecotourism and protected area conservation policy on welfare, and that the marginal effect of ecotourism on welfare is equal to $\beta_1 + \beta_3 Tour_j$. The negative coefficient on the interaction term suggests that, in the case of Ecuador, the combination of ecotourism and protected areas have a negative effect on welfare. Furthermore, the marginal effect of ecotourism will be negative, as the signs of both β_1 and β_3 are negative, suggesting that the development of an ecotourism industry in protected areas has a negative effect on the welfare of people living nearby. This is a surprising result that seems at odds with results from estimating the previous equations as well as being at odds with theoretical predictions and empirical evidence from Yergeau *et al's* study in Nepal. Thus, evidence on the extent to which ecotourism is a mechanism through which protected area conservation influences welfare is mixed with respect to Ecuador. Potential reasons for this mixed result will be discussed further in Chapter 5.

4.3 Evaluating PES and comparing the two conservation policies.

This section will report results from regression estimation that seek to evaluate the local welfare effects of payments for ecosystem services in Ecuador and test the extent to which PES programs can serve as a mechanism through which conservation can influence welfare. Subsequently, direct comparison between the two dominant conservation policies, protected areas and PES schemes, is performed to determine which has the strongest welfare effects in Ecuador. Evaluating the local welfare effects of PES schemes and whether PES is a mechanism through which conservation influences welfare can simply be done by estimating the effect that the share of land under a PES contract has on consumption expenditures, as payments from the government, i.e. the environmental good, is dependent on the amount of land conserved. To evaluate the PES mechanism, Equation 3.6 is estimated. To compare the relative welfare effectiveness of protected areas and PES schemes in Ecuador Equations 3.7 and 3.8 are estimated. Table 4.3 reports estimated coefficients of variables of interest from estimating Equations 3.6-3.8.

Table 4.3: Estimated coefficients of variables of interest from Equations 3.6-3.8

	Equation			
	3.6 (1)	**3.6 (2)**	**3.7**	**3.8**
Dependent variable	$\boldsymbol{exp_{ij}}$	$\boldsymbol{exp_{ij}}$	$\boldsymbol{exp_{ij}}$	$\boldsymbol{exp_{ij}}$
$\boldsymbol{PES_j}$	224.296*** (62.4048)	231.357*** (60.9395)	223.910*** (62.3918)	532.709*** (60.8626)
$\boldsymbol{PA_j}$	- -	- -	-5.34729 (28.6518)	-13.6747 (31.9816)
$\boldsymbol{farm_{ij}}$	0.298544*** (0.0430701)	-11.7860 (24.0386)	0.298540*** (0.0430709)	0.304076*** (0.0435266)
$\boldsymbol{tour_j}$	- -	- -	- -	0.00172*** (0.00041)
$\boldsymbol{inter_j}$	- -	- -	- -	-0.003725** (0.00176)
Estimation	OLS	OLS	OLS	OLS
R²	0.44	0.43	0.44	0.44
Observations	39012	39012	39012	39012
***1% significance. **5% significance. Robust standard errors in brackets. All regressions include household level controls for household size, sex of head of household, age of household head. level of education of household head, ethnicity of household head, value of non-farm assets owned by household and geographic controls. All household controls are significant at 1%.				

Like previous sections, two different extractive good income specifications are used when estimating Equation 3.6 for robustness. Equation 3.6(1) uses per household income from agricultural activities and Equation 3.6(2) uses the household's share of income from agriculture. Results are reported in columns 3.6(1) and 3.6(2) respectively. The coefficients for both specifications of the extractive good income are as expected and the magnitude of the coefficient of PES_j does not significant change between the two specifications, meaning it is safe to assume the results are not biased by reverse causality between agricultural income and consumption expenditures.

The coefficient for PES_j is positive and highly significant across both specifications. This suggests that Ecuador's PES scheme has had highly significant welfare benefits for those living nearby areas conserved under PES contracts. These results are not surprising as Ecuador's PES program, the Program Socio Bosque, was designed with strong economic development and poverty alleviation goals. These results therefore suggest that even in its early stage, Ecuador's Socio Bosque Program has been effective in achieving its socioeconomic goals.

To initially compare the relative welfare effects of protected area conservation and PES conservation policies, Equation 3.7 is estimated. Coefficients from estimating Equation 3.7 provide a direct comparison between the welfare effectiveness of each program, which can be simply done by comparing the correlation in consumption expenditures associated with the share of land conserved under a protected area designation against that associated with the share of land conserved under a PES contract per canton. Results are reported in column 3.7. The coefficient for $farm_{ij}$ is of the expected sign and remains unchanged. Likewise, the magnitude and sign for the coefficients of PES_j and PA_j remain similar to that of previously estimated regressions. The coefficient for PES_j still remains positive and highly significant, while the coefficient for PA_j is negative but not statistically significant from zero. These results suggest that there are strong local welfare effects associated with PES-based conservation policy, compared with no significant welfare effects associated with the establishment of protected areas. Therefore it seems plausible to reason that, at least in the Ecuadorian context, payments for ecosystem services have been much more effective that protected areas in improving the economic living standards of people living nearby either type of conservation area.

To further investigate the relative welfare effectiveness of each policy, I will compare each underlying mechanism by estimating Equation 3.8. Results are reported in column 3.8. Again, no interaction term or other additional variable needs to be included to evaluate the PES mechanism, as it is already incorporated in the design of the variable. The coefficient for $farm_{ij}$ remains relatively unchanged of the correct sign. The magnitude of the coefficient of PES_j has however increased substantially following the inclusion of the variables $tour_j$ and $inter_j$, while the coefficient of PA_j has also changed but remains statistically insignificant from zero. As when estimating Equation 3.5 from the previous section, the coefficient of PA_j represents the welfare effects of protected areas when there is no tourism; the coefficient of $tour_j$ represents the welfare effects of ecotourism when there is no protection, and the coefficient of $inter_j$ represents the welfare effects of the combination of protected areas and ecotourism. Coefficient magnitudes and signs for $tour_j$ and $inter_j$ are similar to those encountered when estimating Equation 3.5, and the marginal effect of ecotourism remains negative. These results support the previous findings that Ecuador's PES program has had dominant welfare effects when compared to the establishment of protected areas, and that the PES mechanism appears more potent than the ecotourism mechanism. Overall, it supports the finding that Ecuador's PES policy has been the dominant conservation policy in terms of improving the economic conditions of those living nearby.

Furthermore, the results reported in this section give empirical support to the hypothesis that the relationship between conservation and welfare is dependent the development of an alternative industry, and that this theoretical prediction is applicable to PES schemes. This theoretical prediction has been, up to now, untested in the literature with respect to PES programs, and has only been evaluated by Yergeau *et al* with respect to the development of an ecotourism industry. In fact, as the marginal effects of ecotourism and protected areas appear to be negative in the Ecuadorian context, it appears that the PES mechanism is the sole mechanism through which conservation improves local living standards in Ecuador. This result lends support to the generalisability of Yergeau *et al's* theoretical model, suggesting the specification is able to capture the welfare effects of different types of conservation policies and the mechanism through which they influence welfare.

In Yergeau *et al's* study, the authors used propensity score matching techniques to evaluate the robustness of their OLS regression estimations and determine whether the results were not driven by some unobserved confounding variation at the baseline. The OLS identification strategy rests on the assumption that households living in protected areas prone to ecotourism did not self-select in these areas and that therefore the interaction between conservation and ecotourism can be considered exogenous. Essentially, the authors are assuming that households have not migrated to protected areas for economic or employment related reasons. They originally tested this assumption before conducting their OLS estimation procedure, using a test for a structural equality of coefficients between migrants and non-migrants in their dataset. The test rejected the hypothesis of structural difference between migrants and non-migrants and the authors concluded that migration doesn't bias their results. Indeed, they identified that only 3.5% of households in their dataset ever migrated for work related reasons, a proportion too small to have a significant effect on their results. In turn, the results from their matching estimation were consistent with their regression results, and the authors concluded that their OLS estimation procedure was robust in evaluating the local welfare effects of conservation policy in Nepal.

The ENIGHUR dataset unfortunately does not include data on whether households have ever migrated and the reasons for migration, so this thesis is unable to test for structural equality of coefficients as per Yergeau *et al*. It may therefore be prudent to perform similar robustness checks using matching techniques to examine whether such migration creates a significant bias in the results from OLS estimation. However, this thesis will not do so, as it is reasonable to assume such a bias will be insignificant. This is because while over a longer time period, migration to protected areas for employment reasons may present a significant bias, in the short term there is unlikely to be a significant effect. This can be justified by the relative undeveloped nature of Ecuador's ecotourism industry in the years leading up to and including 2011 (MAE, 2016), which means that it is highly unlikely that there would be a significant motivation to migrate to protected areas for work-related reasons. Furthermore, as this study has replicated the empirical work of Yergeau *et al* (2017), in which matching estimation was consistent with OLS results, it is reasonable to assume that the methodology appropriately isolates the causal effect of conservation on welfare in similar socioeconomic contexts. Therefore, this study will not perform a propensity score matching procedure to test for migration related bias, as it can be safely assumed that any such variation will be too small to significantly effect the results.

Chapter 5 Conclusion

While traditionally the literature surrounding the welfare effects of conservation policy has often arrived at pessimistic conclusions, recent empirical studies have shown that under certain conditions, conservation policies can improve the livelihoods of those living nearby conservation areas. The theoretical literature tends to assume that conservation tools, predominantly protected areas, place a binding restraint on land use options and thus hinder the economic potential of the land. On the other hand, empirical analyses of the welfare effects of protected areas have shown that when controlling for common geographic covariates co-determining poverty and environmental protection, the relationship between conservation and welfare can be positive. It has also been shown that the development of alternative industries on conserved land may generate economic benefits that offset the opportunity cost of conservation and contribute to greater economic welfare. While the divergence in theoretical and empirical results do not apply to the literature on payments for ecosystem services schemes, the same principles apply: a positive conservation-welfare relationship will occur only when the benefits generated by conservation policy outweigh the opportunity costs of conservation.

Yergeau *et al* (2017) recognised the divergence in theoretical and empirical literatures and sought to build a theoretical model explaining the relationship between conservation policy and welfare based on empirical regularities. Initial testing of their theoretical predictions using data from Nepal gave initial support for the model: there appeared to be evidence of a U-shaped relationship between conservation and welfare in Nepal, and ecotourism was found to be a channel through which conservation policy influenced welfare. This thesis builds on the ground breaking work of Yergeau *et al* (2017) by both replicating the hypothesis testing undertaken in their original paper in a different context, using data from Ecuador, as well as extending their analysis to determine whether the model specification is general enough to accurately capture the effects of different mechanisms through which conservation can influence welfare. Using data from the ENIGHUR 2011-2012 survey and remote sensed data on conservation areas, this thesis has found further promising evidence supporting the theoretical predictions of Yergeau *et al*'s model.

Using an OLS estimation procedure with various robustness checks, this thesis provides empirical evidence from Ecuador suggesting that, when controlling for the important covariates that determine the existence of poverty and low agricultural potential, and therefore conservation areas, conservation and welfare appear to share a non-linear cubic relationship that is similar to the hypothesised quadratic U-shaped relationship of Yergeau *et al's* theoretical model. What is particularly important is this result holds when including data on Ecuador's national payments for ecosystem services scheme. This means that not only have the results from Yergeau *et al's* original study been replicated in a different context, but also the author's model is general enough to capture the effects of different conservation policies.

It was shown however that the presence of tourism in protected areas in Ecuador had unclear effects on the welfare of local populations, a result inconsistent with both the theoretical and empirical findings of Yergeau *et al* (2017). One potential reason for this result may be the relative infancy of Ecuador's ecotourism industry in the year of study.

Whilst the growth rate in tourism to protected areas reached it's greatest extent in 2011, the absolute numbers of ecotourists was in fact relatively low. In the context of the Yergeau *et al's* model, this implies that the low development of the environmental industry on protected land, and therefore the benefits from conservation policy may still have been less than the opportunity costs. Since then, the national government and Ministry of the Environment have recognised the potential of ecotourism in protected areas as an effective socioeconomic development tool, and have focused on developing Ecuador's ecotourism industry (MAE, 2016). This has led to an increase in numbers of tourists to protected areas from around 600,000 in 2011 to approximately 2,000,000 in 2015, nearly a fourfold increase (MAE, 2016). It would therefore be relevant to evaluate the welfare effects of ecotourism in Ecuador using more recent and up to date data to determine whether the industry has developed sufficiently to generate benefits in excess of the opportunity costs of conservation policy.

The results of this thesis also highlight the potential success of Ecuador's payments for ecosystem services policy, the Socio Bosque Program, in improving the aggregate living standards of those living in and around areas of conservation. Furthermore, Ecuador's Ministry of Environment has revised the overall incentive structure of the scheme since the study date, in order to encourage further enrolments. It is likely that the welfare effects of the scheme would have strengthened since the date of study. However, the magnitude of the local welfare effects of Ecuador's PES program found in this thesis are already quite large, far greater than the magnitude of results found in previous studies such as Robalino *et al* (2014). The reasons for this are unclear, and it is possible that some unobservable co-varying factor has confounded these results. On the other hand, it could be that Ecuador's Ministry of Environment has targeted the program well to areas of low agricultural potential, and benefits have spread through local economies rather than concentrating in the hands of landowners. Again, further analysis of the welfare effects of Ecuador's conservation policy using more recent data would be particularly insightful, given the maturing of the Socio Bosque Program and the already strong local welfare impacts highlighted in this study.

The results of this thesis also have important implications for environmental conservation policy. When there is competing demands between the need for environmental conservation and the need for local economic development, these results suggest that environmental conservation policy can be effective in achieving both goals simultaneously, as long as conservation policy allows the development of an alternative sector or helps generate economic benefits that lead to greater economic development. Or more generally, there may not necessarily be a trade-off between environmental conservation and the economic development of the world's poorest. Furthermore, even if some environmental conservation policies have no impact on the welfare of local populations, as was found to be the case for protected areas in Ecuador, the use of these policies can still be considered to lead to a Paretian welfare improvement on larger demographic scales, due to the important positive externalities associated with the conservation of the world's remaining land and forested area.

Whilst this thesis provides promising evidence for the potential use of conservation policy in achieving both economic and environmental goals, there remain some important limitations to the results from this study. Firstly, due to the ecological and sociodemographic differences between different countries and regions of the world, it is important to recognise that these results may not necessarily hold for all countries and ecosystems. There is likely to be a different relationship between conservation and welfare in a marine conservation context, or when studying developed countries compared to developing countries. This means that continued replication studies using similar methodologies in different contexts is an important endeavour to determine how widely applicable the theoretical predictions and empirical results are.

The empirical relationship between conservation and welfare found in this thesis is also dependent on the variables included in the study, and there is potential that omitted variables may have biased the results. The lack of adequately disaggregated data on slope and elevation for Ecuador to properly control for the covariates co-determining the existence of protected areas and low economic development is arguably the most limiting variable omission from this study. While theoretically it should have little effect on the estimates associated with PES policy, using appropriately disaggregated slope and elevation data may have a significant effect on the estimation of the effect of protected areas and ecotourism mechanisms on local welfare. Based on other empirical studies that have used appropriately disaggregated data (Andam *et al.*, 2010; Sims, 2010; Ferraro & Hanauer, 2011; Robalino & Villalobos, 2015), it is likely that the estimated welfare effects of protected areas would have been significant and positive for Ecuador. Likewise, it is a strong assumption of Yergeau *et al's* model that environmental conservation does not generate any externalities. It is reasonable to assume that effective environmental conservation policy will generate significant positive externalities highly correlated with human well being, such as the benefits and ecosystem services provided by forests. Thus developing a model that captures these effects, as well as attaining data that allows for statistical estimation of the impacts of these externalities remains important. Furthermore, this thesis employs a very narrow, materialistic definition of welfare. It is likely that conservation policy is positively correlated with non-material forms of welfare as well. Finally, while this thesis has provided evidence on the socioeconomic effectiveness of conservation policies in Ecuador, there is an implicit assumption that these conservation policies have been effective in their environmental goals. This may not be the case, and there is likely to be a trade off between the most environmentally effective mechanism and the mechanism that maximises optimal social welfare, as highlighted by Sims & Alix-Garcia (2017) in their study on Mexico. Continued enforcement, monitoring and funding of conservation programs should ensure that while a trade off remains between the most effective mechanisms in terms of environmental and economic performance exists, no such trade off between welfare and conservation in general remains.

Appendix A: Model Derivations

The following derivations are taken straight from Yergeau *et al* (2017) and do not constitute my own work. They are included in this appendix to aid the reader in understanding Yergeau *et al's* theoretical model and it's predictions.

The Extractive Sector:

The extractive good is produced by a representative firm, from labour and extracted natural resources, such that:

$$Y_x = G\big(L_x, R_x, g(\emptyset)\big)$$

$$0 < \emptyset < 1$$

where Y_x is production in the extractive sector, L_x is labour, R_x is the extracted resource, $\emptyset$ is an exogenous environmental policy parameter measuring conservation effort, and $g(\emptyset)$ is a function that describes how environmental policies affect the extractive sector. Diminishing marginal returns are assumed so that

$$\frac{\partial G(L_x,R_x,g(\emptyset))}{\partial L_x} > 0, \frac{\partial^2 G(L_x,R_x,g(\emptyset))}{\partial L_x^2} < 0, \frac{\partial G(L_x,R_x,g(\emptyset))}{\partial R_x} > 0, \frac{\partial^2 G(L_x,R_x,g(\emptyset))}{\partial R_x^2} < 0,$$

It is assumed that $\frac{\partial g(\emptyset)}{\partial \emptyset} < 0$, so that higher conservation efforts restrict extractive good production.

Moreover it is assumed that $\lim_{\emptyset \to 1} G(L_x, R_x, g(\emptyset)) = 0$ and $\lim_{\emptyset \to 1} \frac{\partial G(L_x,R_x,g(\emptyset))}{\partial g(\emptyset)} \frac{\partial g(\emptyset)}{\partial \emptyset} = 0$. This means that when conservation effort is high, extractive good production approaches zero and the marginal effect of conservation on production is low.

Finally, cross partial derivatives between arguments of $G(L_x, R_x, g(\emptyset))$ are all positive.

All functions are continuous, monotonic and twice differentiable.

The environmental sector

The environmental good is produced by a representative firm, from labour and environmental quality such that:

$$Y_v = F\big(L_v, Q_v(R_x), f(\emptyset)\big)$$

where Y_v is production in the environmental sector, L_v is labour and Q_v is environmental quality. Diminishing marginal returns are assumed so that $\frac{\partial F\left(L_v, Q_v(R_x), f(\emptyset)\right)}{\partial L_v} > 0$, $\frac{\partial^2 F\left(L_v, Q_v(R_x), f(\emptyset)\right)}{\partial l_v^2} < 0$, $\frac{\partial F\left(L_v, Q_v(R_x), f(\emptyset)\right)}{\partial Q_v(R_x)} > 0$, $\frac{\partial^2 F\left(L_v, Q_v(R_x), f(\emptyset)\right)}{\partial Q_v(R_x)^2} < 0$.

Environmental quality is a function of the extracted resource such that $\frac{\partial Q_v(R_x)}{\partial R_x} < 0$ and $\frac{\partial^2 Q_v(R_x)}{\partial R_x^2} < 0$. Production of the extractive good lowers environmental quality and thus has a negative effect on the environmental sector. As the stock of natural resources gets lower, the effect of a marginal extraction on environmental quality gets stronger. Natural resource extraction cost on environmental quality is thus convex. The convexity of the extraction cost can be interpreted as an indicator of land fragility: Environmental quality in an area where the cost is more convex would be relatively more damaged by resource extraction and thus considered more fragile.

The function $f(\emptyset)$ describes how environmental policies affect the environmental sector. It is assumed that conservation effort has a positive effect on environmental good production, such that $\frac{\partial f(\emptyset)}{\partial \emptyset} > 0$,

Moreover we suppose that $\lim_{\emptyset \to 0} F\big(L_v, Q_v(R_x), f(\emptyset)\big) = 0$ and

$\lim_{\emptyset \to 0} \frac{\partial F(L_v, Q_v(R_x), f(\emptyset))}{\partial f(\emptyset)} \frac{\partial f(\emptyset)}{\partial \emptyset} = 0$. This means that when conservation effort is low, the environmental sector has low production levels and the marginal effect of conservation on production is low.

Finally cross partial derivaties between arguments of $Y_v = F\big(L_v, Q_v(R_x), f(\emptyset)\big)$ are all positive. All functions are continuous, monotonic and twice differentiable.

The social optimum

A central planner allocates factors to maximise social welfare for any given level of environmental conservation, described by the function:

$$W = W(Y_x, Y_v)$$

which is assumed to be continuous, twice differentiable and monotonic in Y_x and Y_v. There is diminishing marginal utility of welfare with respect to extractive and environmental good production.

$\frac{\partial W(Y_x, Y_v)}{\partial Y_x} > 0, \frac{\partial^2 W(Y_x, Y_v)}{\partial Y_x^2} < 0, \frac{\partial W(Y_x, Y_v)}{\partial Y_v} > 0$ and $\frac{\partial^2 W(Y_x, Y_v)}{\partial Y_v^2} < 0.$

The planner chooses an allocation of factors that solves:

$$\max_{L_x, R_x} W\big[\, G\big(L_x, R_x, g(\emptyset)\big), F\big(1\text{-}L_x, Q_v(R_x), f(\emptyset)\big)\big]$$

Taking and combining the FOC's with respect to L_x and R_x yields the following equilibrium condition:

$$\frac{\dfrac{\partial F\big(1\text{-}L_x, Q_v(R_x), f(\emptyset)\big)}{\partial L_x}}{\dfrac{\partial F\big(1\text{-}L_x, Q_v(R_x), f(\emptyset)\big)}{\partial R_x}} = \frac{\dfrac{\partial G\big(L_x, R_x, g(\emptyset)\big)}{\partial L_x}}{\dfrac{\partial G\big(L_x, R_x, g(\emptyset)\big)}{\partial R_x}}$$

The economy is assumed to be closed and composed of four cleared markets. Labour supply equals labour demand in both extractive and environmental sectors, and extracted resources are assumed to be fully utilised in extractive good production.

Let $L_x^*(\emptyset)$ and $R_x^*(\emptyset)$ denote solutions to the above equilibrium condition.

$G^*(\emptyset) = G\left(L_x^*(\emptyset), R_x^*(\emptyset), g(\emptyset)\right)$ and $F^*(\emptyset) = F\left(\left(1\text{-}L_x^*(\emptyset)\right), Q_v\left(R_x^*(\emptyset)\right), f(\emptyset)\right)$, are the production levels that maximise social welfare $W^*(\emptyset) = W\left(G^*(\emptyset), F^*(\emptyset)\right)$. Optimal factor allocation and welfare depends on environmental policies.

Using the implicit function theorem, it can be shown that $\frac{\partial L_x^*(\emptyset)}{\partial \emptyset} < 0$ and $\frac{\partial R_x^*(\emptyset)}{\partial \emptyset} < 0$ which yields:

$\frac{\partial F^*(\emptyset)}{\partial \emptyset} > 0$ and $\frac{\partial G^*(\emptyset)}{\partial \emptyset} < 0$.

The level of extractive good production that maximises welfare is negatively affected by conservation, while optimal environmental good production varies postively with conservation.

Conservation and optimal welfare: Proof of proposition 1:

Optimal welfare varies according to the following:

$$\frac{\partial W^*(\emptyset)}{\partial \emptyset} = \frac{\partial W^*(\emptyset)}{\partial G^*(\emptyset)} \frac{\partial G^*(\emptyset)}{\partial g(\emptyset)} \frac{\partial g(\emptyset)}{\partial \emptyset} + \frac{\partial W^*(\emptyset)}{\partial F^*(\emptyset)} \frac{\partial F^*(\emptyset)}{\partial f(\emptyset)} \frac{\partial f(\emptyset)}{\partial \emptyset}$$

The first term on the right of the equality is by definition negative, as it describes how extractive good production affects welfare with respect to changes in environmental conservation policy. The second term on the right of the equality is on the other hand positive, and describes how environmental good production affects welfare with respect to changes in environmental conservation policy. The first term is thus the relationship between the opportunity cost of conservation and welfare, while the second term is the relationship between conservation benefits and welfare.

Therefore, for the term on the left of the equality to be positive, the second term on the right must be greater than the first term on the right.

$\lim_{\emptyset\to 1}\frac{\partial G(L_x,R_x,g(\emptyset))}{\partial g(\emptyset)}\frac{\partial g(\emptyset)}{\partial \emptyset}=0$ and $\lim_{\emptyset\to 0}\frac{\partial F\left(L_v,Q_v(R_x),f(\emptyset)\right)}{\partial f(\emptyset)}\frac{\partial f(\emptyset)}{\partial \emptyset}=0$ implies that for $\emptyset\to 0$:

$$\frac{\partial W^*(\emptyset)}{\partial \emptyset}=\frac{\partial W^*(\emptyset)}{\partial G^*(\emptyset)}\frac{\partial G^*(\emptyset)}{\partial g(\emptyset)}\frac{\partial g(\emptyset)}{\partial \emptyset}<0.$$

and for $\emptyset\to 1$:

$$\frac{\partial W^*(\emptyset)}{\partial F^*(\emptyset)}\frac{\partial F^*(\emptyset)}{\partial f(\emptyset)}\frac{\partial f(\emptyset)}{\partial \emptyset}>0.$$

When conservation is low, optimal welfare varies negatively with conservation, as conservation costs are greater than benefits. However as conservation effort approaches 1, optimal welfare varies positively with conservation, as conservation benefits outweigh opportunity costs.

Let $\widehat{\emptyset}$ be the value of conservation effort that is associated with optimal social welfare. Therefore:

$$\frac{\partial W^*(\emptyset)}{\partial \emptyset}<0,\qquad \forall\,\emptyset\quad 0<\emptyset<\widehat{\emptyset}$$

$$\frac{\partial W^*(\emptyset)}{\partial \emptyset}>0,\qquad \forall\,\emptyset\quad \widehat{\emptyset}<\emptyset<1$$

For a level of conservation effort below a certain threshold, conservation effort generates a welfare decrease, while conservation effort above the threshold has a positive effect on welfare.

For the relationship between conservation and optimal welfare to be U-shaped, we must have that:

$$\frac{\partial^2 W^*(\emptyset)}{\partial \emptyset^2} > 0, \quad \forall\, \emptyset \quad 0 < \emptyset < 1$$

The above equation will be verified when:

$$\frac{\partial W^*(\emptyset)}{\partial G^*(\emptyset)}\frac{\partial^2 G^*(\emptyset)}{\partial \emptyset^2} + \frac{\partial W^*(\emptyset)}{\partial F^*(\emptyset)}\frac{\partial^2 F^*(\emptyset)}{\partial \emptyset^2} + \frac{\partial^2 W^*(\emptyset)}{\partial G^*(\emptyset)^2}\left(\frac{\partial G^*(\emptyset)}{\partial \emptyset}\right)^2 + \frac{\partial^2 W^*(\emptyset)}{\partial F^*(\emptyset)^2}\left(\frac{\partial F^*(\emptyset)}{\partial \emptyset}\right)^2 > 0$$

When conservation is low Yergeau *et al* (2017) go onto define under which conditions the above equation holds by using function forms to satisfy properties in the model derivations. However, the authors also demonstrate that their theoretical result is empirically valid.

Appendix B: Regression Output

Equation 3.1

Equation 3.1 (1): OLS, using observations 1-39012

Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-129.8819059	29.79631593	-4.358992106	1.31E-05
Cons	477.1217837	95.28830269	5.007139074	5.55E-07
sq_Cons	-1791.511014	383.9626014	-4.665847683	3.08E-06
cb_Cons	1515.190242	356.5965826	4.249031863	2.15E-05
Farm	0.304191233	0.043582955	6.979591716	3.01E-12
HHS	68.45124395	1.38469957	49.43400389	0
Eth	19.57205975	1.562445676	12.52655376	6.27E-36
Sex	-91.52387825	5.903495178	-15.50333751	4.78E-54
Age	3.376942107	0.199621833	16.91669721	5.74E-64
Edu	45.76246801	0.79352538	57.66982277	0
NFA	2.979258277	0.07414931	40.1791775	0
LaCosta	-48.84399699	20.0611287	-2.43475817	0.014906199
LaSierra	4.591301904	21.92273629	0.20943106	0.834112842
LaAmazonia	-28.52831116	22.95895226	-1.242578966	0.214030498
Zone1	0.232136028	9.655058998	0.024042942	0.980818479
Zone2	81.35902944	11.90156879	6.835992037	8.26E-12
Zone3	62.08690094	11.67303171	5.318832543	1.05E-07
Zone4	9.500202877	10.55861996	0.899758009	0.368254602
Zone5	-6.099346278	9.714561537	-0.627856054	0.530101919
Zone6	47.87216473	12.09462245	3.958136349	7.57E-05
UrbRur	-132.7735625	5.971102829	-22.2360201	7.33E-109

Mean dependent var	824.7764896	S.D. dependent var	697.8632787
Sum squared resid	10716413483	S.E. of regression	524.2549554
R-squared	0.435944698	Adjusted R-squared	0.435655372
F(20, 38991)	768.7675455	P-value(F)	0
Log-likelihood	-299637.4177	Akaike criterion	599316.8355
Schwarz criterion	599496.8396	Hannan-Quinn	599373.8787

Equation 3.1 (2): OLS, using observations 1-39012

Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-141.4367538	29.78937821	-4.74789211	2.06E-06
Cons	412.1603152	95.89113387	4.298210883	1.73E-05
sq_Cons	-1564.869121	386.8209992	-4.045460626	5.23E-05

cb_Cons	1354.341713	358.7404786	3.775268735	0.000160072
FarmShare	-7.90770949	19.95545571	-0.396268048	0.691909464
HHS	69.01592687	1.38545857	49.81450068	0
Eth	19.66760117	1.565764521	12.56102109	4.06E-36
Sex	-94.81993482	5.92582148	-16.00114603	1.91E-57
Age	3.472612003	0.199991821	17.36377014	2.78E-67
Edu	45.8515885	0.794059443	57.74326961	0
NFA	2.992034896	0.074262975	40.2897258	0
LaCosta	-54.03060761	20.15746958	-2.680426102	0.00735594
LaSierra	0.253671963	22.00196378	0.011529515	0.990801041
LaAmazonia	-30.35940076	23.02627538	-1.318467718	0.187354869
Zone1	1.392511349	9.67583434	0.143916411	0.88556722
Zone2	78.10859806	11.91713095	6.554312305	5.66E-11
Zone3	62.27754743	11.68593423	5.329274168	9.92E-08
Zone4	10.43373092	10.60490195	0.983859254	0.325190825
Zone5	-7.483373467	9.75140697	-0.767414742	0.442839613
Zone6	47.05177428	12.12595405	3.880253389	0.000104519
UrbRur	-116.8635764	5.845150842	-19.99325244	1.75E-88

Mean dependent var	824.7764896	S.D. dependent var	697.8632787
Sum squared resid	10761025297	S.E. of regression	525.3450437
R-squared	0.433596568	Adjusted R-squared	0.433306038
F(20, 38991)	762.8559678	P-value(F)	0
Log-likelihood	-299718.4515	Akaike criterion	599478.9031
Schwarz criterion	599658.9072	Hannan-Quinn	599535.9464

Equation 3.2

Equation 3.2: OLS, using observations 1-39012

Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-143.1687751	29.76976055	-4.809201432	1.52E-06
Cons	371.6641528	98.37635845	3.77798242	0.000158339
sq_Cons	-1452.089753	388.4202666	-3.73845002	0.000185423
cb_Cons	1257.809474	358.1626456	3.511838795	0.000445521
Farm	0.304822424	0.043622862	6.987675945	2.84E-12
Tour	0.000736069	0.000216184	3.40482752	0.000662725
HHS	68.41662434	1.383493582	49.45207209	0
Eth	19.5985995	1.56176946	12.5489709	4.73E-36
Sex	-91.72070423	5.907079155	-15.5272516	3.30E-54
Age	3.386805945	0.199630894	16.9653398	2.52E-64
Edu	45.78861194	0.793584994	57.69843465	0
NFA	2.975998441	0.074207684	40.10364242	0
LaCosta	-31.73907242	20.22826403	-1.569045785	0.116645386

LaSierra	18.15162639	21.94726718	0.827056337	0.408210192
LaAmazonia	-7.702661543	23.09812465	-0.333475625	0.73877708
Zone1	1.320818382	9.653326024	0.136825212	0.891169661
Zone2	76.89666886	11.95385278	6.432793701	1.27E-10
Zone3	68.48706547	11.82825219	5.790125572	7.09E-09
Zone4	10.23065926	10.55565834	0.969210913	0.332445979
Zone5	-8.332605462	9.729171504	-0.85645581	0.391750969
Zone6	41.06581732	12.24505916	3.353664263	0.00079825
UrbRur	-134.0431133	5.977681868	-22.42392891	1.15E-110

Mean dependent var	824.7764896	S.D. dependent var	697.8632787
Sum squared resid	10712952569	S.E. of regression	524.1770151
R-squared	0.436126862	Adjusted R-squared	0.43582316
F(21, 38990)	734.1144086	P-value(F)	0
Log-likelihood	-299631.1172	Akaike criterion	599306.2343
Schwarz criterion	599494.8101	Hannan-Quinn	599365.994

Equation 3.4

Equation 3.4 (1): OLS, using observations 1-39012
Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-142.2954052	29.93792807	-4.753014467	2.01E-06
Cons	378.5960731	99.27145237	3.813745684	0.000137087
sq_Cons	-1474.400525	390.1621068	-3.778943416	0.000157729
cb_Cons	1274.727576	359.0670018	3.550110618	0.000385522
Farm	0.304780934	0.04361789	6.987521297	2.84E-12
tourhat	0.000687686	0.000227869	3.01790437	0.002546935
HHS	68.41889995	1.383570584	49.45096459	0
Eth	19.596855	1.561905621	12.54676002	4.86E-36
Sex	-91.70776651	5.907262616	-15.52457923	3.44E-54
Age	3.386157577	0.199676843	16.95818866	2.85E-64
Edu	45.78689345	0.793668151	57.69022404	0
NFA	2.976212716	0.074238903	40.08966458	0
LaCosta	-32.86340997	20.57483054	-1.597262728	0.110215259
LaSierra	17.2602818	22.21060227	0.777119035	0.437093259
LaAmazonia	-9.071569055	23.45722424	-0.386728155	0.698959581
Zone1	1.249257327	9.656386153	0.129371103	0.897064679
Zone2	77.18998787	11.95141463	6.458648642	1.07E-10
Zone3	68.06637112	11.85963121	5.739332861	9.58E-09
Zone4	10.18264505	10.5585035	0.964402299	0.334850251
Zone5	-8.185809308	9.728053784	-0.841464232	0.400093075
Zone6	41.51321081	12.22361572	3.396148222	0.000684095
UrbRur	-133.9596634	5.986758454	-22.37599269	3.34E-110

Mean dependent var	824.7764896	S.D. dependent var	697.8632787
Sum squared resid	10713689808	S.E. of regression	524.1950511
R-squared	0.436088058	Adjusted R-squared	0.435784335
F(21, 38990)	733.7777601	P-value(F)	0
Log-likelihood	-299632.4595	Akaike criterion	599308.9189
Schwarz criterion	599497.4947	Hannan-Quinn	599368.6786

Equation 3.4 (2): OLS, using observations 1-39012
Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-153.4364643	29.93705135	-5.125303174	2.98E-07
Cons	316.9969425	99.92125361	3.172467629	0.001512666
sq_Cons	-1258.620229	393.1888179	-3.201058044	0.001370337
cb_Cons	1122.139022	361.3142631	3.10571471	0.001899559
FarmShare	-7.050444987	19.95355543	-0.353342792	0.723833379
tourhat2	0.000664872	0.000227642	2.92069563	0.003494509
HHS	68.98561795	1.384353215	49.83238179	0
Eth	19.69359051	1.565297393	12.5813731	3.14E-36
Sex	-94.99038646	5.929522624	-16.01990455	1.42E-57
Age	3.481265747	0.200050235	17.40195783	1.44E-67
Edu	45.87558923	0.794213518	57.76228708	0
NFA	2.989120779	0.074350484	40.20311108	0
LaCosta	-38.55538319	20.66431937	-1.865794972	0.062077559
LaSierra	12.52472787	22.28531042	0.562017205	0.574107528
LaAmazonia	-11.53208611	23.52094255	-0.490290135	0.623931365
Zone1	2.377856258	9.677543203	0.245708669	0.805909054
Zone2	74.0904034	11.96805191	6.190681991	6.05E-10
Zone3	68.06013655	11.87311263	5.73229099	9.98E-09
Zone4	11.09542868	10.60496984	1.046248018	0.295453024
Zone5	-9.494954337	9.765999026	-0.972246087	0.330934169
Zone6	40.91160109	12.25450306	3.338495319	0.000843123
UrbRur	-118.0634847	5.856603668	-20.15903608	6.45E-90

Mean dependent var	824.7764896	S.D. dependent var	697.8632787
Sum squared resid	10758479537	S.E. of regression	525.2896351
R-squared	0.433730563	Adjusted R-squared	0.433425571
F(21, 38990)	728.0448041	P-value(F)	0
Log-likelihood	-299713.8364	Akaike criterion	599471.6728
Schwarz criterion	599660.2486	Hannan-Quinn	599531.4325

Equation 3.5

Equation 3.5: OLS, using observations 1-39012

Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-140.7359958	31.9723765	-4.401799655	1.08E-05
PA	-17.78163746	31.96916148	-0.556212194	0.578068996
Tour	0.001685409	0.00040969	4.113868222	3.90E-05
inter	-0.003667616	0.001762103	-2.081386371	0.037405063
Farm	0.302737808	0.023837389	12.70012443	6.99E-37
HHS	68.47668115	1.404453946	48.75680072	0
Eth	19.65792924	1.971878496	9.9691382	2.22E-23
Sex	-91.58236816	6.39284292	-14.32576544	1.98E-46
Age	3.397373087	0.190416911	17.84176142	6.42E-71
Edu	45.84260418	0.644710652	71.10570311	0
NFA	2.976616164	0.032259836	92.27003366	0
LaCosta	-23.03072027	20.22526661	-1.138710342	0.254830984
LaSierra	24.32915907	21.53031225	1.129995645	0.258485011
LaAmazonia	7.796474721	23.16408745	0.336575949	0.736438401
Zone1	7.3433234	10.06442919	0.729631384	0.465619916
Zone2	77.98605401	11.19639312	6.965283657	3.33E-12
Zone3	78.95098621	11.12688378	7.095516387	1.31E-12
Zone4	11.03873673	10.48983598	1.052326915	0.292656109
Zone5	-16.78171165	11.0038093	-1.525082015	0.127246753
Zone6	42.03334834	11.80442066	3.560814169	0.000370147
UrbRur	-135.9237744	6.782796783	-20.03948796	7.00E-89

Mean dependent var	824.7764896	S.D. dependent va	697.8632787
Sum squared resid	10714646190	S.E. of regression	524.211725
R-squared	0.436037719	Adjusted R-square	0.435748441
F(20, 38991)	1507.330123	P-value(F)	0
Log-likelihood	-299634.2006	Akaike criterion	599310.4013
Schwarz criterion	599490.4054	Hannan-Quinn	599367.4446

Equation 3.6

Equation 3.6 (1): OLS, using observations 1-39012

Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-102.5466035	29.4571603	-3.481211441	0.000499697
PES	224.2961956	62.40841485	3.594005651	0.000326034
Farm	0.298544104	0.043070141	6.931579431	4.23E-12
HHS	68.5594796	1.385303742	49.49057563	0
Eth	19.58187476	1.562354419	12.53356762	5.74E-36
Sex	-91.29668404	5.899204077	-15.476102	7.28E-54
Age	3.379459461	0.199667359	16.92544781	4.95E-64
Edu	45.88917322	0.79421359	57.77938556	0

NFA	2.985142645	0.074120726	40.27406132	0
LaCosta	-60.37477895	20.05777892	-3.010043096	0.002613776
LaSierra	-8.361508741	22.02585938	-0.379622361	0.704227827
LaAmazonia	-43.18229319	23.12271221	-1.867527166	0.061835503
Zone1	2.81267332	9.505669905	0.295894277	0.767312398
Zone2	83.76050031	11.58846218	7.227921961	4.99E-13
Zone3	66.92206689	10.99850339	6.084652113	1.18E-09
Zone4	8.073626639	10.59315837	0.762154813	0.445972222
Zone5	-17.85072711	9.711529202	-1.838096426	0.0660558
Zone6	53.08024091	12.04221867	4.407845626	1.05E-05
UrbRur	-135.741398	5.90665399	-22.98109864	4.27E-116

Mean dependent var	824.7764896	S.D. dependent var	697.8632787
Sum squared resid	10718173332	S.E. of regression	524.2845541
R-squared	0.435852069	Adjusted R-squared	0.435591646
F(18, 38993)	852.6502314	P-value(F)	0
Log-likelihood	-299640.6207	Akaike criterion	599319.2415
Schwarz criterion	599482.1023	Hannan-Quinn	599370.8521

Equation 3.6 (2): OLS, using observations 1-39012
Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-118.0936252	30.58569507	-3.861073778	0.000113072
PES	231.3567844	60.9394825	3.796500641	0.000146975
FarmShare	-11.78602621	24.03860315	-0.490295802	0.623927356
HHS	69.10434538	1.406619714	49.12795169	0
Eth	19.6729938	1.976625926	9.952815827	2.61E-23
Sex	-94.62809533	6.412142018	-14.75764184	3.73E-49
Age	3.475406118	0.191037459	18.19227565	1.20E-73
Edu	45.95897337	0.645851185	71.16031442	0
NFA	2.996674484	0.032259761	92.89202396	0
LaCosta	-63.89391458	18.42323397	-3.468116113	0.000524686
LaSierra	-11.44626698	20.36364874	-0.562093126	0.574055802
LaAmazonia	-43.93788366	21.5128767	-2.042399269	0.041118654
Zone1	2.751007892	10.18379467	0.270135836	0.787057183
Zone2	79.92635817	10.97704289	7.281228556	3.37E-13
Zone3	65.71817419	10.61421573	6.191524262	6.02E-10
Zone4	9.250667646	10.48398214	0.882362019	0.377586507
Zone5	-17.8656658	10.93301381	-1.634102555	0.102245391
Zone6	51.29781953	11.18452667	4.586498923	4.52E-06
UrbRur	-119.1559058	7.061025407	-16.87515608	1.15E-63

Mean dependent var	824.7764896	S.D. dependent var	697.8632787

Sum squared resid	10761242217	S.E. of regression	525.3368655
R-squared	0.433585151	Adjusted R-squared	0.433323681
F(18, 38993)	1658.264922	P-value(F)	0
Log-likelihood	-299718.8447	Akaike criterion	599475.6895
Schwarz criterion	599638.5503	Hannan-Quinn	599527.3001

Equation 3.7

Equation 3.7: OLS, using observations 1-39012
Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-102.0765952	29.49337115	-3.461001278	0.000538746
PA	-5.347293093	28.65182312	-0.186630117	0.851951623
PES	223.9098277	62.39177661	3.588771468	0.000332647
Farm	0.298539881	0.043070874	6.931363411	4.23E-12
HHS	68.5629884	1.385892795	49.4720722	0
Eth	19.57803244	1.562328066	12.53131968	5.90E-36
Sex	-91.30402152	5.901397086	-15.4715943	7.80E-54
Age	3.379671626	0.199679094	16.92551559	4.94E-64
Edu	45.88950607	0.794214503	57.7797382	0
NFA	2.985208938	0.07412875	40.27059594	0
LaCosta	-60.55124892	20.06201963	-3.018203055	0.002544427
LaSierra	-8.645312792	22.03378998	-0.392366125	0.694789856
LaAmazonia	-43.01869543	23.16025955	-1.857435809	0.06325671
Zone1	2.835341397	9.512367966	0.298068936	0.765652138
Zone2	84.0746173	11.85205692	7.093673095	1.33E-12
Zone3	67.50460428	11.50561231	5.867102287	4.47E-09
Zone4	8.102369612	10.60604356	0.763938934	0.444908257
Zone5	-18.1058996	9.750059881	-1.857003939	0.063318129
Zone6	53.4354748	12.08611007	4.421230198	9.84E-06
UrbRur	-135.7550423	5.905790526	-22.98676895	3.75E-116

Mean dependent var	824.7764896	S.D. dependent var	697.8632787
Sum squared resid	10718165157	S.E. of regression	524.2910771
R-squared	0.435852499	Adjusted R-squared	0.435577602
F(19, 38992)	807.8426964	P-value(F)	0
Log-likelihood	-299640.6059	Akaike criterion	599321.2117
Schwarz criterion	599492.6442	Hannan-Quinn	599375.5387

Equation 3.8

Equation 3.8: OLS, using observations 1-39012

Dependent variable: Exp

	coefficient	std. error	t-ratio	p-value
const	-142.3650778	31.96963339	-4.453134513	8.49E-06
PA	-13.67469932	31.98162236	-0.427579913	0.668959354
Tour	0.00171726	0.000409703	4.19147792	2.78E-05
inter	-0.003724583	0.001761858	-2.114008473	0.034520875
PES	232.7093148	60.86261442	3.823518215	0.000131765
Farm	0.301926813	0.023834171	12.66781268	1.05E-36
HHS	68.51065258	1.404236835	48.78853115	0
Eth	19.61357828	1.971568327	9.948211289	2.74E-23
Sex	-91.63784486	6.391743193	-14.33690968	1.69E-46
Age	3.395752425	0.190384135	17.83632033	7.07E-71
Edu	45.85441892	0.644605491	71.13563191	0
NFA	2.976264593	0.032254335	92.27487193	0
LaCosta	-21.31376742	20.22672053	-1.053743111	0.292007075
LaSierra	23.01269867	21.52930636	1.068901073	0.285120866
LaAmazonia	-0.218135479	23.25470646	-0.009380272	0.992515783
Zone1	1.887688935	10.16333129	0.185735256	0.852653345
Zone2	75.63206078	11.21135524	6.746023044	1.54E-11
Zone3	74.14776484	11.19564328	6.622912411	3.57E-11
Zone4	10.98515335	10.48801381	1.047400733	0.294921286
Zone5	-18.43731786	11.01040573	-1.674535736	0.094033377
Zone6	37.05510265	11.87395945	3.120703148	0.001805515
UrbRur	-135.2881023	6.783650067	-19.94326077	4.72E-88

Mean dependent var	824.7764896	S.D. dependent var	697.8632787
Sum squared resid	10710630242	S.E. of regression	524.1201972
R-squared	0.436249097	Adjusted R-squared	0.435945461
F(21, 38990)	1436.750083	P-value(F)	0
Log-likelihood	-299626.8882	Akaike criterion	599297.7765
Schwarz criterion	599486.3522	Hannan-Quinn	599357.5361

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