

TWO BIRDS, ONE STONE

Essays on the values of Swiss forest ecosystem services

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Two birds, one stone: Essays on the values of
Swiss forest ecosystem services

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Autorise l'impression de la présente thèse.

Neuchâtel, le 12 février 2018

Le doyen

Mehdi Farsi

- *What is a cynic? A man who
knows the price of everything
and the value of nothing.*
- *And a sentimentalist is a man
who sees an absurd value in
everything, and doesn't know the
market price of any single thing.*

Oscar Wilde (1854-1900)
Lady Windermere's Fan,
1892, Act III

Abstract

Forests provide several valuable services to the Swiss population such as wood, recreational opportunities, carbon sequestration and habitat for biodiversity, among others. Since wood exploitation contributes to forests maintenance, it is acknowledged that a reasonable intensification of wood harvest would benefit other forest ecosystem services in Switzerland. In addition, because of its CO₂ neutrality, wood is expected to take a growing part of the material in construction and energy production. However, in a context of international competition and harvest restrictions, wood prices are pressured downward and marginal costs increase. Hence, the Swiss forest industry is not willing to harvest more wood, despite the associated potential benefits for the society.

This thesis examines Swiss people preferences regarding forests ecosystem services. It applies different market and non-market valuation methods to analyze how much the Swiss population benefits from the forest. Non-market forest ecosystem services, such as recreation or biodiversity are found to be highly valued. I argue that, since a reasonable wood harvesting creates positive externalities on other forest ecosystem services and, since the forest industry is responsive to prices, a better institutionalized Payment for Ecosystem Services system, by increasing the wood production, could assure both economic and environmental sustainability of Swiss forests and thus kill two birds with the same stone.

Keywords: Switzerland, Forest, Ecosystem Services, Non-market valuation, Wood

JEL classification: D61, Q23, Q26, Q31, Q57

Résumé

Une pierre, deux coups : Essais sur la valeur des services des écosystèmes forestiers suisse

Les forêts fournissent de nombreux services à la population suisse : approvisionnement en bois, activités récréatives, séquestration du carbone et habitat pour la biodiversité comptent parmi les fonctions forestières. Il est reconnu qu'en l'état actuel des choses, l'exploitation du bois contribue à l'entretien des forêts suisses. Ainsi, une intensification raisonnable de sa production serait favorable aux autres services des écosystèmes forestiers. De par sa neutralité carbone, l'attrait du bois comme matériau de construction et pour la production énergétique devrait croître dans le futur. Cependant, dans un contexte de compétition internationale et de restrictions d'exploitation, les prix du bois diminuent et les coûts marginaux de production augmentent. L'industrie forestière suisse n'est ainsi pas disposée à produire plus de bois, malgré les potentiels bénéfiques engendrés pour la société.

Cette thèse de doctorat examine les préférences de la population suisse pour les services des écosystèmes forestiers. Elle applique différentes méthodes d'évaluation, marchande et non-marchande, pour analyser les bénéfices générés par la forêt. Les services non-marchands, comme les activités récréatives ou l'habitat pour la biodiversité sont particulièrement appréciés et la population y attribue une valeur économique très importante. Comme la production de bois génère des externalités positives sur les autres services des écosystèmes forestiers et, comme l'industrie forestière est sensible aux variations de prix, il serait judicieux d'améliorer le système de paiements pour les services écosystémiques des forêts suisses afin d'intégrer ces externalités. En faisant croître la production de bois, ces paiements pourraient assurer la durabilité économique et environnementale des forêts suisses et ainsi faire d'une pierre, deux coups.

Mot-clés : Suisse, Forêt, Services écosystémiques ; Évaluation non-marchande ; Bois

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List of Abbreviations

2SLS	2 Stage Least Squares
3SLS	3 Stage Least Squares
ADF	Augmented Dickey-Fuller test
ADF	Augmented Dickey-Fuller test
AIC	Akaike Information Criteria
BIC	Bayes Information Criteria
CBA	Cost-Benefit Analysis
CC	Complete Combinatorial
CE	Choice Experiment
CH	Swiss
CHF	Swiss Francs
CICES	Common International Classification of Ecosystem Services
CS	Consumer surplus
CV	Contingent Valuation
DV	Dependent Variable
ECM	Error Correction Model
ES	Ecosystem Services
ETC	Effective Travel Costs

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EUR	Euro
FES	Forest Ecosystem Services
FOEN	Federal Office for the Environment
FSO	Federal Statistical Office
GE	Geneva
ghansen	Gregory and Hansen (1996) test
H	Hurdle
HPM	Hedonic Pricing Method
HZT	Hurdle Zero Truncated model
HZTNB	Hurdle Zero Truncated Negative Binomial model
IDV	Independent Variable
KPSS	Kwiatkowski, Philips, Schmidt and Shin test
KS	Kolmogorov-Smirnov test
LAM	Lagged Adjustment Model
LR	Likelihood Ratio
LR	Long Run
NB	Negative Binomial law
NOAA	National Oceanic and Atmospheric Association
OCT	Opportunity Cost of Time
OLS	Ordinary Least Squares
PAVA	Pooled Adjacent Violator Algorithm
PES	Payment for Ecosystem Services
PPP	Purchasing Power Parity

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RP	Revealed Preferences
RUM	Random Utility Model
SB	Structural Break
SBDC	Single Bounded Dichotomous Choice
SP	Stated Preferences
SR	Short Run
TCM	Travel Cost Method
TEEB	The Economics of Ecosystem and Biodiversity
TEV	Total Economic Value
WTP	Willingness To Pay
ZI	Zero-Inflated
ZTNB	Zero Truncated Negative Binomial
ZTP	Zero Truncated Poisson

Introduction

Since the launch of the Millennium Ecosystem Assessment in 2000 (MEA, 2005), the concept of ecosystem services (ES) and its economic valuation have received a great attention from scholars. Undertaken by the The Economics of Ecosystem and Biodiversity (TEEB), this approach mainly aims at “recognizing value”, “demonstrating value” and “capturing value” of ecosystem services (TEEB, 2010). The use of the ES concept has a number of interesting advantages: First, since “all decisions that involve trade-offs involve valuation, either implicitly or explicitly” (Costanza et al., 2014, p.153), ES values can be integrated in more complete Cost-Benefit Analyses (CBA) thus ensuring a more efficient allocation of resources. Second, improving indicators of economic development is another goal that can be achieved through the assessment of ecosystem services. The demand for better sustainable development indicators, which would encompass non-market goods and services provided by the environment, has indeed been stressed by many economists, notably Stiglitz et al. (2009). Third, although this use is controversial, the assessment of ES could be used to derive compensations for environmental damages, as was done in the Exxon Valdez (1989) (see Carson et al., 1992) or Deepwater Horizon (2010) (see Bishop et al., 2017b) cases. Finally, ES assessments can be used to design Payments for Ecosystem Services (PES) and internalize economic externalities.

Nevertheless, the ES concept comes with a number of reservations, either ethical or in connection with the methods. First, as Monbiot (2012) argues, the valuation of ES is often linked, at least in the population’s mind, with commodification of nature, which, in turn, is tied to privatization of ecosystems. Then, since neo-classical economists usually think in marginal terms, this approach may not correctly take into account thresholds effects. Indeed, the gradual depletion of a given resource may be economically justified until the (mostly uncertain and unpredictable) threshold of irreversibility is reached.

Another criticism of ES elicited values is its subjectivism. Indeed, the economic assess-

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ment of ES uses the so-called preference-based approaches, which assumes that each individual knows her preferences and is able to reflect her individual perceptions of value. While this assumption is questionable, many criticize the very anthropocentric nature of the approach.

Although some criticism is acceptable for some cases, the benefits brought by the ES approach largely justify its study and usage in parallel with other approaches, if done cautiously with up-to-date and tailor-made methods.

Forest ecosystem services

Forests cover about 30% of the Swiss territory (Source: FSO) and the population directly and indirectly enjoys the valuable goods and services that they provide. These services, known as Forest Ecosystem Services (FES) are defined and categorized into five main functions according to the Swiss Federal Office for the Environment (FOEN, 2014c) and four main functions according to TEEB (2010)¹. In this thesis, we use the following FOEN typology (the TEEB correspondence is indicated in parenthesis).

1. **Production function (Provisioning):** forests produce natural resources. On the one hand, they supply wood, which has a broad range of uses: construction, paper, furniture, energy production, etc. On the other hand, non-ligneous products such as wild game, fruits and mushrooms can be collected in forests.
2. **Purification function (Regulating):** healthy forests sequester carbon and purify the air. Their existence thus reduces the greenhouse gas stock in the atmosphere, which helps mitigate climate change. Forests also naturally filter water and transform rain into drinking water at lower costs than artificial treatments.
3. **Protection function (Regulating):** forests protect land from soil erosion and infrastructures from avalanches and rock slides.
4. **Cultural function (Cultural):** forests provide areas of recreational activities and preserve the landscape diversity.
5. **Biodiversity function (Habitat):** forests are home to many animal and vegetable species.

¹The TEEB (2010) is based on the Common International Classification of Ecosystem Services (CICES (2016))

By providing goods or services, these functions contribute to the economic welfare of the Swiss population. The sum of the above-mentioned FES' values corresponds to the concept of forest Total Economic Value (TEV) (Costanza et al., 1997). In Switzerland, the only attempt to assess forests TEV was made by Rauch-Schwegler (1994).

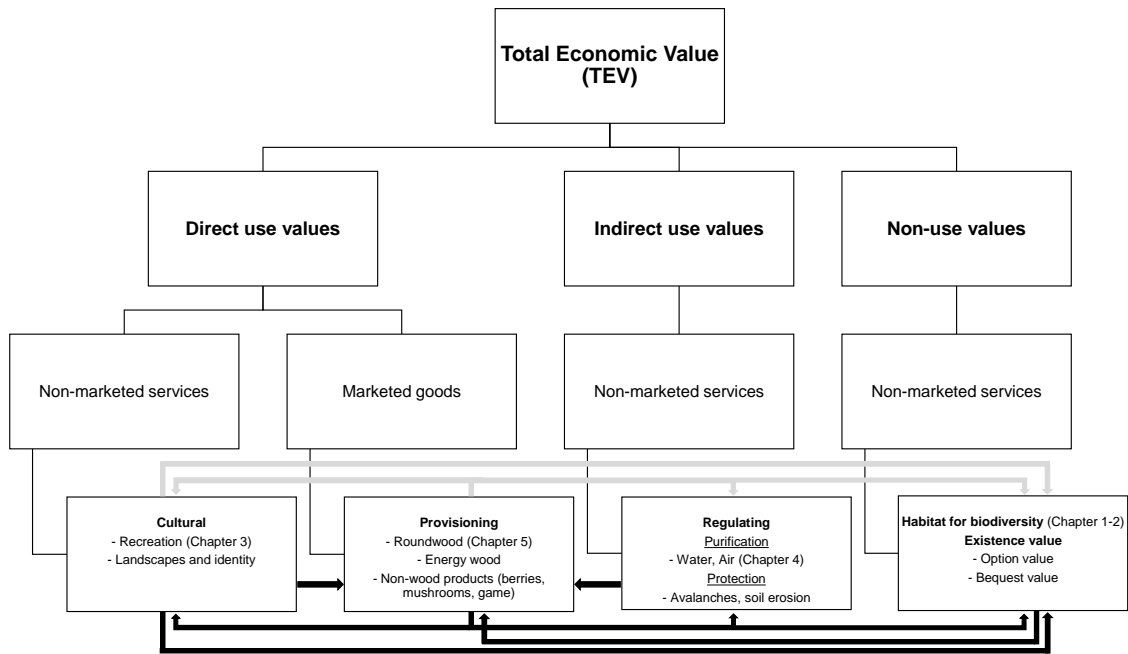


Figure 0.1: Categories of forest values and their links (Source: own conception but based on Montagné et al., 2005)

A representation of forest TEV and its components, split according to the type of values is given in Figure 0.1. These values can be split into 3 main categories: i) direct use values, which, in the case of FES correspond to the uses of forest products and recreation, ii) indirect use (or passive use) values, which refer to passive uses, such as the enjoyment of free protection and purification infrastructure offered by forests and iii) non-use values, whose concept is usually linked to biodiversity but not exclusively, since it is not specific to any function but can encompass them all. Krutilla (1967) was the first to define the existence value that stems out from the very existence of an ecosystem. Option value refers to a potential future use of FES and bequest value to the possibility for future generation to enjoy it.

In Figure 0.1, we indicate the rough correspondence between the values under scrutiny

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and the corresponding chapters of this manuscript. However, in this thesis, we do not fully adopt the TEV framework because of its rigidity. The TEV concept, if understood as the total stock's value of an ecosystem, as often, is controversial. There are indeed several reservations to its use, which has led scholars to present a multitude of values for each FES rather than a single aggregated value. First, use and non-use values are difficult to compare: methodologies are different and each methodology comes with its own biases. In addition, values can be elicited in marginal terms or in absolute terms, which can only be compared with difficulty.² Second, it is often difficult to clearly disentangle values, which leads to the problem of double counting. Third, conflicts and synergies, also represented in Figure 0.1 with the black and grey arrows, respectively, are badly taken into account in the TEV framework, as of today and should be extensively studied. Wood exploitation, in particular, can indeed impose positive or negative externalities (see Borzykowski and Kacprzak, 2017), which would need to be integrated in the TEV. On biodiversity, first of all, forest lightning can foster some endangered species that need light to develop. However, the heavy machinery used in forest exploitation can cause soil compaction and thus reduce habitat opportunities for fauna and flora. In addition, an appropriate management of dead wood is crucial to develop fungi and insect biodiversity and unexploited "natural" forests can also host a number of species that are unable to adapt in other types of forests. Then, on recreational activities, the forest exploitation creates, maintains and secures forest paths, which allow increasing forest recreational opportunities. On the other hand, it can cause noise and restrict access to some forest zones. On the protection function, finally, the rejuvenation of forests resulting from wood exploitation, improves forest ability to retain rock slides or avalanches. Young trees are also better able to resist wildfires and to capture the CO₂ from the atmosphere, hence to mitigate climate change.

Recreational activities can also conflict with other forest functions. The population visits can bother fauna and destroy flora. In addition, they impose higher costs to the forests exploitation as more caution and securitization of the work spaces are needed.

Biodiversity can also impact other forest functions. A diverse forest in terms of fauna

²Although the TEEB advise to elicit marginal values, communication sometimes requires the estimation of absolute values. While this is acceptable on a small scale, the use of absolute values on a larger scale comes with its own issues. For example, the harvest of all trees in Swiss forests, by increasing the supply, would certainly impact the price of wood. It is therefore impossible to use the current price as a correct indication of value. In addition, this baseline scenario corresponds to a situation where forests do not exist in Switzerland, which is unrealistic, in particular when assessing the value of forest protection function. Humans have indeed settled in forested regions on purpose. If the forest were not present, they would not have settled in these regions.

and flora can attract recreationists, hunters and pickers and thus improve the forest recreational value. In exchange, the particular care to forest biodiversity imposes a higher cost burden to the forest economic exploitation. The same occurs with the protection function.

Analyzing conflicts and synergies between FES and their values is certainly of great interest. A better understanding of these relationships would for example make the TEV framework more credible. This, however, is out of the scope of this thesis, given the available data, and is thus left for future research. However, a consistent theoretical TEV framework could be derived, as explained in Johansson and Kriström (2015).

These values are expected to change considerably in the near future due to climate change. First of all, harsher meteorological conditions will test forests' ability to adapt. In accordance, forest biodiversity may decrease or increase. Forests could also be under higher pressure because of more frequent natural disasters. Second of all, one can expect a growing demand for FES. Indeed, climate warming and demographic growth may increase the number of people willing to enjoy a walk in cool forests. The value of forest recreation may therefore increase, as well as other FES.

While goods are available on markets, most services provided by forest ecosystems possess public goods characteristics. Indeed, it is obvious that existence values and other non-use values have non-rivalry and non-exclusivity properties. This is also usually verified for other ecosystem services such as recreation, purification and protection. Therefore, there exists no market and thus no price for these services. While priceless and valueless are antagonist adjectives linguistically, in the case of ecosystem services the lack of price may lead policy-makers to underestimate the value of an ecosystem and design inefficient resource allocations. This fact points out the need for other valuation techniques known as non-market valuation.

Context

Although there are important regional differences, in general, Swiss forests grow both in surface and wood volume since several decades at a rate of 0.2% per year on average (Source: FSO). There are three main reasons for this evolution: First, climate warming allows forests to grow at higher altitudes, where trees could not survive in the past. Second, the surface of agricultural land has decreased, in particular in mountainous regions, leaving room for forests to develop. Third, the wood harvest is lower than Swiss forests natural growth. The latter fact also causes forest ageing, which, in a

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context of fast changing climate, can be problematic. Indeed, old forests usually are unable to sequester more CO₂, which affects climate warming. They are also less able to adapt to a changing climate. Hence, to reduce the risk, forests owners should rejuvenate their forests and choose the tree species accordingly.

The Swiss legal framework highlights forest multifunctionality by ensuring that “forest can fulfill their [multiple] functions” (LFO, 2013, art. 1, al. 1, let. c). The Swiss law on forest is indeed one of the most restrictive regarding the wood harvest. In particular, clear cutting is forbidden and the wood production is only one forest function among others. The Swiss civil code (CC, 2017, art 699, al. 1 ch. 1) also highlights the open nature of forests by allowing the free access to all of them. Therefore, according to legal and economic definitions, forests provide public goods and services, whose financing is usually problematic.

In this context, it is acknowledged that a (reasonable) increase in the wood harvest would be positive for other FES and improve forest resilience (Borzykowski and Kacprzak, 2017). Following this observation, the Swiss government is willing to increase the wood production by 50%³, promote the use of Swiss wood in construction and for energy provision with its wood resource policy (FOEN, 2008) and its forest policy 2020 (FOEN, 2013b). However, forest owners already complain about the costs caused by the multifunctional forest management, which are not fully compensated and imposed by the law. While there are already cases of PES for some Swiss FES, none of them is linked to the quantity of wood produced. The Confederation indeed subsidizes specific cantonal measures fostering biodiversity, maintaining protective forests and forests roads to about 40% of their costs, following convention-programs between the Confederation and the Cantons (FOEN, 2015,b, 2016). Cantons are then free to allocate the money to the forests owners according to the programs. These PES, however, do not give incentives for more harvest.

The production of Swiss wood is thus too low, compared to the optimal level. The observed under-provision of Swiss wood is indeed a standard economic issue when positive externalities are present.

However, while a production intensification would be mostly positive, foresters also recommend that some forests zones (10% of the total forest surface) remain unexploited. These indeed host a particular fauna and flora, which need to be protected to avoid

³It is worth noting that production levels are very low as of today. They indeed reached the lowest level in the last 10 years in 2016, such that a 50% increase would not stop the growth of the standing wood stock in Swiss forests.

their disappearance. A healthy Swiss forest would therefore be composed of diversified forests types.

Economic vs. environmental sustainability

A sustainable use of forest ecosystem services has two interconnected sides: the environmental sustainability and the economic sustainability. Inevitably, in the “laissez-faire” situation, the balance leans towards one side or the other, leading, in the extreme cases, either to forest destruction or to the forest industry collapse. Hence, the Swiss law on forest (LFo, 2013) prevents the degradation of forests ecosystems but also imposes a higher burden on the forest industry by increasing harvesting costs⁴. Environmental sustainability may therefore be obtained at the expense of economic sustainability.

Indeed, the forest industry is currently under pressure: revenues from wood production generally do not cover the costs, which leads to important deficits, and firms involved in forest management are either heavily subsidized or publicly-owned. In a context of international competition, wood prices are indeed pressured downward and marginal costs are high.

Given the positive externalities of wood harvesting, an institutionalized PES system linked with the quantity produced could however increase the wood production and increase the profitability of forest exploitation. Indeed, as per standard in microeconomics, integrating positive externalities in the price would lead to the socially optimal provision (Pigou, 1920), hence improving both economic and environmental sustainability of Swiss forests.

However, unexploited “natural” forests might also be appreciated by the population since they can host other fauna and flora species than exploited forests. Also, forests owners might not be profit driven and hence, might not be responsive to price changes.

In this thesis, I assess the value of Swiss forests functions and apply different methods from revealed and stated preferences to understand how much the population benefits from the forests. I first find that the population is willing to pay an important amount of money to promote natural forests reserves and forest biodiversity and that the creation of new forest reserves is justified in terms of cost-benefit analysis. Second, forest recreational benefits are also found to be substantial. Third, an analysis of the Swiss

⁴See Monat (2017)

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roundwood market reveals that actors are sensitive to price changes, particularly on the demand side.

I argue that, since a reasonable wood harvesting creates positive externalities on other forest ecosystem services and, since the forest industry is responsive to prices, a better institutionalized Payment for Ecosystem Services system to the forest industry, by increasing the wood production, could assure both economic and environmental sustainability of Swiss forests and thus kill two birds with the same stone.

The remainder of this thesis is structured as follows: A brief overview of methodologies and data is presented at the end of this Introduction. Then, Chapter 1 analyses the responsiveness to scope of the Contingent Valuation (CV) method. Indeed, according to the National Oceanic and Atmospheric Association (NOAA) panel (Arrow et al., 1993), CV estimates must show adequate responsiveness to scope to be considered valid. I thus analyze the answers to a cantonal survey and find that the identification of scope responsiveness depends on the assumption on the statistical distribution of willingness to pay. This first survey serves as a pre-test for Chapter 2. Chapter 2 thus builds on Chapter 1 and analyses the CV answers of a national survey with the goal of assessing a non-use value of Swiss forests biodiversity. It gives economic justification to a federal program of the Forest Policy 2020 aiming at increasing the surface of protected forests. Chapter 3 considers Swiss forests recreation function and uses the Travel Cost Method (TCM) to estimate the use values of different forests zones. It derives recommendation for the management of forest recreational zones. Chapter 4 uses an experimental approach to analyze the acceptability of international vs. domestic reforestation as voluntary carbon offsetting. Chapter 5 uses a rich yearly time series data set to derive supply and demand price-elasticities for roundwood. Finally, a general conclusion is made.

Methodologies

The economic analysis and assessment of FES require different methodologies (Riera et al., 2012), the so-called Preference-based approaches. Three categories of techniques can be mentioned: i) *(Indirect) Revealed Preferences* methods (RP), ii) *Stated preferences* methods (SP) and iii) *Market* methods sometimes referred to as *direct revealed preferences*. The choice of the method is subject to the type of value assessed (use or non-use values) and, obviously, to the type of data available. A bibliography of Swiss FES assessments using these methodologies can be consulted in Elsasser et al. (2009) and Elsasser et al. (2016).

Revealed Preferences

Revealed preferences methods derive people's preferences by observing their behavior. These methods are therefore reserved to use values, since they imply some kind of action. The *Travel Cost Method* (TCM) is a very common RP technique first developed by Hotelling in the 40s. It aims at deriving an implicit demand curve for some activity using costs (in particular travel costs) that individuals bear as price and frequency as the quantity purchased. Indeed, "the essence of the travel cost model stems from the need to travel to a site to enjoy its service. A participant who chooses to visit a site must incur the cost of overcoming the distance." (Haab and McConnell, 2002, p. 138) and these costs are necessarily lower than or equal to the benefits of a site's visit. The *Hedonic Pricing Method* (HPM) is another RP technique which is often used in relationship with health or housing markets. HPM consists in decomposing a given price into different components to isolate their effects on price. This method is of particular interest for the assessment of forests proximity on housing prices (see Schaerer et al. 2008).

Within the framework of this thesis, TCM will be applied to assess the demand for recreation in Swiss forests. To my knowledge, the most recent article on this topic at the national level is the one published by von Grünigen and Montanari (2014) based on WaMos2 (FOEN, 2013a), a national survey launched by the Swiss Federal Office for the Environment and before them, on the basis of WaMos1, the work of Ott et al. (2005). These studies only provide estimates of mean travel costs and do not derive any demand curve nor consumer surplus. Also, Swiss forests are considered as homogeneous in these studies, which is an important drawback given their actual variety. Among

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other studies, Baranzini and Rochette (2008) assess the demand for a particular forest, namely the Pfynd wood in Wallis. This study first suffers from endogenous stratification as the survey was administered on-site. Also, the authors use a simple OLS estimation. The technique can indeed be improved by applying a stratified count model instead. An interesting meta-analysis of forest recreation values in Europe is provided by Zandersen and Tol (2009) and guidelines in Parsons (2003).

Stated Preferences

Stated Preferences methods apply, generally but not exclusively, to non-use values. In theory, any good or service can be assessed through SP methods. However, when data on behaviors are available, RP are generally preferred. Some scholars indeed argue that SP data are less reliable than RP data because of hypothetical and strategic biases, although SP methods have become more acceptable in recent years (Haab and McConnell, 2002).

The *Contingent Valuation* (CV) method is a SP economic valuation technique, which elicits the individual Willingness To Pay (WTP) for a change in environmental quality, by proposing a hypothetical scenario. Since the Exxon Valdez oil spill in Alaska in 1989 (Carson et al., 1992), the literature has grown rapidly, with variable confidence (see Carson, 2012). For the sake of comparability and reliability, in 1993 the National Oceanic and Atmospheric Administration (NOAA) panel provided some guidelines (Arrow et al., 1993) that remain a landmark in the field. A number of criticisms (and answers) have arisen since then and different techniques and validity tests have been developed to mitigate biases⁵, eliminate contradictions with economic theory⁶ and elicit truthful preferences⁷. However, CV WTP estimates remain very sensitive to the assumptions imposed by econometric modeling and are still affected by several biases. Policy implications remain therefore controversial. Hausman (2012), for example, makes a case against the use of CV. Some (subjective) hints to the question “Is some number better than no number?” are available in Diamond and Hausman (1994).

Another SP method is the *choice experiment* (CE) or *discrete choice* that proposes to trade-off between different alternatives and the status quo, each of them having different

⁵Hypothetical bias, yea-saying bias, starting-point bias, part-whole bias, among others.

⁶Scope effects, temporal validity, among others.

⁷Incentive compatibility or strategic behavior.

levels of attributes (Boxall et al., 1996) (See Olschewski et al. (2012) for an example about forest's protection function in Switzerland).

In this thesis, I apply the contingent valuation method to assess the WTP for a program based on the Swiss Forest Policy 2020 (FOEN, 2013b), which consists in doubling the surface of protected forests in Switzerland (from 5% to 10% of total forest surface). This scenario thus mainly assesses non-use values of the forest biodiversity function.

CV has been applied to different forest services in Switzerland. Bernath and Roschewitz (2008), for example, propose a CV, assessing WTP for an entrance permit in urban forests areas near the city of Zurich. On the topic of tropical forests conservation, Baranzini et al. (2010) analyze WTP for a decrease in deforestation. Related work, but not specific to forest is the PhD dissertation by Jäggin (1999) that elicits WTP for a biodiversity conservation program in the Jura.

Recent Swiss studies use the payment card elicitation format, which is not considered as incentive-compatible according to Carson and Groves (2007). Also, the NOAA panel (Arrow et al., 1993) recommends to use the referendum format. Meta-analyses of CV forest ecosystem valuation are available in Barrio and Loureiro (2010) and Meshreky et al. (2014).

Market methods

Some forest ecosystem goods such as wood products or non-wood products are available on the market. In these cases, market methods can be used if the market is not deficient and if the price integrates all externalities (Monke and Pearson, 1989). In the case of non-wood products, Kilchling et al. (2009) have surveyed consumers to assess their demand.

The case of the Swiss roundwood market will be analyzed in this thesis. The study of the demand for an ecosystem good allows to reveal price and cross-elasticities and analyze the impact of different covariates on demand and supply. Using time series analysis, changes in technology along time and structural breaks can also be analyzed. In Switzerland, the only empirical work investigating historical wood consumption is Pauli et al. (2009). This study, however, suffers from an important drawback as the empirical analysis is performed with a simple OLS.

An analysis of preferences for international vs. domestic forest carbon offsets is also performed with an experimental approach, which can be considered as a market method.

Data

Several data types and sources were used in this thesis. The different methodologies indeed require specific data, such as survey data, experiments and macro data. The different data types and sources used in this thesis are presented in the following subsections.

Survey data

Non-market valuation is usually based on survey data. To understand the perceptions towards Swiss forests, assess their value, and test the scope responsiveness issue (Carson and Mitchell, 1993a), we first ran a face-to-face pilot survey in the streets of Geneva from January to March 2014. The construction of the questionnaire was cautiously preceded by pre-tests, focus-groups and qualitative surveys. Descriptive statistics and results from this pilot survey are available in Baranzini et al. (2014) and Baranzini et al. (2015).

After the pilot, we integrated the information into a phone survey at the national level and collected 1200 representative observations in Q4 2014. The first part of the questionnaire was designed to apply the individual travel cost method and assess the recreational values of Swiss forests. The second part tried to observe potential conflicts arising from the different forests functions. The third submitted an hypothetical scenario to use the contingent valuation method and elicit the individual WTP for the creation of new forest reserves.⁸

Experimental data

We ran an online laboratory experiment at the end of 2015 on more than 300 participants, who were advertised that they could earn up to CHF 10. Once their endowment was determined thanks to some exercises, they were asked if they were willing to allocate some of it to carbon offsetting reforestation programs, either domestically or internationally. Participants were randomly assigned an informational treatment, trying to foster or hamper international carbon offsets and could really spend their money on each program.⁹

⁸The questionnaire is available in the Appendix B, in French.

⁹The questionnaire is available in the Appendix D.

Macro data

I collected historical data on wood markets in Switzerland by accessing to the archives of the Federal Statistical Office and its website (FSO, 2015c). Many different sources were used but in particular Siegenthaler and Ritzman-Blickenstorfer (1996) and yearly numbers of the *Statistique forestière suisse* and the *Annuaire la forêt et le bois* (FSO, 1976, 1990; FOEN, 1996, 2014g). I was able to collect data on quantities (1851-2013) of aggregate timber and energy wood production in Switzerland, prices (nominal and real) of these aggregates (1928-2013) and prices of substitutes (steel and heating oil (1906-2013)).¹⁰

¹⁰A complete description of sources, assumptions and aggregation methods are available in the Appendix E, in French.

Part I

Stated preferences

Chapter 1

Scope effects in contingent valuation: does the statistical distribution assumption of WTP matter?

Written with A. Baranzini and D. Maradan and published in *Ecological Economics* (Borzykowski et al., 2018). We are grateful to the staff and students of the Laboratory of Market Studies for their valuable support for the survey, to members of the Geneva green spaces service for their comments on the questionnaire, to Bengt Kriström and to three anonymous reviewers of *Ecological Economics*. We thank participants to the 2015 Workshop on Non-Market Valuation in Nancy and to the 2016 EAERE conference in Zurich for their comments.

Abstract

Economic theory assumes that willingness to pay (WTP) increases with the quantity of the consumed good. This implies that there should be a scope effect in contingent valuation studies. However, in previous issues of *Ecological Economics*, several authors criticized the contingent valuation (CV) method for the absence of such effect or its inadequacy. In this paper, we contribute to this on-going debate by proposing to systematically apply several WTP statistical distribution assumptions to test for scope effects and check its plausibility, following Whitehead's (2016) recent recommendations. We perform this approach using data from a Swiss case study assessing the WTP for an increased surface of forest reserves. We find that both mean WTP and scope effects are sensitive to the statistical distribution assumption. Regarding plausibility, scope elasticities provide mixed result and also depend on the assumed statistical distribution of WTP. For small sample size CV studies, a non-parametric analysis, a spike model or an open-ended format can thus be better suited to reveal scope effects than the classical parametric dichotomous choice analysis. We thus recommend to systematically apply several statistical distribution assumptions of WTP to test for scope effects and their plausibility.

Keywords: Contingent valuation, Scope effects; Forests; Scope elasticities; Plausibility

JEL classification: Q23 - Q57

1.1 Introduction

The supposed insensitivity of the willingness to pay (WTP) to the scope of the assessed good in stated preferences methods, and all the more in contingent valuation (CV) studies, is a hot controversy in the literature. Kahneman and Knetsch (1992) were the first to find no significant impact of scope in their CV study, thus casting fundamental doubts on this valuation method. Indeed, if Kahneman and Knetsch (1992, p.1) were right in assuming that “contingent valuation responses reflect the WTP for the moral satisfaction of contributing to public goods, not the economic value of these goods”, then the CV method would be fundamentally flawed and could not be used in valuation studies. However, Carson and Mitchell (1993a) reviewed Kahneman and Knetsch’s (1992) study, as well as other CV studies, and observed that the median is always higher for the WTP related to the bigger scope. Also, several studies (e.g. Smith and Osborne, 1996; Carson, 1997; Bandara and Tisdell, 2005) have indicated that a scope effect is detected when correcting WTP for the difference in sub-samples characteristics and applying the appropriate significance test, even with inexpensive survey methods such as face-to-face interviews (Whitehead et al., 1998). Meta-analyses have also shown that the scope of the assessed good has an impact on WTP (Richardson and Loomis, 2009; Ojea and Loureiro, 2011; Hjerpe et al., 2015). Recently, Bishop et al. (2017b) included two scopes of avoided injuries and found evidence of responsiveness to scope in WTP studies to avoid oil spills like the 2010 Deepwater Horizon in the Gulf of Mexico. However, the WTP difference is quite small relative to the hypothetical change in scope and their results are discussed as well (Baron, 2017; Bishop et al., 2017a).

Since the NOAA panel guidelines (Arrow et al., 1993), testing scope effects should be part of the standard validity tests for a contingent valuation survey. However, the recent debate between Chapman et al. (2016) and Desvousges et al. (2016), the contribution of Whitehead (2016) in *Ecological Economics* and Hausman (2012), clearly demonstrate that scholars have not yet reached a consensus on the issue of “adequate” scope responsiveness. Moreover, the general suspicion that the CV method simply does not “pass” the classical scope test still casts doubt on the very CV method (Hausman, 2012). Indeed, studies that do not robustly detect scope effects are not rare (see e.g. Boyle et al. (1994), McFadden (1994), Veisten et al. (2004), Desvousges et al. (2012) and Frontuto et al. (2017)) and the lack of systematic scope tests may also induce distrust for stated preferences methods in general (see Heberlein et al. 2005).

Although, as recommended in the literature the tests of adequacy or plausibility are

legitimate, in this Chapter we maintain that one should firstly address the basic issue of statistically significant scope responsiveness. We thus deal with the following question: Does the assumed statistical distribution of WTP matter to detect scope effects? We argue that, while sensitivity of mean WTP estimates to distributional assumption is acknowledged (Bengochea-Morancho et al., 2005), split-sample comparisons, identification of scope effects and the result of plausibility tests can also be affected. Because of the lower number of degrees of freedom and the higher variability, this is even more pronounced in small samples and valuing complex environmental amenities (Veisten et al., 2004).¹¹

We apply a split-sample CV survey to measure the scope effects on the WTP and its plausibility, for a program aiming at increasing the surface of forests reserves in Switzerland to protect fauna and flora. Since the program implies some access restriction to recreationists, we fundamentally assess non-use values of these reserves. We analyze this issue using different econometric approaches and ad-hoc external scope tests: (i) we begin by calculating mean WTP estimates, accounting for sub-samples differences in characteristics with several parametric models and hence different WTP statistical distribution assumptions; (ii) we then add information regarding “real zeros” and carry out a parametric spike model (Kriström, 1997) with an asymmetric distribution; (iii) afterwards, we compute a non-parametric estimation, free of WTP distribution assumption; and finally (iv) we analyze the answers of an open-ended follow-up question. To test the plausibility of the responsiveness to scope, we follow Whitehead’s (2016) recent recommendation and thus calculate the scope arc elasticities.

Our results show that individuals are, on average, willing to pay more for larger size (Swiss) forests than for smaller (Geneva) forests. However, the significance level of this difference is largely affected by the assumed statistical distribution regarding WTP. Indeed, parametric estimations from the dichotomous choice elicitation format, such as log-logistic and log-normal, fail to detect statistically significant scope effects; results are mixed with the logistic distribution and depend on the inclusion of covariates; and finally non-parametric models, spike models and open-ended estimates robustly reveal significant scope effects. The test of plausibility proposed by Whitehead (2016) does not rule out nor does it confirm the appropriateness of our scope responsiveness, but the outcome of the test is also largely affected by the assumed statistical distribution

¹¹Small samples are not rare in the CV literature. In the meta-analysis of Meshreky et al. (2014), 39 out of the 105 estimates elicited with the CV method and dichotomous choice are drawn from less than 300 observations. For these studies, scope effects would be even harder to detect.

of WTP. We thus suggest that CV studies have to test for scope effects and their plausibility using several distribution assumptions of WTP, especially in small samples studies.

We introduce the CV method and our questionnaire in Section 1.2. The empirical approach and descriptive statistics are provided in Section 1.3. Section 1.4.1 presents the results from different parametric distributions for the dichotomous choice format and different tests for scope effects. Section 1.4.2 analyzes the results from the Turnbull non-parametric estimation, while Section 1.4.3 uses the open-ended follow-up question to provide WTP estimates. We estimate scope elasticities in Section 1.4.4. Section 1.5 discusses and concludes.

1.2 Survey design

The CV questionnaire is composed of three parts. The first aims at understanding preferences on, knowledge of and behavior in forests. The second part is the contingent valuation of the proposed increase in forest reserves. The third part gathers individuals' socioeconomic characteristics.¹² It is worth noting that, in general, Swiss forests are in good health and growing. However, in some regions human activities are in conflict with biodiversity.

We base the scenario for the contingent valuation on an actual federal program, part of the Swiss Forest Policy 2020 (FOEN, 2013b), as recommended in Arrow et al. (1993). This program aims principally at fostering endangered biodiversity by increasing the surface of protected forests, from 5% to 10% of the total forest surface¹³. Transforming productive forests in forest reserves involves opportunity costs for the forest industry, as well as some access restrictions to recreationists.

To analyze the existence of a scope effect, we use the split-sample approach as in Berrens et al. (2000): To a sub-sample (the “Swiss forest sub-sample”, CH) composed of 228 individuals randomly picked in the whole population, we ask if the respondent's

¹²A travel cost analysis and other information about the survey results are available in Baranzini et al. (2015). The full questionnaire is available upon request.

¹³The use of absolute instead of relative changes could have improved the understanding of the contingent question, which might have led to a more robust scope effect identification (Ojea and Loureiro, 2011). However, the use of relative changes is not rare in CV and can be better suited to value complex environmental amenities. The federal policy is also expressed in relative terms.

household would be willing to pay an amount of CHF X to increase the surface of protected forests in Switzerland.

We then administer to another sub-sample from the same population (the “Geneva forest sub-sample”, GE) exactly the same question, but referring to Geneva forests only. To avoid part-whole bias (Whitehead et al., 1998), an issue emerging when individuals believe that the program will apply to a larger scale, we remind the Geneva forest sub-sample that the program will apply to Geneva forests only. It is worth noting that Geneva forests account for about 0.2% of total forest surface in Switzerland, so that the difference in scope between the two versions of the program is substantial. Geneva being part of Switzerland, we consider the two program versions to be perfectly embedded, as recommended in Kahneman and Knetsch (1992). The Geneva program is indeed geographically nested in the Swiss program.¹⁴ However, this assumption can be discussed. Indeed, our programs would not be perfectly embedded if individuals do not believe that their money will be used the same way in Geneva and in Switzerland and if they have a different perception of cantonal vs. federal taxes. However, a Greek study (Remoundou et al., 2012) has found a non-significant impact of the providing institution on the WTP, even with low and significantly different trust levels. In addition, in Switzerland, trust in the institutions is relatively high at the cantonal and federal level¹⁵, and thus this issue should not be very relevant.

We build the question as an advisory referendum, specifying that the results would be used to implement the policy. To reduce the hypothetical bias (Hausman, 2012), we follow an ex ante approach (Loomis, 2011) and thus insist on consequentiality of the survey (Carson and Groves, 2007), with a reminder that the respondent might concretely contribute to the program. We also follow Mitchell and Carson (2013) and Kotchen and Reiling (1999) and add an income constraint reminder to make the respondent aware of the opportunity costs she faces.

WTP is thus elicited through the Single-Bounded-Dichotomous-Choice (SBDC) approach, as is recommended by the NOAA panel (Arrow et al., 1993) and by most recent studies (Carson and Groves, 2007; Mueller, 2014; Bishop et al., 2017b), because of its incentive compatibility, its ability to avoid non-response and outliers and its lower cognitive burden (Bateman et al., 2002). Indeed, by asking if the respondent is willing

¹⁴It is worth noting that, given the small size of Switzerland, each inhabitant lives relatively close to a forest and that all Swiss regions contain wide forest areas.

¹⁵According to the World Value survey, 65.1% of the Swiss inhabitants trust the government in 2009 (WVS, 2017).

to purchase the service at a given price, this format allows mimicking a market-type situation and is thus relatively simple to understand. Furthermore, as Swiss people are often consulted for referenda, this type of question seems particularly appropriate in our context.

We use a federal or cantonal lump-sum tax as payment vehicle, because of forests public good characteristics: as the benefits of forest reserves are non-rival, the appropriate payment vehicle must request contribution from everyone. The off-site survey also requires a payment vehicle that includes forests non-users. In a CV survey on tropical forests, Baranzini et al. (2010) indeed show that a tax provides a higher WTP than a voluntary payment in a forest fund, the latter being subject to free-riding.

With the SBDC approach, a selection of tax amounts (bids) is randomly assigned between respondents. As Haab and McConnell (2002) mention, the selection of bids is of particular importance. A carefully selected bid vector can considerably improve the efficiency of WTP estimates. However, the optimal bid vector can only be designed if the true WTP distribution is known. But, obviously, if true mean WTP is known, there is no reason to derive an optimal bid vector (Haab and McConnell, 2002, p. 129). An exhaustive literature review and a meta-analysis of 47 CV studies on forest in developed countries published between 1993 and 2014 (Meshreky et al., 2014) revealed that the mean WTP for forest programs ranges from USD (2011, PPP) 0 to 650 per household, per year, with a mean at 100 and a median at 68. We therefore select our 6 bids (CHF 10, 60, 100, 250, 500 and 1000)¹⁶ accordingly and confirm them by a preliminary open-ended qualitative questionnaire discussed in focus groups, as recommended in Kanninen (1993) and Haab and McConnell (2002).

After the referendum question, we administer an open-ended follow-up question, which consists of asking maximum WTP for the program, as Garcia et al. (2007). We use this approach to compute an open-ended estimate of WTP. This estimate, however, suffers from the incentive incompatibility issue (Carson and Groves, 2007). Indeed, because of the public good nature of the program, respondents usually tend to strategically understate their true WTP with open-ended questions. The bid proposed in the referendum question also creates anchoring, which pushes the maximum WTP towards the proposed bid.

We design a second follow-up question to distinguish protest bids (Jorgensen and Syme, 2000) from “real zeros”. If the answer to the previous question is zero, then the respon-

¹⁶On December 31st 2014, CHF 1=EUR 1.20=USD 0.98

dent has to state the reason in a closed-ended question. We identify protesters if the reason for not contributing is unrelated to the value of forest¹⁷. Other reasons are considered “real zeros”.

1.3 Empirical approach and descriptive statistics

Based on the Random Utility Model (McFadden, 1973), first applied by Hanemann (1984) for CV, the individual’s probability to answer “Yes” to the bid can be modeled by the bid itself, a vector of explanatory variables and an error term, and estimated with a binary model. However, before estimating the model, the statistical distribution of WTP still has to be assumed. This assumption can be made using different plain parametric models (Bishop and Heberlein, 1979), such as probit, logit, log-logit, log-normal or mixture models such as the spike model (Kriström, 1997). This choice is not necessary when using non-parametric models, since the latter do not require to assume any particular WTP distribution (Kriström, 1990). The logit model is the most frequently used model, because the calculation of mean WTP is easier (Bateman et al., 2002) and it is often confirmed with a non-parametric approach. For example, Bishop et al. (2017b), use a probit model and confirm the estimations by a non-parametric model.

We test different distribution assumptions, by using several parametric and non-parametric models, either including covariates or not. Adding independent variables to the models should not change mean WTP as the latter is evaluated at covariates mean. However, it allows to control for heterogeneous characteristics of split-samples, which may, in our case, have a different effect on mean WTP. The inclusion of covariates in the model thus allows to better extrapolate the WTP from one sample to another, which enables estimating what respondents from one sub-sample would be willing to pay for the program proposed to the other sub-sample. Covariates may also help decreasing unobserved heterogeneity, thus decreasing the variance. The final model choice is thus based on differences in split-samples characteristics and intuition regarding the effect of

¹⁷“I would like more information on this topic before accepting paying this amount”, “I do not trust the state. I have no guarantee that the money will indeed be used to finance the program.”, “I already pay enough taxes”, “Forest is a public good, so it is not reasonable to ask me to pay for it” and “The state, the forests owners or forest users should pay, not me.”.

variables on bid acceptance.¹⁸ The sample is composed of 419 independent observations from which the sub-sample GE has 191 and CH 228 observations. The final matrix of explanatory variables is described in Subsection A, in the Appendix.

As Table 1.1 shows, each bid has been proposed to 16 persons minimum. The acceptance rates, unsurprisingly, decrease with the bid amount in both sub-samples and, while the acceptance rate of the Geneva program falls to 6% for a cost of CHF 1000, it reaches 18% for the Swiss program for the same cost. This may indicate that the range of the bid vector could have been wider for the Swiss program. We observe a non-monotonous decrease in the acceptance rates in both sub-samples, which is not a particularly rare result with small sample sizes (Kriström, 1990; Bateman et al., 2002).

Table 1.1: Structure of the answers to bids

	10	60	100	250	500	1000	Total
Yes	26	22	18	12	6	6	90
No	16	12	24	29	29	28	138
(incl. protester)	(9)	(7)	(10)	(12)	(2)	(5)	(45)
(incl. real zeros)	(7)	(4)	(8)	(9)	(11)	(10)	(49)
CH N	42	34	42	41	35	34	228
Acceptance rate	0.62	0.65	0.43	0.29	0.17	0.18	0.39
Protest rate	0.21	0.21	0.24	0.29	0.06	0.15	0.20
Follow-up max. WTP ^a	23.44	54.07	87.81	124.48	171.67	303.10	126.84
(Std. dev.)	(34.60)	(27.63)	(110.85)	(115.22)	(226.11)	(386.98)	(212.07)
Yes	34	25	19	3	3	1	85
No	6	15	20	37	13	15	106
(incl. protester)	(3)	(7)	(6)	(12)	(6)	(5)	(39)
(incl. real zeros)	(3)	(7)	(9)	(8)	(2)	(1)	(30)
GE N	40	40	39	40	16	16	191
Acceptance rate	0.85	0.63	0.49	0.08	0.19	0.06	0.45
Protest rate	0.08	0.18	0.15	0.30	0.38	0.31	0.29
Follow-up max. WTP ^a	46.24	40.50	60.40	84.68	203.00	141.82	79.30
(Std. dev.)	(54.87)	(34.10)	(54.88)	(83.02)	(216.75)	(136.59)	(101.90)

^a Mean of the follow-up open-ended question about maximum WTP, excluding protest answers

Protest rates are stable across bids¹⁹ and are not significantly different across sub-samples.²⁰ It is interesting, but not surprising, to observe that the mean maximum

¹⁸Because the low response rate for the income question drastically reduces the number of observations, we do not include any income variable in the final model. For information, we provide the descriptive statistics of income in both sub-samples in Table a.1 in the Appendix. While income and its distribution could be drivers of WTP (Baumgärtner et al., 2017), there is no reason to think that it may impact scope. Indeed, mean income and income distribution in both sub-samples are not statistically different.

¹⁹With the exception of the relatively low protest rate of the 500 bid in CH and the 10 bid in GE.

²⁰Protest bids should not be removed unless the sub-sample of protest bidders reveals the same

WTP elicited with the open-ended follow-up question usually increases with the bid proposed for the Swiss program, revealing an anchoring effect.

1.4 Results

1.4.1 Parametric estimations

The use of parametric modeling techniques implies to impose a statistical distribution of WTP. Normal and logistic distributions are often used because of their relative ease to handle. However, these distributions suffer from an important drawback: since they are defined symmetrically over $] - \infty : +\infty[$, they include the possibility of negative or infinite willingness to pay. As Bateman et al. (2002) mention, if an individual does not value the improvement in the provision of the good, we expect a zero WTP. A negative WTP is acceptable only if the program can be considered as a deterioration (see Boman and Bostedt (1999) and the wolves example). In addition, an individual's WTP shall not be higher than her income and WTP should thus lie in the interval $[0 : y]$ (with y the income) in most cases. Asymmetric distributions such as the log-normal or log-logistic can take care of the negative WTP issue but cannot rule out infinite WTP. Mixture models such as spike models or truncated models could also be used and are recommended in Bateman et al. (2002).²¹

Since there is no consensus on the statistical distribution and given that we are more interested in testing the scope effects and its robustness across distributions, rather than in the value of WTP, we decide to run different parametric models (logistic, log-normal, log-logistic) on our split-samples and apply different tests for scope effects such as the Z-test, the non-overlapping confidence intervals test (Park et al., 1991), and the Complete Combinatorial (CC, Poe et al., 2005) test. Since logistic and normal

characteristics as other respondents (Halstead et al., 1992). In the CH sub-sample, protesters are on average significantly older, they are less likely to be members of environmental associations, live in a more urban environment and go less often to forests than non-protesters. In the GE sub-sample, protesters are more often men and live in a more urban environment. Protesters characteristics are apparently different from non-protesters and dropping those observations may hence bias our estimates because of self-selection. However, considering them as real zeros would create a downward bias. There is no universally acknowledged simple method to deal with protest bids (see Strazzera et al. (2003)). In the following analysis we hence exclude protesters but, in terms of scope effects, results are similar when protesters are included as real zeros. Results including protesters are available upon request.

²¹In this Chapter, we do not artificially truncate the parametric distributions. However, results regarding scope effects are similar with a truncation point above CHF 1000.

distributions usually give similar results, we rule out the normal distribution thanks to the prediction accuracy. The logistic distribution is modeled by a logit, the log-normal and log-logistic distributions are, as usual, computed with probit and logit models respectively and applying the logarithm on the *Bid* variable.

Full estimation results are presented in Table a.2 in the Appendix. We observe that the coefficients associated with the *Bid* variables are always significantly negative, which was expected. *Ceteris paribus*, the probability of accepting the bid thus significantly decreases with its amount in both sub-samples. Effects of covariates are commented in Subsection A, in the Appendix.

Before calculating WTP estimates, we check whether both sub-samples respond differently to the bid proposed and if coefficients are similar across sub-samples. We therefore run pooled models on top of models on split-samples and test for poolability using the Likelihood Ratio test (*LR*) as in Berrens et al. (2000) or Veisten et al. (2004). We find that sub-samples should not be pooled, which confirms our split-sample methodology²².

As Poe et al. (1994) stress, if mean WTP does not reveal any scope effects, one should anyway check if statistical distributions are different. An analysis of mean, median and WTP distribution is therefore necessary to analyze scope effects. The calculation of WTP central tendency (mean and median) depends on the distributional assumption (see Aizaki et al., 2014).

Mean and median WTP resulting from parametric estimations are presented in Table 1.2.

As expected, estimates are very sensitive to the distributional assumption and range from CHF 277 to 2064 for the Swiss program and CHF 183 to 335 for the Geneva program. WTP arising from log-distributions are higher, because of the asymmetry and the right skewness of these distributions. This is a standard result, as acknowledged in Bengochea-Morancho et al. (2005).

According to these parametric approaches, we find that respondents from our sample are willing to pay on average more for new protected areas in Swiss forests than for the same program, but applied to Geneva forests only. However, using Z-tests, the difference is

²² The LR test is written as $LR = -2[\ln L_{Pooled} - (\ln L_{CH} + \ln L_{GE})] \sim \chi^2(10)$, where $\ln L_{Pooled}$ is the log-likelihood from the pooled model, $\ln L_{CH}$ the log-likelihood from the CH model, $\ln L_{GE}$ the log-likelihood from the GE model. The test statistic follows a χ^2 with 10 degrees of freedom, the number of equality restrictions.

Table 1.2: WTP estimates from the plain parametric distributions

	Scope	Mean WTP	Std. Err.	CI ^a	Δ CH-GE	Med. WTP	Std. Err.	CI ^a	Δ CH-GE	Covariates	N
Logistic	CH	276.69	(53.97)	[175; 421]		n.a. ^b	-	-	-	No	183
	GE	183.11	(42.99)	[125; 540]	93.57	-	-	-	-	No	152
	CH	303.02	(51.45)	[179; 442]		n.a. ^b	-	-	-	Yes	183
	GE	182.34	(38.22)	[120; 420]	120.68*	-	-	-	-	Yes	150
	GE at CH	188.17	(45.67)	[120; 420]	114.85*	-	-	-	-	Yes	150
Log-normal	CH	2064.38	(1990.39)	[582; 64939]		132.26	(31.23)	[79; 216]		No	183
	GE	334.65	(142.99)	[186; 1417]	1729.73	110.94	(19.47)	[78; 164]	21.32	No	152
	CH	1578.97	(1344.96)	[542; 53227]		148.04	(33.95)	[90; 249]		Yes	183
	GE	280.55	(107.90)	[167; 1271]	1298.42	107.82	(17.94)	[75; 160]	40.22	Yes	150
	GE at CH	289.05	(124.17)	[167; 1271]	1289.92	111.09	(24.11)	[75; 160]	36.95	Yes	150
Log-logistic	CH	n.a. ^c	-	-		136.08	(31.87)	[81; 220]		No	183
	GE	-	-	-	-	112.00	(18.48)	[80; 163]	24.08	No	152
	CH	n.a. ^c	-	-		151.25	(35.64)	[89; 257]		Yes	183
	GE	-	-	-	-	110.76	(17.62)	[77; 165]	40.49	Yes	150
	GE at CH	-	-	-	-	111.48	(23.64)	[77; 165]	39.77	Yes	150

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Std. Err. computed with the Delta Method in parenthesis

^a Krinsky and Robb CI at 95%, computed with 1000 replications^b Logistic distributions are symmetrical and hence mean WTP equals the median.^c Mean WTP is undefined for $\sigma > 1$ for the log-logistic

statistically significant for the logit model with covariates only. The difference in median WTP values for log-distributions do not reach the significance level either.

Similarly, the non-overlapping confidence interval method (Park et al., 1991) using Krinsky and Robb (1986) confidence intervals at 95% does not reveal any significant scope effect, since the major part of the intervals overlap for each WTP distribution.

A complete combinatorial approach, as proposed in Poe et al. (2005) aims at testing the difference between two distributions. This methodology requires Krinsky-Robb simulation technique. We simulate 1000 replications of WTP for both sub-samples and subtract each possible combination of these WTP. The proportion of positive differences can be interpreted as the p-value for $H0: WTP_{CH} = WTP_{GE}$. This test rejects $H0$ with 90% confidence for the log-normal models with and without covariates. In all other models $H0$ is not rejected, and the test concludes that no scope effects are observed.

To check if differences in samples characteristics play a role in the determination of scope effects, we follow Carson and Mitchell (1993b)'s procedure and evaluate WTP for the Geneva program at CH sub-sample covariates mean (\bar{CH}), to get an estimate of what respondents from the CH sub-sample would be willing to pay for the Geneva program. The results are shown in rows GE at \bar{CH} . When differences in sub-samples characteristics are taken into account, estimates display similar results as if this difference was not corrected for. Thus, no significant scope effects can be observed in this case either, except for the logistic distribution. We can therefore conclude that the correction for sub-samples differences in characteristics does not help revealing scope effect and that these differences do not play any significant role in its determination in this case.

Kriström (1997) proposes a spike model that split real-zeros and positive WTP in two groups. This distribution thus has two parts: a spike at zeros to account for excess real-zeros and an asymmetric distribution for strictly positive bidders. The advantage of this model is that, by allowing a distributional break at 0, it may better fit the real distribution and therefore better reveal scope effect, assuming there is one. Coefficients from the log-normal model applied on positive bidders are presented in Table a.3 in the Appendix²³. They will allow to calculate a mean WTP conditioned on positive WTP. We obtain the unconditional mean WTP by multiplying the conditional mean by the proportion of positive bidders. WTP resulting from the spike log-normal model are presented in Table 1.3 and show an important difference between the mean WTP for

²³Spike models also reject the null hypothesis for poolability given by the LR test.

the programs. When adding covariates, this difference is significant for conditional and unconditional WTP estimates. Furthermore, the CC approach rejects the hypothesis of same distribution with and without covariates. By giving more information, the spike model with log-normal distribution on positive bidders thus reveals scope effects, even with a lower number of observations, contrary to the “plain” log-normal model. This shows that one should test more sophisticated parametric models and try to better fit the real WTP distribution, particularly with small samples.

Table 1.3: WTP estimates from the spike log-normal distribution

	CH	GE	CH	GE
Cond. mean WTP	832.56	294.88	746.96	234.75
(Std. Err.)	(342.37)	(82.57)	(259.32)	(27.69)
CI ^a	[462; 3025]	[206; 714]	[432; 2742]	[209; 407]
Δ CH-GE	538.12		512.21**	
Uncond. mean WTP	609.63	236.68	546.95	188.42
(Std. Err.)	(250.70)	(66.28)	(171.87)	(22.23)
Δ CH-GE	372.95		358.53**	
Cond. med. WTP	336.66	198.49	388.64	202.85
(Std. Err.)	(65.57)	(32.18)	(77.46)	(21.23)
Δ CH-GE	138.17*		185.79**	
Covariates	No	No	Yes	Yes
Observations	134	122	134	120

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Std. Err. computed with the Delta Method

^a Krinsky and Robb CI at 95%, computed with 1000 replications

Figure 1.1 represents the acceptance rate for each bid (excluding protesters) and the estimated survival function of the assumed WTP distributions. We observe that none of the assumed statistical distributions perfectly fits the data and that the choice of one statistical distribution over the others is impossible. This fact further highlights the importance of testing different statistical distributions of WTP in this context.

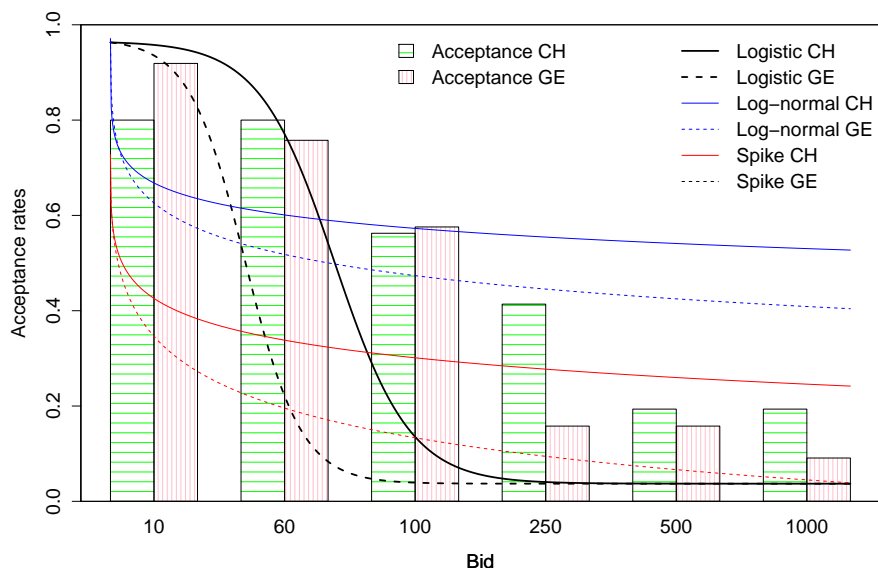


Figure 1.1: Acceptance rate and assumed WTP distributions (estimated with covariates)

1.4.2 Non-parametric estimation

We follow the Turnbull non-parametric approach for binary data, also known as the Ayer estimator (Ayer et al., 1955), which has been developed in Kriström (1990) for the CV method. The advantage of this approach is that a specific distribution assumption for WTP is not necessary. The only assumptions are that the probability of accepting a bid at CHF 0 is 100%, which rules out negative WTP and that the probability of accepting some high bid, the truncation point, is 0. The truncation point should be chosen according to respondents' preferences or income constraints, information that is usually missing. The relative strength or weakness of these assumptions depend on the program being valued.

We build the survival function of bid acceptance for discrete choice WTP data as in Bateman et al. (2002). The estimated points of the survival function are thus calculated as:

$$\hat{S}(Bid_j) = \frac{n_j}{N_j} \quad (1.1)$$

where Bid_j is the bid level ($j = 1 \dots 6$), N_j is the number of persons to whom the bid has been proposed, n_j the number of persons who said "Yes" to the given bid and \hat{S} the

estimated survival function.

A valid survival function, from well-behaved preferences, has to be monotonously decreasing. As this is not the case for some bid levels, we correct for this issue using the Pooled Adjacent Violators Algorithm (PAVA) method, proposed by Robertson et al. (1988) and also called Turnbull Self Consistency Algorithm.²⁴ This method, presented in Haab and McConnell (2002), pools the Bid_j with Bid_{j-1} if the acceptance rate for Bid_j is higher than for Bid_{j-1} .

As for the parametric estimation, we do not include protesters. Following Kriström (1990), we interpolate linearly between bids, but a step function, as proposed in Bateman et al. (2002) is also applicable. We arbitrarily truncate our survival function at 1200²⁵, which is likely to underestimate the true WTP, because the last bid and the truncation point are close. However, this applies to both sub-samples estimations and should therefore not affect scope effects. The resulting survival functions are illustrated in Figure 1.2, which shows that the survival function for the Swiss forest sub-sample (plain line) is usually higher than the Geneva forest sub-sample's survival function (dashed line). It is interesting to see that the survival functions are close at low bids and seem to diverge only after a certain threshold.

To compare the survival functions in Figure 1.2 and test for differences between these two functions, we use the non-parametric Kolmogorov-Smirnov test (KS). This test does not reveal any significant difference between CH and GE distributions as a whole. However, a KS test concludes that the survival functions between the bids 250 and 1000 are significantly different at the 5% confidence level. In our bid design, since the bids are not equidistant, there may be troubles with the KS test as all points of the estimated survival function have the same weight, while the highest bids have the strongest impact on WTP estimates. To correct for that issue, we interpolate \hat{S} with 6 hypothetical equidistant bids and test again for significant difference in survival function. This manipulation does not distort respondents' preferences. Indeed, if the individual accepts to pay 250, she should also accept to pay 166.66. This procedure allows to reject the hypothesis of same WTP distributions for both sub-samples at

²⁴For the sake of replication ease, the data used to estimate the non-parametric model are available in Table a.4, in the Appendix.

²⁵The maximum WTP, as stated in the open-ended follow-up question, indicates that no respondent is willing to pay more than 1000. Since the acceptance rate of the 1000 bid is still high (18% and 6% for CH and GE respectively) and given the incentive incompatibility of the open-ended format, it would be unrealistic to truncate at 1000. We thus choose 1200 to stay conservative. The estimations with a truncation at 1000 display the same results in terms of mean WTP scope responsiveness.

the 95% confidence level, revealing that WTP distribution is, on average, statistically higher for the Swiss program than for the Geneva program.

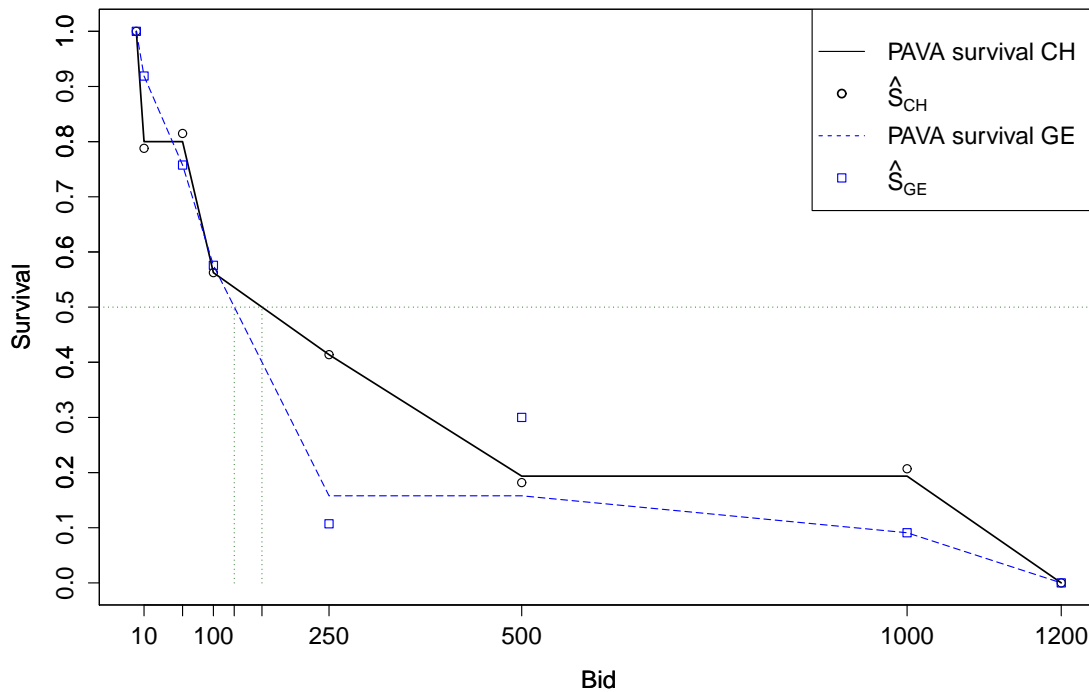


Figure 1.2: PAVA survival function of WTP

Using the Turnbull approach, the median WTP for the Swiss forest sub-sample on graph 1.2 corresponds to the point where the function hits 0.5 on the Y axis. Mean WTP can be calculated as the area under the survival function.

Table 1.4 presents the WTP central tendency estimates of the non-parametric approach. CH mean WTP is again larger than GE. Furthermore, a Z-test reveals that the CH mean WTP is significantly higher than GE WTP at the 99% confidence level. Hence, where parametric estimates fail to reveal scope effects by lack of efficiency, the Turnbull estimator and the associated tests manage to distinguish the WTP difference in both sub-samples.

Table 1.4: Non-parametric WTP estimates

	CH	GE
Mean WTP	341.52***	243.96***
Std. Err.	(27.32)	(26.54)
Δ CH-GE	97.56***	
Median WTP	163.04***	127.20***
Std. Err.	(28.21)	(23.40)
Δ CH-GE	35.85	
Observations	183	152

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

1.4.3 Using the anchored open-ended follow-up

As mentioned earlier, our survey has a follow-up open-ended question asking the maximum WTP for the program. While the first aim of this question was to identify protest bids, the answers also give information about (stated) maximum WTP in an anchored context²⁶. Protest bids were again excluded from the sample to avoid the protest bias. As highlighted in Desvousges et al. (1987), although the preceding dichotomous choice question should moderate this issue, open-ended questions may also suffer from outliers. This seems not to be the case in our sample, since the stated maximum WTP never overcomes CHF 1000, which corresponds to the highest bid proposed and to a little fraction of respondents' mean stated income.

As our bids are the same in both sub-samples, we assume that each anchor (each bid) has the same effect on the maximum stated WTP in both sub-samples. There are no clear evidence to support this assumption in the literature. However, there is no theoretical reason to believe that the anchoring effect would be different either. Therefore, we run a simple analysis of weighted means to test for scope effects. The weights are computed to keep the exact same proportion of each bids in both sub-samples, to ensure the same anchoring effect. As shown in Table 1.5, we again find a larger mean WTP for the Swiss forest sub-sample. Applying a Welch test, the difference is significant at the 90% confidence level. More efficient estimates produced by the open-ended format are thus better able to reveal scope effects in our case.

²⁶In addition to the anchoring bias, these answers suffer from incentive incompatibility (Carson, 2012) and may thus be affected by a strategic bias. Indeed the open-ended format does not give the incentive to respondents to truthfully reveal their preferences. Yet, we assume that this bias is similar in both sub-samples. Therefore, the strategic biases should cancel out when looking at WTP differences.

Table 1.5: Weighted average maximum WTP from the open-ended follow-up

	CH	GE
Mean WTP	126.84	97.36
Std. dev.	(212.07)	(48.83)
Δ CH-GE	29.47*	
Observations	182	119

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

1.4.4 Plausibility of the scope responsiveness

As noted by the NOAA panel, findings from CV must show “adequate” responsiveness to scope to be considered reliable (Desvousges et al., 2012), an issue that needs to be tested with an adding-up test (Diamond and Hausman, 1994). Unfortunately, as the Geneva and Swiss programs are not defined incrementally²⁷, we cannot discuss the adequacy of the scope responsiveness with this method. Very recently, Whitehead (2016) proposed to calculate the scope elasticity of WTP as an indicator of economic significance or “plausibility”, rather than only statistical significance. Scope elasticities (ε_Q) are defined for an infinitesimal change in quantity (the scope: Q) such that $\varepsilon_Q = \frac{dWTP}{dQ} \frac{Q}{WTP}$. Hence a continuous WTP-scope function is necessary. Our split sample methodology does not allow to derive a continuous WTP-scope function since only two WTP points were estimated. We therefore calculate the variation of WTP in terms of “arc elasticity” such that: $\varepsilon_Q = \frac{\Delta WTP}{\Delta Q} \frac{\bar{Q}}{\bar{WTP}}$ (Whitehead, 2016, p. 20), with \bar{Q} and \bar{WTP} the mean values of Q and WTP respectively. Arc elasticities thus represent an average elasticity between two distant points. For our case:

$$\varepsilon_Q = \frac{(WTP_{CH} - WTP_{GE})}{(Q_{CH} - Q_{GE})} \frac{(Q_{CH} + Q_{GE})}{(WTP_{CH} + WTP_{GE})} \quad (1.2)$$

With WTP_{CH} the mean WTP for the Swiss program, WTP_{GE} the mean WTP for the Geneva program, Q_{CH} the scope of the Swiss program and Q_{GE} the scope of the Geneva program (in hectares). Q_{CH} is equal to 10% of the Swiss forest surface and Q_{GE} equals 10% of Geneva forest surface (i.e. 126'040 hectares and 301 hectares respectively in 2014 (FSO, 2016a)). Elasticities whose confidence intervals fall into the $[0; 1]$ range are considered plausible, according to Whitehead (2016), since they would respect the positive but decreasing marginal utility theory.

²⁷The adding-up test requires to value 3 scopes such that $A=B+C$ (Whitehead, 2016). We only have information about one part (B) and the whole (A) but lack C to implement the adding-up test.

Table 1.6: Arc scope elasticities

Statistical distribution	WTP central measure	Covariates	ε_Q	$IC_{95\%}$
Logistic	Mean	No	0.20	[-0.08 ; 0.49]
Logistic	Mean	Yes	0.25**	[0.0010 ; 0.50]
Log-normal	Mean	No	0.72***	[0.23 ; 1.22]
Log-normal	Median	No	0.088	[-0.20 ; 0.38]
Log-normal	Mean	Yes	0.70***	[0.23 ; 1.17]
Log-normal	Median	Yes	0.16	[-0.11 ; 0.43]
Log-logistic	Median	No	0.098	[-0.18 ; 0.38]
Log-logistic	Median	Yes	0.16	[-0.12 ; 0.43]
Spike	Conditional mean	No	0.48**	[0.10 ; 0.86]
Spike	Unconditional mean	No	0.44**	[0.049 ; 0.84]
Spike	Conditional median	No	0.26**	[0.027 ; 0.49]
Spike	Conditional mean	Yes	0.52***	[0.28 ; 0.76]
Spike	Unconditional mean	Yes	0.49***	[0.24 ; 0.74]
Spike	Conditional median	Yes	0.32***	[0.12 ; 0.52]
Non-parametric	Mean	No	0.12	
Non-parametric	Median	No	0.12	
Open-ended	Weighted mean	No	0.13	

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Confidence intervals computed with the Delta Method

The resulting arc scope elasticities and their confidence intervals at 95% are presented in Table 1.6. Confidence intervals of the logistic with covariates, log-normal and spike model are strictly positive. However, elasticities from the log-normal model may exceed 1, which would contradict the decreasing marginal utility theory. These elasticities, according to Whitehead (2016), tend to show that WTP elicited through plain models do not robustly show plausible responsiveness to scope, with the exception of the logit model with covariates. However, elasticities from the spike distributions fall in the plausible range. Hence, by adding more information on the WTP distribution and thus reducing the variance, the spike model results in more plausible scope responsiveness in our case.

The arc scope elasticities confirm that the responsiveness to scope is sensitive to the distribution assumption of WTP. Moreover, not only the statistical significance, but also the plausibility, is affected by this assumption. Similarly to the statistical significance, the logit model with covariates and the spike models are better able to reveal plausible

responsiveness to scope.

1.5 Conclusion

We test for scope effects and evaluate their plausibility applying several WTP statistical distribution assumptions: parametric estimations, a non-parametric estimation and an estimation based on the open-ended format. We apply this approach on data from a CV survey assessing the WTP for a program aiming at increasing the surface of protected Swiss and Geneva forests. While the sensitivity of mean WTP to the statistical distribution assumption is acknowledged, we note that it also has an impact on split-samples comparison and on the ability to detect scope effects. Non-parametric models such as the Turnbull model, which assume no a priori WTP statistical distribution, are better able to reveal scope effects than plain parametric models (logit, log-logit, log-normal). More sophisticated models such as the spike model, by giving more information about individuals' WTP distribution, are also more powerful in revealing statistically significant and plausible scope effects. Open-ended formats, despite biases, could also reasonably be used for this purpose. For small sample sizes, a non-parametric analysis, a spike model or an open-ended format can therefore constitute better options than the classical parametric analysis for comparing two WTP estimations, in particular for complex non-market goods. Since the results will depend on the real WTP distribution, we suggest that CV studies have to systematically apply various statistical distributions of WTP, and different ad-hoc statistical tests, paying particular attention to both differences in point estimates such as the mean and the median, but also to differences in statistical distributions.

Since the NOAA panel guidelines (Arrow et al., 1993), testing scope effects should be part of the standard validity tests for a contingent valuation survey. However, some studies do not successfully detect scope effects and argue that the very CV method may be unreliable. The debate has recently gone further in *Ecological Economics* with Whitehead (2016), Chapman et al. (2016) and Desvousges et al. (2016) about adequacy, rather than the very existence of the scope responsiveness. We argue that the debate on the existence of scope effects is not closed yet and that studies with mixed conclusions will continue to appear also with Whitehead's (2016) new plausibility test. We therefore recommend to pay particular attention to the assumed statistical distribution of WTP, since it has a major incidence on the detection of scope effects.

Chapter 2

Are there enough forest reserves in Switzerland? A contingent valuation

Written with A. Baranzini and D. Maradan and published in French as "Y a-t-il assez de réserves forestières en Suisse? Une évaluation contingente" in *Economie Rurale* (Borzykowski et al., 2017b). We are grateful to the anonymous referees of *Economie Rurale* for their comments, which helped improving the paper significantly. We thank the participants to the Workshop on valuation of forest ecosystem services, held in 2016 at HEG-Geneva for their contributions.

Abstract

We run a contingent valuation on a representative sample of the population to estimate the willingness to pay (WTP) for a program aiming at creating new forest reserves in Switzerland. Since the scenario includes access restrictions to the forest zones, the analysis focuses on non-use values, in particular existence values. The parametric and non-parametric analyses of the single-bounded-dichotomous-choice answers indicate a mean WTP of about CHF 470 to 500 (about EUR 390 to 415) per year and household. We study the selection bias caused by protest bidders and find that it does not statistically affect the WTP. The analysis of WTP acceptance determinants reveals that income has a positive but bounded impact and that city-dwellers are more prone to accept paying for the program.

Keywords: Contingent valuation; Switzerland; Forest reserves; Willingness to pay

JEL Classification: D61 - H41 - O13 - Q23 - Q57

2.1 Introduction

The Swiss Federal Council adopted the Forest Policy 2020 in 2011 to harmonize cantonal forest policies, optimize wood exploitation, assure forest multifunctionality and protect them against climate change. Indeed, while the Swiss forest surface grows, the biodiversity and the global forest health are under pressure because of housing development around urban areas and climate change, particularly in the Alps (Fischer et al., 2015). A measure proposed by the government is to increase the surface of forest reserves to 10% of the total forest surface up to 2030 (Gattlen, 2012). The intermediary goal of 5% has been reached in 2015, although some critical voices rise about the non-representativity of these forest areas (FOEN, 2014d).

The Swiss Confederation defines forest reserves as “large areas durably protected, [...] and secured by a contract between the Canton and the forest owner (in general for 50 years time and sometimes for 99 years). [...] In these areas, the priority is given to the biodiversity over all other forest-linked interests.” (FOEN, 2015b)

This policy implies some costs, in particular opportunity costs. Indeed, when a forest area is protected, the economic exploitation is slowed down (Bolkesjø et al. 2005, Lepänen et al. 2005): wood production is reduced and the area can not be used to other purposes such as agriculture, housing, etc. In a Swiss case study, Krähenbühl (2016) shows that a hectare of biodiversity forest is not economically profitable for the forest owner, contrarily to a productive hectare of forest. Therefore, the transformation from a productive forest to a forest reserve implies some economic shortfalls for the forest industry.

In return, new forest reserves foster biodiversity (Parviainen et al. 2000, Küffer and Senn-Irlet 2005) and, to a lower extent, allow forests to better sequester carbon, filtrate water and protect against natural hazards. Since the status of forest reserve is only given to existing forests, and given the restrictive application of the Swiss Law on Forest (LFo, 2013)²⁸, one only observes a marginal improvement of forest functions that are not linked with biodiversity. Some reserves are also open to the public, who can observe fauna and flora’s diversity, even though some non-secured areas can be dangerous for hikers, in particular because of dead trees (Borzykowski and Kacprzak, 2017). However, access restrictions to some other areas can also decrease the recreational opportunities.

²⁸The goal of the Swiss law on Forests is to “insure that forests can accomplish their role, in particular their protective, social and economic role.” (LFo, 2013, art. 1 al. 1 letter c) by forbidding clear cuts, for example (LFo, 2013, art. 22).

The Confederation compensates forests owners for the creation of new forests reserves. This compensation amounts CHF 60²⁹ per year and hectare on the Midland area, between CHF 20 and 60 in the Jura region and CHF 20 in the Alps (OFEV 2014f; 2015b). These transfers amount CHF 1.6 millions per year (own estimations for 2012) and should rise up to CHF 3.4 millions per year in 2030. These voluntary agreements can be considered as some kind of payment for ecosystem services (Tacconi, 2012), similarly to those of the Natura 2000 policy in the European Union (Hily et al., 2015).

Are benefits associated with the creation of new forest reserves comparable to the costs? We answer this question with a Contingent Valuation (CV) from a phone survey and analyze the impact of different variables on the acceptability to bear the costs of such a program.

The CV is a stated preferences method, which consists in asking the Willingness to Pay (WTP) for a hypothetical program. It has become very successful after its usage in calculating the compensation amount of the Exxon Valdez oil spill in Alaska (see Carson et al. 1992). Despite the biases highlighted in the literature (Alberini and Kahn, 2006), the approach allows to estimate non-use values, which is not possible with revealed preferences methods. As the scenario of our contingent valuation plans to restrict access in the forest reserves, the recreational uses in such zones are not possible. Hence, the estimation of non-use values, such as the existence value (Krutilla, 1967) is meaningful and justifies the use of the CV method in our case. There are several studies analyzing recreational benefits of forest reserves.³⁰ In Switzerland, Baranzini and Rochette (2008) use the travel cost method to assess the value of recreational services in the Pfyn/Finges pine forest reserve in Wallis (Switzerland). Other studies assess the recreational activities, using the CV method, like Scarpa et al. (2000) in the case of the creation of new forest reserves. These studies run on-site surveys and thus only focus on forest users. This methodology, in addition to implying endogenous stratification (Shaw, 1988), does not (or imperfectly) consider the non-use values.

There are several contingent valuation studies on forests conservation (see Barrio and Loureiro 2010 for a meta-analysis). For example, Kniivilä et al. (2002) estimate the benefits for a forest conservation program in Northern Finland. These authors conclude that conservation programs are justified by a cost-benefit analysis at the national and regional levels but their results are less clear cut at the local level. Indeed, the exploita-

²⁹In December 2014, CHF 1=EUR 0.83 (Swiss National Bank, 2015).

³⁰See the meta-analysis of Zandersen and Tol (2009) for examples. It includes 26 studies that use the travel cost method to assess the recreational benefits of European forests.

tion restrictions can affect close inhabitants more strongly than those living further away. These results highlight the importance of non-use values compared to use-values or market values, in particular in a national level context. In the same spirit, Pouta et al. (2000) find that WTP for the Natura 2000 program increases with income and if the individual lives in an urban environment. Lehtonen et al. (2003) analyze the WTP for a conservation program in Finland with a choice experiment, another stated preferences method, and a contingent valuation and Lindhjem and Navrud (2011) propose a similar program for Norway. While these studies indeed use stated preferences methods, the resulting WTPs include use and non-use values.

In Switzerland, to the best of our knowledge, there are no analysis on the existence value of forest reserves. Only a few studies assess forest biodiversity but include use and non-use values as well. Jäggin (1999) runs a contingent valuation study with the inhabitants of Basel City, to assess the biodiversity in the Jura region, including its forests. In 1998, the Basel-dwellers were willing to pay between CHF 324 and 1536 per year and household for a biodiversity conservation program in the Jura. With a choice experiment, Bade et al. (2011) find a WTP for the promotion of forest biodiversity in Swiss forests between CHF 40 and 80 per year and household.

Our study differs from these contributions by the assessment of forest reserves non-use values. The main goal of our program being the protection of biodiversity, which would imply access restriction in our case, we only assess the existence value of forest biodiversity. We find that the Swiss inhabitants' WTP for such a program is relatively high (even slightly higher than WTP from other European studies, which include use and non-use values). This result probably reflects the high income level in Switzerland and people's strong preferences towards forest conservation.

The remainder of this Chapter is structured as follows: Section 2.2 present the questionnaire and the survey, Section 2.3 explains the econometric methods, Section 2.4 presents the data, while results are presented in Section 2.5. Section 2.6 discusses and concludes.

2.2 The survey

We ran the survey in December 2014, at any time of the day and any day of the week, on a sample of 1200 adult inhabitants of Switzerland. The survey is administered by phone, which comes with some disadvantages, as it is impossible to use visual mediums.

This can indeed be restrictive when presenting the contingent scenario. However, before the phone call, we sent a letter with some information about Swiss forests and the study. A phone survey can also cause some sample selection, since elderly people are generally easier to survey than young and single managers. This is more and more the case, as the latter have less fix phones. Nevertheless, an internet or face-to-face survey also comes with the same kind of sample selection. To minimize this issue, the sample is chosen with the random quota method and is thus roughly representative of the Swiss population. We nevertheless observe some over-representation of the inhabitants of Tessin (the Italian speakers) and of elderly people³¹. The questionnaire³², whose administration lasts about 15 minutes, is composed of 28 questions. It has been translated from French to German and Italian, the other two national languages in Switzerland³³. After some filter questions, the first part is designed to assess the recreational use of forest in general, with the aim of applying the travel cost method (see Chapter 3). The second part allows to evaluate the concerns about Swiss forest's health and the respondent's membership to environmental friendly associations or her proximity to the forest industry. Finally, before the socio-demographics, the third part of the questionnaire submits a hypothetical scenario to apply the contingent valuation method. The questionnaire has been pre-tested at a small scale and with focus-groups (see Baranzini et al. 2015), as recommended in the literature. We also ran some validity tests by comparing our questionnaire with WaMos2 (FOEN, 2013a) and running a scope test (Carson and Mitchell, 1993a). Results of the latter are available in Chapter 1.

The contingent scenario is worded as follows:

“A third of the Swiss territory is covered by forests, including 5% of protected forests. Those host a rich and diverse ecosystem, allow to mitigate the effects of climate change and protect against some natural hazards (avalanches, land slides, erosion...). To preserve and durably develop the Swiss forest and its multiple functions, the Confederation considers doubling the surface of protected forest reserves up to 2030. The creation of new forest reserves has the following advantages:

- A better protection of biodiversity
- A lower number of natural hazards (avalanches, land slides)
- A stronger climate change mitigation

³¹Table b.1, in the Appendix compares some socio-demographics of our sample with those of the Swiss population. The rejection rate is 49%.

³²The complete questionnaire is available in the Appendix, in French.

³³These versions are available upon request.

However, this program would also engender costs:

- Higher logistic costs to implement the program
- Economic shortfalls for the wood industry
- Access restriction to the protected zones

The Confederation considers financing these costs with a specific tax and needs to know the population's opinion on this topic, to orient its environmental policy and study how this program could be implemented. You could concretely contribute to this program. Hence, it is important that your answer really reflects your willingness to contribute to the creation of new forest reserves. Therefore, before answering, think about your income constraints, and the other causes that you might be willing to contribute to. Be aware, however, that the success of the program principally hangs on its financing.”

Then, the respondent is asked if she would be willing to pay a federal tax, whose amount (“bid”) is randomly and uniformly chosen among CHF 12, 60, 120, 240, 480, 780 and 1000. These amounts were selected after a comprehensive literature review and a meta-analysis (Meshreky et al., 2014). They were first confirmed by an open-ended question in focus-groups and by a pilot study on a sample of 300 Geneva inhabitants (Chapter 1). This procedure is recommended by Kanninen (1993).

The binary elicitation format, which is called referendum format or Single-Bounded-Dichotomous-Choice (SBDC), is the most reliable format according to the literature. It is also recommended by the National Oceanic and Atmospheric Association (NOAA, Arrow et al. 1993). Indeed, with this format, there are no incentive to answer strategically, which is a common issue in the valuation of public goods (Carson and Groves, 2007). In addition, the cognitive burden is lighter, in comparison with an open-ended elicitation format (Bateman et al., 2002). The Double-Bounded-Dichotomous-Choice approach is now more and more used for its ability to increase the statistical efficiency, at the expense of the incentive compatibility (Alberini, 1995) and of the anchoring effect. Therefore, since the number of observations is relatively high in our case, we prefer the SBDC format. Moreover, Swiss people are used to referenda, which increases the credibility of our scenario. We opt for a yearly instead of single payment because the program runs over the long term. Also, with a single payment format, future benefits should be discounted by the respondents, which would involve a higher cognitive bur-

den. The annuality indeed implies that the costs and benefits discounting cancel out (Egan et al., 2015).

We pay a particular attention to the reduction of the contingent valuation biases: We try to reduce the hypothetical bias by adding a “cheap talk” (Cummings and Taylor, 1999), reminding income constraints and insisting on the respondent’s answer consequentiality (Herriges et al., 2010). As payment vehicle, we opt for a federal tax, rather than a voluntary payment, to reduce the free-riding issue (cf. Baranzini et al. 2010). To identify protest answers (Jorgensen and Syme, 2000), if the individual rejects the referendum, we administer an open-ended follow-up question asking the respondent’s maximum WTP³⁴. If this is 0, another question asks the reason why. All answers that have no direct link with the respondent’s income constraint or her lack of interest in forests is considered as a protest answer³⁵. We first analyze the protest answers’ characteristics and then use a version of Heckman (1979) selection model, composed of two simultaneous probit models, to correct for the selection bias caused by protest answers.

2.3 Empirical approach

Two types of econometric approaches exist to analyze answers of a SBDC contingent valuation: the parametric approach, as proposed in the seminal paper of Bishop and Heberlein (1979) and the non-parametric approach proposed by Kriström (1990). The former requires an a priori assumption regarding the statistical distribution of WTP, while the latter does not impose any restriction with this respect.

Based on the Random Utility Model (RUM; McFadden 1973), it is generally acknowledged that the respondent will accept the bid (A) proposed in the referendum if her WTP is higher:

$$Prob(“yes”) = Prob(WTP \geq A) = Prob(WTP - A \geq 0) = F(\Delta u(.)) \quad (2.1)$$

With F the assumed statistical distribution function and Δu the difference between the contingent program utility and the bid utility.

The mean WTP then corresponds to the surface under the distribution function such that:

³⁴It is worth noting that answers to this question are subject to anchoring, since the question follows the bid proposition. Therefore, we do not analyze the results of the maximum WTP in this paper.

³⁵For example: “It is not my duty to pay for such a program”, “I already pay enough taxes”, “I do not trust the government”.

$$E(WTP) = \int_0^{\infty} F[\Delta u(\cdot)]dA - \int_{-\infty}^0 1 - F[\Delta u(\cdot)]dA \quad (2.2)$$

With a linear utility such that $\Delta U = \alpha - \beta A$ and F a symmetric distribution (logistic or normal)³⁶, the log-likelihood function is:

$$\ln L = \sum_{yes} \ln(F(A)) + \sum_{no} \ln(1 - F(A)) \quad (2.3)$$

With the maximum likelihood method, the mean WTP is equal to its median for a symmetric statistical distribution:

$$E(WTP) = \frac{\alpha}{\beta} = med(WTP) \quad (2.4)$$

The parametric estimation of WTP is thus equivalent to estimating the following binary model:

$$P(Y = 1|A) = F(A\beta_1) \quad (2.5)$$

With Y the binary answer to the bid A and β_1 the coefficient resulting from the estimation.

This approach also allows to add some explanatory variables Z (for example socio-demographics), such that the model becomes:

$$P(Y = 1|A, z) = F(A\beta_1 + Z'\beta_2) \quad (2.6)$$

And the mean and median WTP:

$$E(WTP) = \frac{\alpha + \beta_2 \bar{Z}}{\beta_1} = med(WTP) \quad (2.7)$$

With α the constant resulting from the estimation and \bar{Z} a vector of mean values of Z . The explanatory variables do not affect mean WTP but allow to study factors, which can impact the bid acceptance.

³⁶Another statistical distribution assumption is also possible: log-normal, log-logistic, Weibull or Gamma are also used in the literature (Bateman et al., 2002). We opt for a statistical distribution that is defined over $]-\infty; \infty[$ because access restrictions could engender negative WTP.

With respect to the non-parametric estimation, also called Turnbull estimator, one builds a monotonously decreasing survival function with the help of the “yes” proportions for each bid and the Pooled Adjacent Violator Algorithm (PAVA), developed by Ayer et al. (1955)³⁷. The mean WTP is then calculated as the surface under the survival function.

2.4 Descriptive statistics

The sample is composed of 1200 individuals, including 46, who did not want or could not answer the dichotomous question. These observations thus had to be dropped, as well as 19 other non-complete observations. In addition, we identify 194 protest answers, corresponding to 17% of the sample. This proportion is similar to other studies in the literature (see Halstead et al. 1992).

Table 2.1 presents the answer to the dichotomous choice. We observe that the “yes” proportions decrease monotonously with the bid increase, such that the Ayer et al. (1955) algorithm in the non-parametric analysis is useless. This fact is probably due to the relatively high number of observations for each bid.

Table 2.1: Answers to the dichotomous choice

Bid (A)	«No» ^a	«Yes»	% of « yes »	Total	% of total	Protests	Total
12	12	99	89.2	111	11.8	17	128
30	23	106	82.2	129	13.7	21	150
60	22	78	78.0	100	10.6	24	124
120	36	85	70.2	121	12.9	28	149
240	55	63	53.4	118	12.5	26	144
480	82	50	37.9	132	14.0	32	164
780	83	38	31.4	121	12.9	18	139
1000	80	29	26.6	109	11.6	28	137
Total	393	548	58.3	941	100	194	1135

^aWithout protest bids

2.4.1 Explanatory variables

We introduce explanatory variables in the parametric model, to better understand the factors that influence the bid acceptance and correct for the sample selection bias,

³⁷This algorithm allows to make the survival function monotonously decreasing for the non-parametric estimation.

which arises from dropping the protest answers. As usual, the included variables are chosen according to their economic interest and thanks to the *Pseudo-R*² and Akaike (*AIC*) and Bayes (*BIC*) information criteria. The indicators provided by the Stata12 command `fitstat` also helped discriminating between available explanatory variables. Since some individuals did not answer some questions of the questionnaire, the inclusion of explanatory variables causes some observations loss. From the 1200 observation, dropping the non-response, the final sample contains 987 observations including protest answers and 808 excluding them.

The income question, in particular, decreased the number of observations, since 14% of the respondents did not want to answer it. However, the socio-demographic characteristics and the answers to the dichotomous choice do not differ for the individuals who did not answer the income question. We therefore rule out any self-selection bias.

Table 2.2 presents the explanatory variables included in the parametric model, for non-protests and protests.

Table 2.2: Descriptive statistics

Variable	Non-protests		Protests	
	Mean	(Std. dev.)	Mean	(Std. dev.)
<i>R35</i>	0.082	(0.274)	0.112	(0.316)
<i>R35_50</i>	0.165	(0.371)	0.173	(0.379)
<i>R50_80</i>	0.241	(0.428)	0.257	(0.438)
<i>R80_120</i>	0.318	(0.466)	0.279	(0.450)
<i>R120_160</i>	0.109	(0.312)	0.095	(0.294)
<i>R160_200</i>	0.051	(0.220)	0.045	(0.207)
<i>R200</i>	0.035	(0.183)	0.039	(0.194)
<i>FR*</i>	0.287	(0.453)	0.346	(0.477)
<i>IT</i>	0.160	(0.367)	0.179	(0.384)
<i>Age*</i>	50.38	(15.014)	53.71	(14.94)
<i>Female*</i>	0.512	(0.500)	0.380	(0.487)
<i>Jura</i>	0.024	(0.152)	0.028	(0.165)
<i>Rural</i>	0.293	(0.456)	0.313	(0.465)
<i>Often*</i>	0.527	(0.500)	0.631	(0.484)
<i>Member</i>	0.397	(0.485)	0.335	(0.473)
<i>Swiss Wood</i>	0.535	(0.499)	0.598	(0.492)
<i>Reserve*</i>	0.658	(0.475)	0.503	(0.501)
<i>Number of Children</i>	0.756	(1.051)	0.821	(1.071)
Observations	808		179	

* Statistically different characteristics between both groups

Variables R are binary variables that take the value 1 if the gross household's income lays in the proposed interval. For example, if $R35 = 1$, the household's gross income is less than CHF 35,000 per year; if $R35_50 = 1$ the household earns between CHF 35,000 and CHF 50,000 per year.

Variables FR and IT indicate the language in which the questionnaire was administered (French and Italian respectively). It is also a relatively precise indication of the region where the respondent lives, since French speakers live on the Western side, and Italian speakers on the Southern side. Age indicates the age of the respondents, $Female$ if the respondent is a woman, $Jura$ if the individual lives in the Canton of Jura, $Rural$ if the individual lives in a rural environment. $Often$ takes the value 1 if the individual "often" visits forests, in opposition to "sometimes" or "never". This variable is thus a respondent's subjective indication of forest visit frequency. $Member$ is a binary variable, which equals 1 if the individual is member of or donates to one or several environment friendly associations. We use the latter as a proxy for environmental preferences.

$Swiss Wood$ equals 1 if the individuals prefers the Swiss wood, which is more expensive, rather than imported wood. Two hypotheses regarding this variable can be considered: on the one side, the individual could consider that the wood production is important for the economy and thus favor the interest of the Swiss forest industry. In this case, as the creation of new reserves implies restriction in the wood harvest, the individual would have a lower propensity to accept the bid, all things being otherwise equal and thus, the coefficient associated with the $Swiss Wood$ variable would be negative. On the other side, the local production of wood could be preferred for its higher environmental sustainability. In this case, the individual could have a preference for forest multifunctionality, which would come with a positive sign of the coefficient associated with this variable.

$Reserve$ is a dummy variable, which takes the value 1 if the individual agrees to restrict the access in protected forests to protect fauna and flora. Given the access restrictions proposed in our program, an individual who agrees with this kind of measure would be more prone to accept the bid, all things being otherwise equal.

$Number of Children$ indicates the number of children in the household. This variable could have two different effects: on the one hand, a household with children should have a higher bequest value (Krutilla, 1967), which should increase the probability to accept the bid. On the other hand, the number of children reduces the household's income per capita. In this case, if the income has a positive impact on the bid acceptance, the

coefficient associated with this variable should take a negative sign.

We first describe the non-protests sample. Like the general population, the household's income is skewed to the right: only 4% of the sample earns more than CHF 200,000 per year, while 9% have less than CHF 35,000. The mode is between CHF 80,000 and 120,000. About 55% of the respondents often visit forests and 55% favor Swiss wood, rather than cheaper imported wood. 37% are members of or donate to environment friendly associations and 63% of the respondents would agree to restrict access to forests to protect fauna and flora. Finally, the households have, on average 0.8 children.

Protest individuals are statistically more French speaking, less members of "green" associations, older, more males and visit forests more often than non-protests³⁸. As highlighted by Garcia et al. (2009) and Meyerhoff et al. (2014), dropping protest answers can lead to a selection bias if these individuals have different characteristics from others and if these characteristics have an impact on the WTP. These statistically significant differences are also found with a probit model (hereafter binary selection model), which analyzes the probability of being a protest bidder. Results of this model are presented in Table b.2 in the Appendix.

Given these differences in characteristics, a variant of Heckman (1979) selection model for probit models (Van de Ven and Van Praag, 1981) can be necessary. We hence first include the inverse of the Mills ratio (λ)³⁹ from the binary selection model in the main binary model. If the coefficient of λ is significant, the estimation is affected by a selection bias (Strazzera et al., 2003) and, hence, using Van de Ven and Van Praag (1981) model is justified. An application of this econometric approach is available in Whitehead et al. (1993) or Petrolia et al. (2010) in the case of contingent valuations for Kentucky wetlands or the use of ethanol in gas, respectively.

³⁸Protests in Strazzera et al. (2003) have similar characteristics. An explanation given by these authors is that individuals, who often use forests are less willing to accept paying for a service that they could get for free. In our case, with the access restrictions, this is even more understandable.

³⁹The inverse of the Mills ratio is calculated as $\lambda = \phi(Z_i'\beta_i)/\Phi(Z_i'\beta_i)$ with ϕ the density function and Φ the cumulative density function of a standard normal distribution.

2.5 Results

2.5.1 Parametric analysis

In Table 2.3, we present the results of the parametric estimates from the maximum likelihood method for the probit model⁴⁰ without explanatory variable (column 1), with explanatory variables (column 2) and with λ , the inverse of the Mills ratio from the binary selection model (column 3). The latter model allows to test the utility of Heckman's selection model proposed by Van de Ven and Van Praag (1981) for our case. Since the coefficient associated with λ is negative and statistically significant at the 90% confidence level, it is possible that a selection bias affects the estimated WTP. To correct for this, we estimate Van de Ven and Van Praag (1981) model⁴¹, combining the selection model and the main model. Results of this estimations are displayed in Table 2.4. We observe that this model's results are very similar to those from Table 2.3. Moreover, the Wald test of independent equations⁴² indicates that the null hypothesis of independence between the selection model and the main model cannot be rejected (p-value=0.59). Hence, the use of a simultaneous model does not seem indispensable (Whitehead et al. 1993, Strazzera et al. 2003), which is why we prefer model (2) from Table 2.3. However, results from the other models are not statistically different.

Coefficients of the explanatory variables have the expected signs. As predicted by economic theory, the coefficient associated with the bid variable is negative and statistically significant (p-value<0.01) in each model.

We observe that the impact of the income is not linear. Indeed, comparing with the 80-120 class (the mode of the income distribution), lower classes accept significantly less often the bid. This effect is particularly strong for the lowest class. Contrarily, higher classes do not accept the bid more often. One can thus observe a threshold effect: after a certain level, the income does not have any statistically significant effect on the probability of acceptance. This result is in line with the literature, which often finds that income has a decreasing influence on WTP for environmental goods (see Kriström and Riera 1996b).

With respect to linguistic regions and associated cultural differences, the French speakers are more prone to refuse to pay the proposed bid than German speakers, while

⁴⁰We trade-off between probit and logit with the help of different R^2 values.

⁴¹This model can be estimated with Stata12 using the `heckprob` command.

⁴²This test is similar to the likelihood ratio test on the null hypothesis $\rho=0$.

Italian speakers are not statistically different. In contrast, the inhabitants of the Jura region - the densest region in terms of protected forests - accept more often the bid than inhabitants of other Swiss regions.

Living in a rural environment is associated with a more frequent rejection of the bid. Hence, proximity to forests seems to play a negative role in the bid acceptance. This can be explained by the additional constraint incurred by the new forest status for close inhabitants (access restriction, loss of economic opportunities). This result contradicts the “distance decay” hypothesis (Bateman et al., 2006), which predicts that WTP decreases with distance and is generally confirmed for use values. In contrast, the hypothesis of decreasing marginal utility with proximity, which is more coherent in the case of non-use values, can be proposed: an individual who lives close to a forest (i.e. the rural inhabitants) benefits from a lower marginal utility of new forest reserves than the individual living further away (i.e. the urban inhabitants).

All other things being equal, we observe that frequent forest visitors accept more often the bid than others. Respondents who prefer Swiss wood and “green” members accept it more often as well, similarly to individuals who agree to restrict access to forest to protect fauna and flora. Hence, individuals with “greener” preferences have a higher probability to accept the bid than others. In addition, the positive coefficient associated with the *Swiss Wood* variable may indicate that the preference towards local wood is tied to the sustainable nature of the Swiss forest management and not to purely economic considerations.

The number of children in the household has a negative effect on the acceptance probability of the bid. We assume that a higher number of children could reduce the per capita income, which is why respondents agree less often the bid, despite a potentially higher bequest value.

We present different mean WTP estimates from the parametric analysis in Table 2.5. Column (1) presents the mean WTP estimated without explanatory variable (equation 2.4). The mean WTP in column (2a) corresponds to equation 2.7 excluding protests, while column (2b) includes the protests characteristics in \bar{Z} ⁴³. Finally, column (3) presents the mean WTP from the Van de Ven and Van Praag (1981) model.

While estimates (1) and (2a) are naturally close, since the bids were randomly attributed, we observe that (2a) and (2b) are not statistically different. Similarly, while

⁴³To calculate $E(WTP)$ in column (2a), we use the statistics of the non-protests sample from Table 2.2, while $E(WTP)$ in column (2b) uses statistics for the whole sample in \bar{Z} .

Table 2.3: Estimation results of the parametric models (probit)

	(1)	(2)	(3)
	Without explanatory variables	With explanatory variables	With explanatory variables and λ
<i>Bid (A)</i>	-0.00170*** (0.0001)	-0.00195*** (0.0002)	-0.00164*** (0.0001)
<i>R35</i>		-0.616*** (0.188)	-0.530*** (0.181)
<i>R35_50</i>		-0.327** (0.156)	-0.270** (0.136)
<i>R50_80</i>		-0.358*** (0.132)	-0.313*** (0.118)
<i>R120_160</i>		-0.0120 (0.176)	-0.0874 (0.154)
<i>R160_200</i>		-0.291 (0.230)	-0.303 (0.212)
<i>R200</i>		0.231 (0.330)	0.274 (0.249)
<i>FR</i>		-0.313*** (0.119)	-0.207** (0.113)
<i>IT</i>		-0.212 (0.143)	-0.118 (0.136)
<i>Jura</i>		0.658* (0.337)	0.463 (0.297)
<i>Rural</i>		-0.223** (0.112)	-0.148 (0.0991)
<i>Often</i>		0.242** (0.101)	0.189* (0.104)
<i>Member</i>		0.200* (0.104)	0.157* (0.0940)
<i>Swiss Wood</i>		0.197* (0.101)	0.083 (0.0892)
<i>Reserve</i>		0.446*** (0.107)	0.372*** (0.130)
<i>Number of Children</i>		-0.131*** (0.046)	-0.106** (0.043)
λ			-1.029* (0.595)
Constant	0.804*** (0.063)	0.801*** (0.154)	0.776*** (0.229)
Observations	941	808	987
<i>Pseudo - R</i> ²	0.144	0.218	0.168

Heteroskedasticity-robust standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table 2.4: Estimation results of the probit model with selection

	Selection (protest : yes/no)	Valuation (Bid : yes/no)
<i>Bid (A)</i>		-0.0019*** (0.0002)
<i>R35</i>	-0.251 (0.189)	-0.594*** (0.193)
<i>R35_50</i>	-0.106 (0.150)	-0.319** (0.156)
<i>R50_80</i>	-0.114 (0.131)	-0.350*** (0.132)
<i>R120_160</i>	0.0006 (0.176)	-0.011 (0.175)
<i>R160_200</i>	-0.069 (0.240)	-0.283 (0.230)
<i>R200</i>	0.0428 (0.247)	0.230 (0.329)
<i>FR</i>	-0.198* (0.111)	-0.297** (0.121)
<i>IT</i>	-0.211 (0.136)	-0.195 (0.146)
<i>Jura</i>	0.078 (0.328)	0.649* (0.336)
<i>Rural</i>	-0.001 (0.109)	-0.221** (0.112)
<i>Often</i>	-0.200 (0.100)	0.255** (0.103)
<i>Member</i>	0.137 (0.103)	0.191* (0.105)
<i>Swiss Wood</i>	-0.151 (0.100)	0.206** (0.102)
<i>Reserve</i>	0.363*** (0.100)	0.417*** (0.118)
<i>Number of Children</i>	-0.103 (0.051)	-0.128*** (0.047)
<i>Age</i>	-0.010*** (0.004)	0.844*** (0.169)
<i>Female</i>	0.266** (0.103)	
Constant	1.502*** (0.253)	
athrho		-0.172 (0.323)
rho		-0.171
Observations		987
Non-selected observations		179
Selected observations		808

Wald test of independent equations (rho=0) : chi2(1) = 0.28 Prob > chi2 = 0.59

Heteroskedasticity-robust standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

WTP in (3) is higher⁴⁴, it does not differ, statistically speaking, from the other models. This means that the selection bias caused by dropping the protests is not statistically significant in our case. The parametric estimation thus indicates that Swiss households are willing to pay between CHF 470 and 500 per year to create new forest reserves (these estimates are between CHF 394 and 615 with 95% confidence).

Table 2.5: WTP per year and household (parametric estimates)

	(1)	(2a)	(2b)	(3)
	Without explanatory variables	With explanatory variables	With explanatory variables and protests characteristics	With explanatory variables and correction for selection
$E(DAP)$	474.31 (27.59)	479.42 (27.98)	470.37 (27.90)	497.98 (57.55)
$IC_{95\%}$	[422 ; 532]	[421 ; 524]	[421 ; 524]	[394 ; 615]
Observations	941	808	987	987

$IC_{95\%}$ calculated with Krinsky and Robb (1986) procedure with 1000 replications
Standard errors calculated with the Delta method in parenthesis

2.5.2 Non-parametric analysis

For the non-parametric analysis, we build the survival function as in Figure 2.1 with the “yes” to the dichotomous choice proportion (cf. 4th column of Table 2.1), without protests. We opt for a linear interpolation between point estimates as in Kriström (1990) and to truncate at CHF 1200. This decision is justified for conservative reasons. Indeed, observing the slope of the distribution between bids CHF 780 and 1000, one can consider that our truncation point is relatively low, which will tend to underestimate the mean WTP.

It is also possible to create a step survival function, as in Bateman et al. (2002). With a truncation point at 1000, this function can be used to estimate a lower bound for the mean WTP. We calculate mean and median WTP for both estimators and present the results in Table 2.6.

⁴⁴This is coherent with the sign of rho presented in Table 2.4 (see Strazzera et al. 2003).

Table 2.6: WTP per year and household (non-parametric estimates)

	Kriström (1990)	Bateman et al. (2002)
Mean	473.32 (13.38)	398.77 (12.44)
Median	292.45	277.23
Observations	941	941

Standard error in parenthesis

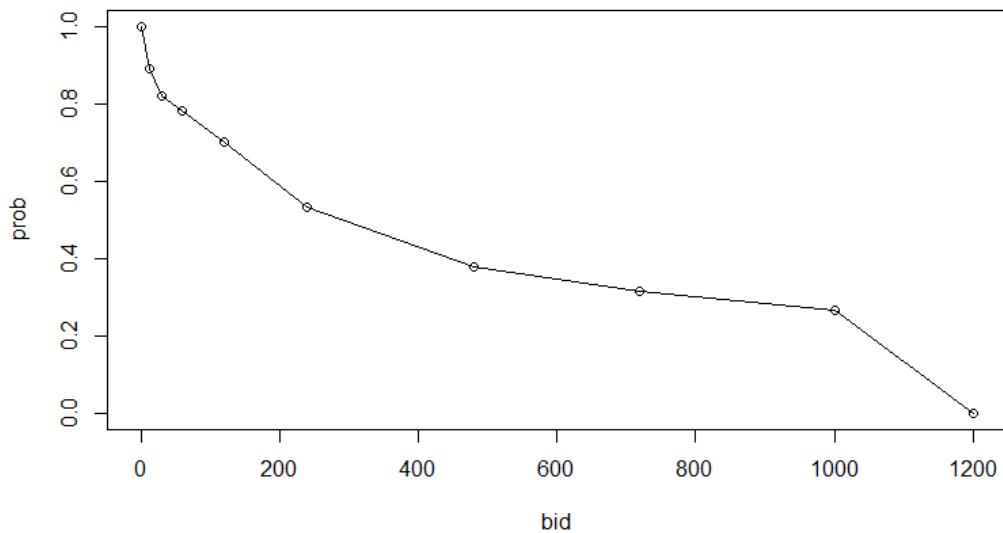


Figure 2.1: Survival function

Results of the non-parametric estimations confirm those from the parametric estimations. While the lower bound, the Bateman et al. (2002) estimator, is around CHF 400, the Kriström (1990) estimator confirms the parametric estimates with a mean WTP of CHF 473 per year and household. Since median WTP associated with these approaches are lower than their means, it seems that the WTP distribution is non-symmetric and skewed to the right.

2.6 Discussion and conclusion

We estimate Swiss households' willingness to pay for the creation of new forest reserves, thanks to the contingent valuation method. Since the scenario is designed to promote biodiversity and plans to restrict access to forests, our analysis mainly reveals forest's biodiversity non-use values. The dichotomous choice analysis reveals that parametric and non-parametric estimates of mean WTP are between CHF 470 and 500 per year and household⁴⁵. The lower bound Bateman et al. (2002) non-parametric estimate confirms this result with a mean WTP of CHF 400 per year and household. These estimates are somewhat higher than those of the international literature about forest conservation. For example, Lehtonen et al. (2003) find that a WTP between EUR 60 and 223⁴⁶ per year for Finnish households. More recently, Lindhjem and Navrud (2011) obtain a mean WTP between EUR 196 and 227⁴⁷ per year and household for a program that implies the creation of new forest reserves in Norway. These differences probably reflect the high income level and the strong preferences in favor of forest conservation in Switzerland.

With respect to explanatory variables, individuals who live in an urban environment accept more often to create new forest reserves. This indicates that the distance between the residence and the forest has a positive impact on WTP. Indeed, a direct proximity with an access-restricted forest could limit economic or recreational activities (Kniivilä et al., 2002). Income has a non-linear influence on WTP: for lower class income levels, the WTP is statistically lower than WTP of the modal class. Inversely, we do not observe a significant difference with higher income levels.

Extrapolated to the whole population, the amount revealed by our contingent valuation would reach 1.66 to 1.77 billion CHF per year, which is much higher than the amount compensating forests owners for the creation of new forest reserves. Nevertheless, this estimation should be interpreted carefully, since it is subject to some biases. In particular, the questionnaire did not explicitly mention the duration of the tax payment. While it was hinted that the tax would be permanent, respondents could have interpreted as a tax on a defined duration, which would overestimate their annual WTP. Moreover, as in every contingent valuation, the hypothetical bias could not be completely removed, which generates a higher WTP than in the case where the program

⁴⁵USD 366 to 389 in 2014 Purchasing Power Parity (PPP) (Source: World Bank (2017a))

⁴⁶USD 73 to 279 in 2014 PPP (Source: World Bank (2017a))

⁴⁷USD 161 to 187 in 2014 PPP (Source: World Bank (2017a))

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would really be implemented. However, the large difference between the costs and the benefits revealed by our survey indicates that, the program of the Forest Policy 2020, which aims at doubling the surface of forest reserves in Switzerland is most probably justified in terms of cost-benefit analysis.

Part II

Revealed preferences

Chapter 3

A travel cost assessment of the demand for recreation in Swiss forests

Written with A. Baranzini and D. Maradan and published in the *Review of Agricultural, Food and Environmental studies* (Borzykowski et al., 2017a). We would like to thank the anonymous referees of the *Review of Agricultural, Food and Environment studies* for their valuable suggestions.

Abstract

This chapter analyzes the demand for recreation in Swiss forests using the individual travel cost method. We apply a two-step approach, i.e. a hurdle zero-truncated negative binomial model, that allows accounting for a large number of non-visitors caused by the off-site phone survey and over-dispersion. Given the national scale of the survey, we group forest zones to assess consumer surpluses and travel cost elasticities for relatively homogeneous forest types. We find that forest recreation activities are travel cost inelastic and show that recreation in Swiss forests provides large benefits to the population. The most populated area is associated with greater consumer surpluses, but the lack of recreational infrastructure may cause a lower recreational benefit in some zones. For these zones, recreational benefits may be lower than costs caused by maintenance. More efficient management would require either improving recreational infrastructure, thus increasing benefits, or switching the forest status from recreational to biodiversity forest, hence decreasing management costs.

Keywords: Travel cost method; Hurdle Zero-Truncated-Negative-Binomial; Forest recreation; Switzerland

JEL classification: H41 - Q26 - Q57

3.1 Introduction

Recreation is one of the many forest functions: population practices sports, observes fauna and flora, picnics, benefits from fresh air and collects valuable resources such as mushrooms, fruits and wild game in forests. Swiss forests cover about 30% of the country's surface and the Swiss Civil Code ensures the general right to freely enjoy its recreation function. With the exception of the use of special infrastructures (tree climbing, campings...), recreation in Swiss forests is thus free. In recent decades, amenities aiming at attracting people have been installed and the development of forest leisure infrastructure continues.

Due to its public good characteristics and the absence of related markets, forest recreation is a non-market service and its demand is hence not directly observable. Therefore, economic valuation techniques have been developed to assess the demand for this particular environmental service. Revealed preferences methods and in particular the travel cost method (TCM) are particularly appropriate for the valuation of recreational sites or activities. First mentioned by Harold Hotelling in the 1940's, TCM aims at deriving the demand for a given activity using the travel costs that individuals must incur as the price and the visit frequency as the quantity. The TCM assumes that these costs are lower or equal to the benefits of a recreational site's visit, so the journey is worth it.

Based on Hotelling's idea, the TCM was developed by Clawson and Knetsch in the 60's (Clawson, 1959; Clawson and Knetsch, 1963). Since then, a large number of studies have used this method to assess the demands for non-marketed goods or services such as recreation (see Zandersen and Tol (2009) for a meta-analysis on forest recreation and Phaneuf and Smith (2005) for a historical review). Two different approaches have been used in the literature: zonal travel costs (Bowes and Loomis, 1980) or individual travel costs (Willis and Garrod, 1991). The latter, based on micro-data, is more precise, but requires more resources to obtain individual travel cost information.

In this Chapter, we derive the implicit demand for recreation in Swiss forests using the individual TCM. Because our interview is done by phone, and thus off-site, we do not assess the use of a specific forest, but rather recreation in Swiss forests in general. Our estimates are thus forest function-specific at the regional level rather than forest-specific. Only a few studies analyze the demand for recreation on a regional scale (Bartczak et al., 2008; Garcia and Jacob, 2010; Bestard and Font, 2010), probably because of the forest heterogeneity. Applying TCM to value recreation at the national

level indeed requires some caution. Following Garcia and Jacob (2010) methodology, we treat this issue by splitting Swiss forests into four coherent categories referring to Swiss geographical areas (i.e Midland/Central Plain; Jura; Prealps/Alps/Southern Alps grouped into a single Alpine zone: Alps) and urban forests. Those categories correspond to Swiss forest zones as defined by the Swiss Federal Statistical Office. This approach allows counting visits in each forest zone and thus assessing a separate value for each of them. It is indeed likely that each forest zone attracts individuals with different preferences. Also, as respondents usually go to the closest forests and less frequently to those located further away, asking only one general question may underestimate the average travel costs and hence the benefits. Indeed, respondents could rather describe their habits regarding the forest they visited last and forget about the further away forests they visited longer ago.

Our off-site phone survey also implies to deal with a large number of non-visitors. We therefore use a two-step methodology as developed by Creel and Loomis (1990) accounting for this kind of individuals. We then calculate travel cost elasticities and consumer surpluses for recreation in the Swiss forests zones.

The remainder of this Chapter is organized as follows: Section 3.2 presents the questionnaire and Section 3.3 the empirical approach. We provide descriptive statistics in Section 3.4 and results in Section 3.5. We discuss them in Section 3.6 and conclude in Section 3.7.

3.2 Survey

We surveyed by phone 1200 adults living in Switzerland in November and December 2014. The sample is chosen with the method of random quotas for gender, age and geographic areas and is thus roughly representative of the Swiss population. Five days before the phone call, interviewees received a letter, which includes the map of Swiss forest zones as in Figure c.1 and gives information about Swiss forests, forests regions and the project in general. The interview lasts about 15 minutes and is composed of four parts.⁴⁸ The first one analyzes the perceptions and behaviors of the Swiss population regarding its forests and is designed to apply the individual TCM. The second part investigates the potential conflicts between the different forest functions from the population point of view. The third part submits an hypothetical scenario

⁴⁸The full questionnaire is available in the Appendix of Chapter 2, in French.

to apply the contingent valuation method and assess the willingness to pay for the creation of new forests reserves in Switzerland (Chapter 2). The final part collects the usual socio-demographic characteristics. The questionnaire has been previously tested on a smaller scale and with focus-groups (cf. Baranzini et al. (2015) and Chapter 1) as recommended by the literature (Phaneuf and Smith, 2005).

Table c.1 presents the characteristics of Swiss forest zones. The Alpine zone (Alps, Prealps and South) accounts for about 63% of Swiss forests surface and is the largest forest zone in Switzerland. The Midland area is more densely populated and thus has a smaller forest coverage and a lower surface of forest per inhabitant, compared to the other areas. Interestingly, the proportion of private owners in the Midland is higher than in the other areas, maybe because of the ease of access and the potential higher economic returns of Midlands forests. Indeed, Alpine and Jura forests are more prone to be protective rather than productive forests and their exploitation is thus more costly. This is confirmed by the wood production intensity index (m^3 of harvested wood per hectare) that is much lower in the Alps and the Jura. The types of forest are defined, among other characteristics, according to their flora composition. The percentage of conifers, which impacts the type of fauna and flora, is an important decision element for individuals who would like to observe nature. Conifers can be found especially in Alpine forests, because they are located at a higher altitude.

To apply TCM, we ask how often the respondent visited each forest zone during the last twelve months. If the answer is not zero, the interview continues asking distance, means of transport, number of accompanying persons and duration of the visit. A controversy of TCM is the multi-purpose, or incidental trips issue (Parsons and Wilson, 1997; Loomis, 2006), which can be difficult to handle. Indeed, such trips must be treated with caution, by correctly disentangling travel costs by visited sites. If the entire travel costs are attributed to the assessed site, the value of the given site would be overestimated. To deal with this issue, we require the respondent to state the distance from the very point of departure to the entrance of the forest. We provide respondents with the following example to ensure that side or incidental trips are correctly taken into account: “If I go to Zermatt for holidays and that, among other things, I walk in a forest, I must indicate the distance from Zermatt to the entrance of the forest, not from my residence.”

As we deal with Swiss forests in general, it is not possible to account for substitution possibilities between forests as recommended in Parsons (2003). In addition, poten-

tial substitutes (all leisure activities) are very varied and controlling for them in an appropriate way is not practically feasible.

3.3 Empirical approach

Given that the dependent variable, the annual visit frequency, is a non-negative integer, defined on \mathbb{N}_+^* only, the use of OLS is inappropriate. Indeed, OLS would allow predicting negative and/or non-integer frequency. Therefore, the literature usually considers count models such as Poisson or Negative Binomial (NB). NB is often preferred for its ability to deal with over-dispersion, a common issue with survey data and all the more with TCM data.

Simple count models allow zero frequency. However, non-visitors do not incur any travel cost, as they do not travel to forests. For them, the travel cost variable thus takes the value 0. On the one hand, the inclusion of this type of individual pushes the estimation towards the corner (0;0), thus artificially decreasing estimates. On the other hand, excluding zero values is a form of sample selection, which causes non-representativity. Therefore, it is sometimes necessary to allow non-visitors to have different motivations and behavior and to include them in a first step model of participation. For example, as mentioned by Haab and McConnell (2002), non-visitors could have no interest in the site for reasons such as health and age, and hence would not be responsive to prices. The whole sample must hence pass into a first step (a hurdle, H), where only visitors are selected. The behavior of the selected individuals is then modeled with Zero Truncated Poisson (ZTP) or NB (ZTNB) models. This is the very purpose of the two-step models, the so-called hurdle models. While Zero-Inflated models (ZI) (Lambert, 1992; Greene, 1994) look appealing, they allow for a zero frequency, even when the hurdle is crossed. In other words, and using the example on which ZI models are based, people may choose to participate in fishing, but still catch zero fish. For forest recreation, this situation is not possible, since people who choose to participate in forest recreation must go at least once in a given forest. The Hurdle Zero-Truncated models (HZT) (Creel and Loomis, 1990) composed by any binary choice model and a conditional truncated count model are therefore the most appropriate empirical approach in our case. It is intuitively similar to a Heckman (1979) sample selection model except for the discrete nature of the statistical distribution. The possibility to distinguish the participation from the integer level at which this participation takes place and the ability to correctly deal with

over-dispersion makes a case in favor of the Hurdle-Zero-Truncated-Negative-Binomial model (HZTNB). Our analysis will thus be based on this model, following Bilgic and Florkowski (2007) and Shrestha et al. (2002). This choice will be confirmed by the ad-hoc statistical tests reported in Section 3.5.

Our model is thus composed of: i) a binary choice model (equation 3.1) explaining the probability of participation in forest recreation (π_i) and ii) a truncated count model for the forest visit conditional frequency ($NV_i|NV_i > 0$) (equation 3.2).

$$Pr(NV_i > 0) = \pi_i = F(X_{1i}) \quad (3.1)$$

Where NV_i is the number of visits of individual i ; X_1 the matrix of independent variables explaining the probability of participation in forest recreation; and F the assumed probability law.

$$NV_i = f(TC_i; X_{2i}) \text{ for } NV_i > 0 \quad (3.2)$$

With TC the travel cost variable; X_2 the independent variables explaining the frequency of forest visits; and f the second step model distribution law.

NB count models are defined with mean $E(NV_i|X_{2i}) = \lambda_i$ and variance $Var(NV_i|X_{2i}) = \lambda_i(1 + \alpha\lambda_i)$ (α a parameter) and assume that $\ln(\lambda_i) = TC_i'\beta_{TC} + X_{2i}'\beta_{X_2}$ to introduce the explanatory variables TC_i and X_{2i} and regression coefficients β_{TC} and β_{X_2} .

After the first step, ZTNB models the annual number of visits NV_i conditioned on the participation. It is written as follows:

$$Pr(NV_i = nv|X_{2i}) = \begin{cases} (1 - \pi_i) & \text{if } NV_i = 0 \\ \pi_i q_i \left[\frac{1}{1 - (1 + \alpha\lambda_i)^{-1/\alpha}} \right] & \text{if } NV_i \geq nv; nv = 1, 2, \dots \end{cases} \quad (3.3)$$

With q_i the usual density of the Negative Binomial law⁴⁹ and π_i the probability of participation derived from the first step binary choice model.

Since we value four types of forests, our design does not exactly correspond to the single-site TCM as presented in Parsons (2003). We hence first estimate a pooled model with interaction variables between the travel cost variables and a dummy for the forest zones, following Garcia and Jacob (2010). Since we observe the individuals' visiting behavior for each of the forest zones and thus have four observations per individual, we handle the pooled data as a panel. However, individuals might possess quite different preferences

⁴⁹ $q_i = Pr(NV_i = nv) = \frac{\Gamma(nv + \frac{1}{\alpha})}{\Gamma(nv+1)\Gamma(\frac{1}{\alpha})} \left(\frac{\frac{1}{\alpha}}{\frac{1}{\alpha} + \lambda_i} \right)^{\frac{1}{\alpha}} \left(\frac{\lambda_i}{\frac{1}{\alpha} + \lambda_i} \right)^{nv}, nv = 1, 2, 3, \dots$

over the forest types and thus the number of visits to each forest zone may respond differently to the covariates. In addition, creating interaction variables for all covariates would require to present the coefficients of 32 independent variables in the first step and 32 other independent variables in the second step. We thus prefer the estimation of four separate models for each four valued forest zone, as in Cho et al. (2014) and present a simplified pooled model in the Appendix, to confirm our results.

3.4 Data description

3.4.1 First step: participation hurdle

The dependent variables for the first step are the binary variables *Visits: s*, which are equal to 1 when the individual visits a given forest zone *s*. We model the probability of participating to forest recreation according to different covariates that may or may not be included in the second step. Table 3.1 provides descriptive statistics for the first step. From the 1200 individuals that compose our full sample, we drop 50 individuals who work in forests, as their behavior is not related to recreation. An additional 22 individuals are excluded because their answers do not make sense or were badly coded.⁵⁰ Some non-responses also slightly reduce the number of observations.

94% of our sample go to forest at least once a year. The forest zone that is the most visited is the Alps: 40% of the sample visit it at least once a year. It is followed by the Midland zone (34%). This is not surprising, since these zones are the most extensive forests in Switzerland. Although the Alpine zone is the least densely populated area, its special forests might attract more people than the Midland, the most populated zone.

28% live in the French-speaking part of Switzerland (*French*), while 17% live in the Italian-speaking part (*Italian*). 40% of the households have children (*Children*) and 37% are member of or donate to an environment-friendly association (*Member*). The average age of our respondents is 51 (*Age*), 14% of the sample has a secondary residence in Switzerland (*Secondary residence*) and 34% answered correctly to a question on forest growth in Switzerland and is thus well informed (*Well informed*).

As we do not observe the distance for non-visitors, our first step may suffer from omitted variable bias. We try to correct this missing variable with the binary variable *Residence*:

⁵⁰For example, an individual claims that she travels 500km to go to an Urban forest 360 times per year.

Table 3.1: Descriptive statistics for the first step

Variable	Mean	Std. Dev.	Min.	Max.	N
<i>Visits: all zones</i>	0.94	(0.23)	0	1	1'075
<i>Visits: Urban</i>	0.17	(0.37)	0	1	1'038
<i>Visits: Midland</i>	0.34	(0.47)	0	1	1'010
<i>Visits: Jura</i>	0.16	(0.36)	0	1	1'034
<i>Visits: Alps</i>	0.40	(0.49)	0	1	973
<i>French</i>	0.28	(0.45)	0	1	1'075
<i>Italian</i>	0.17	(0.38)	0	1	1'075
<i>Children</i>	0.40	(0.49)	0	1	1'075
<i>Member</i>	0.37	(0.48)	0	1	1'075
<i>Age</i>	50.71	(15.37)	18	94	1'075
<i>Secondary residence</i>	0.14	(0.35)	0	1	1'075
<i>Well informed</i>	0.34	(0.48)	0	1	1'075
<i>Residence: Urban</i>	0.70	(0.46)	0	1	1'038
<i>Residence: Midland</i>	0.49	(0.50)	0	1	1'010
<i>Residence: Jura</i>	0.29	(0.46)	0	1	1'034
<i>Residence: Alps</i>	0.34	(0.47)	0	1	973

s accounting for the region of residence. Used as a proxy for distance, these variables are equal to 1 if the individual lives in the same zone s as the visited forest.⁵¹

3.4.2 Travel costs and second step variables

Travel costs supported by each individual have two components: i) the effective travel costs (ETC) (out-of-the pocket costs) and ii) the opportunity costs of the time spent (OCT). We calculate ETC_i differentiating for the type of vehicle used in as follows:

$$ETC_i = \begin{cases} \frac{D_i C_{PMV}}{Persons_i} & \text{if } i \text{ uses a private motor vehicle} \\ D_i C_{PTi} & \text{if } i \text{ uses public transports} \\ 0 & \text{if } i \text{ walks or rides a bike} \end{cases} \quad (3.4)$$

With D_i the distance in kilometers. A private motor vehicle can host several individuals, thus costs must be divided by the number of persons who occupy the vehicle ($Persons_i$).

⁵¹For some individuals, $Residence$ is equal to 1 in more than one zone. Indeed for city-dwellers (urban residents) $Residence: Urban$ equals to 1 along with another $Residence$ variable, as cities necessarily belong to a larger forest zone. Also, we were unfortunately unable to disentangle individuals living in the Jura from those on the Midland for the Cantons of Vaud, Aargau, Neuchâtel, Solothurn and some individuals in the Canton of Bern, so that the sum of the $Residence$ variables is bigger than 1.

C_{PMV} includes all costs linked with the ownership and use of a private motor vehicle: depreciation, amortization, repairs, tire wear, gasoline and insurance. It amounts to 0.73 CHF/km⁵² for an average car according to the biggest Swiss car-drivers association (TCS). The costs of public transport corresponds to the price of the ticket. To calculate C_{PT} , we use the per kilometer base price of public transport published every year by the Swiss public transport association (VOEV, 2014). Price of public transport is decreasing with distance. According to the Swiss railway company (SBB, 2015), 29% of the Swiss population has a Half-Fare travel card and we therefore uniformly reduce C_{PT_i} by 14.5% to keep consistency across means of transport.⁵³ We finally assume that individuals who walk or ride a bike do not bear any effective cost. Of course, bikes and shoes do depreciate with time and usage and energy is needed to walk and ride. However, we consider that these costs are marginal and that they are best estimated with 0.

Some issues regarding the calculation of travel costs still do not raise consensus. The main one, largely discussed in the literature, is whether to include and to what extent the opportunity cost of time (OCT) spent on-site and during the journey (see Smith et al. 1983). A usual underlying assumption of TCM is that individuals are travel time-neutral. That is, they do not get utility from the time of their journey, i.e. they do not benefit from the travel time to admire the landscape or enjoy a nice discussion. Cesario and Knetsch (1976) first recommended to use a fraction of wage as OCT but this calculation supposes that individuals are relatively free to substitute leisure and work time. Feather and Shaw (1999) have developed a model to control for the imperfect leisure-work substitutability, but it comes with much complication in the empirical approach. Hence, most scholars choose to use a fraction of wage (from 25% to 100%) (Parsons, 2003) or lower (Amoako-Tuffour and Martínez-Espiñeira, 2012). A relatively new approach is to estimate the cost of time through a stated preferences approach (Ovaskainen et al., 2012). The time spent on-site is also a subject of controversy: most scholars consider that excluding OCT on-site leads to downward biasing the estimates (McConnell, 1992) but others (Bockstael et al., 1987) advise not to include it, because time spent on-site is an endogenous decision.

We define the OCT as the product of the travel time Tt_i in minutes and the individual opportunity cost of time Ct_i per minute. In equation 3.5, we calculate Ct_i as a third

⁵²Approximately at the time, EUR 1=CHF 1.2, USD 1=CHF 1

⁵³The Half-Fare travel card can be purchased by any individual, irrespective of age or employment status and offers a 50% reduction on the normal fare.

of the individual's income, which is what is done in Cesario and Knetsch (1976)'s seminal paper. More recently Fezzi et al. (2014) have found that 3/4 of the wage is a more reasonable approximation for the OCT. Our estimates can thus be considered as conservative.

$$Ct_i = \frac{1}{3} \frac{Income_i}{Adults_i} \frac{1}{1585 \cdot 60} \quad (3.5)$$

$Income_i$ corresponds to the middle point of the yearly household income class declared in the survey, $Adults_i$ is the number of adults in the household and 1585 is the average number of hours worked per year in Switzerland (OECD, 2015). Including the time spent on-site in the OCT_i decreases the goodness of fit and significance levels of our model. We thus decide not to include any variable accounting for the time spent on-site, as in Cho et al. (2014).

Different other specifications for the travel cost variable have also been tested. In particular, instead of the declared income variable, which reduces the available observations and sometimes lacks reliability, we tried a fixed amount of CHF 10 in equation 3.5, which approximately corresponds to a third of the median hourly wage in Switzerland, as done in Ott et al. (2005). We also tested different fractions of income as Amoako-Tuffour and Martínez-Espiñeira (2012), instead of 1/3. We finally retain the model in equation 3.5, whose coefficients were statistically significant and with the highest *Pseudo - R*².

From equations 3.4 and 3.5, TC_i is then defined as:

$$TC_i = 2(ETC_i + Ct_i Tt_i) \quad (3.6)$$

Where Tt_i is the travel time and $Ct_i Tt_i = OCT_i$. Note that the right-hand-side of the equation is multiplied by 2 because individuals return after visiting the forest.

Table 3.2 describes the dependent variable NV_i , the TC_i variable and other explanatory variables used in the second step of the separated models.⁵⁴ *Relaxes*, *Does sport*, *Observes nature* and *Collects resource* are categorical variables identifying whether the individual relaxes, does sport, observes fauna and flora or collects resources such as wood, mushrooms, berries or hunting wild game in the forest, respectively. These activities are not mutually exclusive. *Economic interest* takes the value of 1 if the individual has an economic link with the forest industry and *Bad memories* is a variable equal to 1 if the individual has bad memories or has had bad experiences in relation with forests.

⁵⁴We provide the same descriptive statistics for the pooled data in Table c.2 in the Appendix.

Table 3.2: Descriptive statistics for the second step

Zone	Variable	Mean	Std. Dev.	Min.	Max.	N
<i>Urban</i>	<i>NV</i>	51.94	80.75	2	365	173
	<i>TC</i>	6.54	10.15	0.14	78.11	173
	<i>Relaxes</i>	0.93	0.25	0	1	173
	<i>Does sport</i>	0.58	0.50	0	1	173
	<i>Observes nature</i>	0.69	0.46	0	1	173
	<i>Collects resource</i>	0.33	0.47	0	1	173
	<i>Age</i>	49.58	15.95	19	90	173
	<i>Bad memories</i>	0.02	0.13	0	1	173
	<i>Economic interest</i>	0.20	0.40	0	1	173
<i>Midland</i>	<i>NV</i>	46.99	64.08	1	365	343
	<i>TC</i>	9.04	17.91	0.11	150.21	343
	<i>Relaxes</i>	0.93	0.26	0	1	343
	<i>Does sport</i>	0.59	0.49	0	1	343
	<i>Observes nature</i>	0.68	0.47	0	1	343
	<i>Collects resource</i>	0.35	0.48	0	1	343
	<i>Age</i>	49.48	14.61	18	93	343
	<i>Bad memories</i>	0.02	0.14	0	1	343
	<i>Economic interest</i>	0.25	0.43	0	1	343
<i>Jura</i>	<i>NV</i>	40.18	72.65	1	400	163
	<i>TC</i>	19.81	25.84	0.15	127.58	163
	<i>Relaxes</i>	0.91	0.28	0	1	163
	<i>Does sport</i>	0.61	0.49	0	1	163
	<i>Observes nature</i>	0.76	0.43	0	1	163
	<i>Collects resource</i>	0.36	0.48	0	1	163
	<i>Age</i>	52.77	14.29	19	91	163
	<i>Bad memories</i>	0.06	0.23	0	1	163
	<i>Economic interest</i>	0.22	0.42	0	1	163
<i>Alps</i>	<i>NV</i>	43.1	70.35	1	365	394
	<i>TC</i>	27.07	47.24	0.11	352.57	394
	<i>Relaxes</i>	0.94	0.23	0	1	394
	<i>Does sport</i>	0.62	0.49	0	1	394
	<i>Observes nature</i>	0.73	0.45	0	1	394
	<i>Collects resource</i>	0.44	0.50	0	1	394
	<i>Age</i>	50.34	13.74	18	86	394
	<i>Bad memories</i>	0.03	0.16	0	1	394
	<i>Economic interest</i>	0.28	0.45	0	1	394

Urban forests are the most frequently visited forest zone, closely followed by Midland forests, Alpine forests and Jura forests. Again, this is not surprising, since the population density is higher in urban areas and in Midland than in Jura or the Alps. It is interesting to notice that the number of visits, conditioned to the participation (Table 3.2), is very different from the probability to visit a given forest zone (Table 3.1). In particular, people do not necessarily visit Urban forests (only 17% do), but when they do, they visit them more often than people who visit the Alpine forests (52 times per year against 43). On the contrary, a large proportion of people visits Alpine forests (40%), but when they do, they visit them less often than those who visit Urban forests. This could be linked with population density and travel costs. On average, Urban forests are those with the significantly lowest travel costs. They are followed by Midland forests, Jura forests and Alpine forests. It is important to notice that all travel costs variables are prone to high skewness to the right, with many individuals whose costs are low and a few whose costs are very high. The median consumer surplus may therefore be an interesting information regarding the distribution.

In the pretest of this study, Baranzini et al. (2015) applied TCM to a sample of Geneva population and assessed the average and median recreation travel costs. They find that costs incurred for recreation in forests vary between CHF 247 to 583 per year and per person, when excluding and including the opportunity cost of time spent on site respectively. A similar result is found by von Grünigen and Montanari (2014) who estimated the average travel costs to recreate in Swiss forests between CHF 290 and 589. These estimates can be considered as consumer surplus lower bounds, as recreation travel costs are necessarily lower or equal to recreation benefits, which are inferred from the estimated demand. In our case, for comparison, we can calculate annual travel costs including non-visitors in the following way:

$$AnnualTC_{is} = NV_{is} \cdot TC_{is} \cdot Visits_{is} \quad (3.7)$$

This calculation results in CHF 58 for Urban forests, CHF 144 for Midland forests, CHF 127 for Jura forests and CHF 478 for Alpine forests. These estimates are thus slightly smaller than what is found in the recent studies on Swiss forests (von Grünigen and Montanari, 2014; Baranzini et al., 2015). We note however that existing studies consider Swiss forests as a whole, without controls for their heterogeneity.

Almost all visitors go to forest to relax independently of the type of forest (91% to 94%). A high proportion of people who visit Jura forests observes fauna and flora (76%

and 73% respectively) and practice sport activities (61% and 62% respectively). This confirms the presence of a larger biodiversity and number of sports activities in these forests, compared to Urban or Midland forest. Collection of resource is an activity that is more often undertaken in the Alps.

Only a few visitors (2% to 6%) have had bad experiences with forests⁵⁵ and 20% to 30% have an economic interest in the forest industry with a significantly lower proportion for the Urban forests visitors. The latter proportion is surprisingly high as we dropped individuals whose jobs are in forests and only 3% of the Swiss population works in the primary sector (FSO, 2017).

3.5 Results

We specify the first step participation model as the following probit model.

$$Pr(NV_{is} > 0 | X_{1is}) = Pr(Visits_{is} = 1 | X_{1is}) = \Phi(\alpha_s + \beta_{X_{1s}} X_{1is} + \varepsilon_{is}) \quad (3.8)$$

With X_{1is} the explanatory variables described in Section 3.4; $Visits_{is}$ a dummy variable equal to 1 if the individual visits the forest zone s ; Φ the standard normal distribution; α_s a constant; $\beta_{X_{1s}}$ the coefficients associated with X_{1s} and ε_{is} an error term.

The second step estimation explains the annual visit frequency, given that the individual visits forest at least once a year and hence passed the first step hurdle. Since forest types are very different, it is likely that individual preferences vary in a substantive manner. We therefore estimate distinct models for each forest zone, specified as follows for the second step⁵⁶:

$$\ln(\lambda_{si}) = E[NV_{si}] = a_s + \beta_{TC_s} TC_{is} + \beta_{X_{2s}} X_{2is} + u_{is} \quad (3.9)$$

With a_s a constant; β_{TC_s} the coefficient associated with the TC_s variable; X_{2s} the explanatory variables described in Section 3.4.2; $\beta_{X_{2s}}$ the vector of associated coefficients and u_{is} an error term. The models specification is based on the significance levels of covariates coefficients, the joint significance Wald- χ^2 tests, the AIC and different R^2 measures.

⁵⁵This proportion is significantly higher for Jura forests visitors.

⁵⁶A pooled model is presented in the Appendix.

For all estimations, the first and second steps are estimated simultaneously, following Long and Freese (2014). Coefficients of the second step can be interpreted as semi-elasticities.

Estimation results of the separated models are presented in Table 3.3. We observe that, as expected, living in a given zone increases the probability of visiting the forests of this zone. People living in the French-speaking part of Switzerland are less likely to visit a Midland forest, compared to people living in the German-speaking part and the opposite is true in Jura and Alps forest. This could be explained by geographical reasons: a larger part of the Midland area is situated in the German-speaking region, while almost all Jura region is in the French part. This is not the case for Alpine forests however. People living in the Italian-speaking part of Switzerland are less prone to visit an Urban, Midland or Jura forest, compared to people living in the German-speaking part. This is not surprising since the Italian-speaking part is situated in the Alps, and is further away from Midland and Jura forests.

Having a child increases the probability to visit a forest zone, except for the Alps, probably because Alpine forests are steeper and less accessible. Membership in an environment friendly organization is associated with a greater participation in all forest zones, except Midland forests. Interestingly, as shown by the *Age* and *Age*² variables, the age first increases and then decreases the probability of visiting Alpine forests, while we observe the opposite in Urban forests. A significant quadratic effect of age is also found in von Grünigen and Montanari (2014). Ease of access is probably the main explanation. Indeed Urban forests are usually closer by and more accessible, but interest in visiting an Urban forest might only grow after a certain age. Alpine forests usually require a certain ability to do sports or move which might be lower after a threshold. This result may also be due to a change in preferences with age.

Having a secondary residence increases the probability to visit an Alpine forest, but has no effect on other forest zones. We expected this result, since most secondary residences are located in the Alps.

Finally, being well informed increases the participation in Alpine forests. This may be due to reverse causality as those who visit Alpine forests are more likely to notice a forest growth, because this forest zone has grown the most.

According to the second step estimation, all travel cost variables have the expected negative sign, but the effect of travel cost is not statistically significant for Urban forests. The latter result is unsurprising, given that the travel cost to visit Urban

Table 3.3: Results of the HZTNB estimation

	Urban	Midland	Jura	Alps
<i>Visits_s</i> (Participation)				
<i>Residence_s</i>	0.67*** (0.12)	0.54*** (0.095)	1.22*** (0.12)	1.13*** (0.13)
<i>French</i>	-0.13 (0.11)	-0.33*** (0.099)	0.60*** (0.12)	0.19* (0.11)
<i>Italian</i>	-0.31** (0.14)	-0.85*** (0.15)	-0.58** (0.29)	-0.13 (0.15)
<i>Children</i>	0.19* (0.11)	0.20** (0.099)	0.41*** (0.13)	-0.20* (0.10)
<i>Member</i>	0.21** (0.099)	-0.0056 (0.089)	0.36*** (0.11)	0.14 (0.093)
<i>Age</i>	-0.027* (0.015)	0.013 (0.015)	0.019 (0.020)	0.059*** (0.016)
<i>Age²</i>	0.00025* (0.00015)	-0.00015 (0.00015)	-0.000071 (0.00020)	-0.00064*** (0.00016)
<i>Secondary Residence</i>	-0.12 (0.15)	-0.16 (0.13)	-0.15 (0.18)	0.54*** (0.13)
<i>Well informed</i>	-0.037 (0.10)	-0.040 (0.091)	0.20* (0.12)	0.42*** (0.093)
<i>Constant</i>	-0.86** (0.38)	-0.76** (0.37)	-2.86*** (0.52)	-2.06*** (0.39)
<i>NV_s</i> (Frequency)				
<i>TC</i>	-0.0089 (0.016)	-0.0089** (0.0044)	-0.040*** (0.0046)	-0.014*** (0.0019)
<i>Relaxes</i>	0.58* (0.31)	0.18 (0.23)	-0.53 (0.50)	0.31 (0.28)
<i>Does sport</i>	0.45* (0.27)	0.48*** (0.17)	0.26 (0.28)	0.33* (0.17)
<i>Observes nature</i>	-0.0048 (0.23)	0.027 (0.17)	0.30 (0.26)	0.44** (0.18)
<i>Collects resource</i>	-0.14 (0.24)	0.28* (0.15)	0.15 (0.23)	0.25 (0.16)
<i>Age</i>	0.022*** (0.0076)	0.014** (0.0061)	0.0026 (0.0077)	0.0021 (0.0057)
<i>Economic Interest</i>	0.060 (0.30)	0.18 (0.17)	0.48** (0.24)	0.37** (0.16)
<i>Bad Memories</i>	-1.66*** (0.23)	0.33 (0.54)	0.20 (0.53)	0.25 (0.52)
<i>Constant</i>	2.05*** (0.56)	2.49*** (0.41)	3.68*** (0.78)	2.68*** (0.46)
Observations (total)	1038	1010	1034	973
Non-zero observations	173	343	163	394
<i>ln(α)</i>	0.60***	0.40***	0.54***	0.57***
Vuong stat. for ZTNB over ZINB	0.55	-0.41	-5.26***	-2.46***
Accuracy	70%	46%	75%	41%

Heteroskedasticity-robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

forests is generally low and relatively homogeneous among individuals. In addition, in the urban environment, individuals have many other leisure opportunities, which explains the statistically insignificant *TC* coefficient (Bertram and Larondelle, 2017).

The coefficients associated with the activities undertaken in forests show the type of forests preferred for given activities. Urban forests are more visited for relaxation and doing sports, Midland forests for collection of resources and sport and Alpine forests are used for sports or observation of nature. These results show the importance of Urban forests to escape the city stress and the importance of Alpine forests for sports activities such as hiking and skiing. Recent surveys have shown that 44% of the Swiss population hikes and 36% skis in the mountains (Lamprecht et al., 2014), which can explain the positive impact of *Does sport* on the number of visits in Alpine forests. The productive role of Midland forests is also confirmed by the positive coefficient associated with the *Collects resource* variable.

Conditioned on participation, age has a positive impact on the number of visits for Urban and Midland forests. Having bad memories linked with forests decreases the number of visits in Urban forests, but there are very few individuals in this case. Finally, having economic interests in the forest industry, as expected, increases the number of visits to forests in the Jura and the Alps.

The statistically significant $\ln(\alpha)$, which measures the likelihood-ratio test for overdispersion, give clear evidence in favor of the use of the Negative Binomial models over the Poisson models. Vuong tests also confirm the choice to use a hurdle model, rather than a simple NB model.⁵⁷ To confirm our choice of ZTNB over ZINB⁵⁸, we run another Vuong test, as suggested in Long and Freese (2014, pp. 549-551) and find that it does not provide any evidence that the ZTNB fits better than the ZINB for Urban and Midland forests. However, it does for Jura and Alps forests. The choice of the HZTNB is therefore justified.

The computation of the Vuong test also requires to calculate the accuracy of predicted probabilities, which ranges between 41% and 70% depending of the forest zone.

We provide the estimation results of a pooled model in Table c.3 in the Appendix. For this model, the coefficients associated with the dummies *Urban*, *Midland* and *Jura*, which indicate the location of the forest, have a negative impact on the probability to participate in forest recreation, compared to the Alps forests. This is not surprising

⁵⁷This test is provided with the ZINB estimation using the `vuong` option on Stata14.

⁵⁸The ZINB results are available in Table c.6, in the Appendix.

since the Alps forests are the most visited forests. The statistical significance of these variables is a confirmation that preferences are different across forest zones and is a justification to use the separate models. Indeed, while this pooled model has more statistical power thanks to the higher number of observations, coefficients represent an average effect of the covariates across forest zones. A likelihood-ratio test on the first step also rejects the hypothesis that the coefficients are the same across forest zones (LR stat.(24)=312.3, p-value<0.01). The separated models are thus able to take into account more heterogeneity. In addition, the predicted probabilities accuracy scores higher for some separate estimations (53% for the pooled model against 41 to 70% for the separated models). We therefore prefer the separated models and hereafter present their cost-elasticities and consumer surplus. It is worth noting, however, that coefficients of the second step of the pooled model are similar to those resulting from the separated models and that the Vuong test on the pooled model also provides evidence that the ZTNB fits better than the ZINB.

3.5.1 Mean travel costs and elasticities

Cost elasticities (ε_s^{TC}) represent changes in visit frequencies (in percent) for a percent change in travel costs, everything else kept constant. To get elasticities, we calculate the average marginal effects with the prediction function from the estimates.⁵⁹ Cost elasticities from the separated models are shown in Table 3.4.⁶⁰

Table 3.4: Travel costs elasticities

	Urban	Midland	Jura	Alps
ε_s^{TC}	-0.58 (0.10)	-0.08** (0.04)	-0.80*** (0.09)	-0.38*** (0.05)
Mean TC_s	6.5	9.0	19.8	27.1
Observations	173	343	163	394

Standard errors calculated with the Delta method in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Jura forests are the most sensitive to an increase in travel cost, while Urban forests are not sensitive since the effect of TC on NV is not significant. A cost increase of

⁵⁹These elasticities can be easily obtained using the `margins,eyex` command in Stata14.

⁶⁰Cost elasticities from the pooled model are presented in Table c.4 in the Appendix. We observe that this model provides slightly lower elasticities estimates. In particular, the Jura and Alpine forests are less sensitive to a travel cost increase with this approach.

1% would decrease visit frequency to Jura forests by 0.8%, this impact being 10 times lower in Midland forests. However, travel costs associated with Midland forest are on average lower than those associated with Jura forests: mean TC is CHF 9 per visit in Midland against CHF 20 in Jura. In absolute terms, a 1% increase in travel costs for Midland corresponds on average to CHF 0.09 which would decrease annual frequency by 0.04 time. For Jura forests, a 1% increase in travel costs is equal to a CHF 0.19 increase which would decrease frequency by 0.32 time. In the Alps, a CHF 0.20 increase is linked with a 0.16 time decrease in frequency.

3.5.2 Consumer surplus

Marshallian Consumer Surplus (CS) is the area between the demand curve and the price. The average unconditional individual annual CS for forest zone s is hence :

$$CS_{is} = -\pi_{is} \frac{\lambda_{is}}{\beta_{TCs}} \quad (3.10)$$

From (3.9), as in Creel and Loomis (1990), the surplus per visit becomes :

$$\frac{CS_{is}}{\pi_{is}\lambda_{is}} = -\frac{1}{\beta_{TCs}} \quad (3.11)$$

With π_{is} the probability of visiting a given forest, λ_{is} the parameter of the NB law and β_{TCs} the coefficient of the travel cost variables.

We calculate the mean conditional annual CS by multiplying the CS per visit by the average annual frequency. This annual CS is then multiplied by the proportion of visitors to obtain the annual unconditional CS . The consumer surpluses from the separated models are presented in Table 3.5.⁶¹

⁶¹For the pooled model, consumer surpluses, presented in Table c.5, in the Appendix, are similar to the CS from the separated models.

Table 3.5: Individual Consumer Surpluses (CS)

	Urban	Midland	Jura	Alps
CS per visit	112.8	112.7**	24.7***	71.6***
	[-284 ; 510]	[4 ; 222]	[19 ; 30]	[53 ; 90]
Conditional annual CS	5859	5293**	994***	3084***
	[-14771 ; 26489]	[166 ; 10420]	[772 ; 1215]	[2273 ; 3896]
Median conditional annual CS	2256	2704**	297***	1431***
	[-5688 ; 10201]	[85 ; 5322]	[231 ; 363]	[1055 ; 1808]
Unconditional annual CS	977	1798**	157***	1249***
	[-2462 ; 4415]	[57 ; 3539]	[122 ; 192]	[920 ; 1577]
Median unconditional annual CS	376	918	47	580
	[-948 ; 1700]	[29 ; 1808]	[36 ; 57]	[427 ; 732]
Mean density ($CS/100ha$)	n.a.	0.80**	0.067***	0.16***
Observations	173	343	163	394

95% confidence intervals in brackets

Standard deviations in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

n.a. : Statistics about Urban forests size is not available.

The mean conditional annual CS corresponds to the mean recreational benefits from forests obtained by visitors only, while the mean unconditional annual CS refers to mean benefits extrapolated to the whole population according to the proportion of visitors.

Midland forests is the most valued forest zone. The CS per visit in this zone scores higher than in Alpine forests, but the difference is not statistically significant. The effect of secondary residences may reduce travel cost per visit and hence the CS . However, the choice of the secondary residence may also be driven by the forest proximity. Annual unconditional CS is on average CHF 1798 in Midland forests and CHF 1249 in Alpine forests. On the contrary, Jura forests are significantly less valued for their recreational activities (CHF 157 per year). In terms of recreational density (unconditional annual consumer surplus per 100ha), Midland forests are much more intensively valued, which reflects the population density and the high CS per visit in this zone. Jura forests are again less attractive than other forest zones for recreation purposes. This may be due to preferences, but could also be explained by a lower density of infrastructures and roads network or a lower number of incidental activities opportunities.

3.6 Discussion

Baranzini and Rochette (2008) assessed the annual average benefit from the Pfyn pine forest in Switzerland between CHF 1135 and 1540 per individual. This single-site valuation survey has the particularity of dealing with a relatively homogeneous forest in our Alpine region. However, the on-site nature of the survey only selects visitors. In addition, more frequent visitors are likely to be over-represented in the sample, as the probability to survey them is higher than for one-time visitors. This type of survey thus suffers from both truncation and endogenous stratification. An OLS estimation cannot be legitimate in this case either. Their estimates could however be compared with the conditional consumer surplus in Alpine forests. We observe that our estimates are higher. However, Baranzini and Rochette (2008) calculated the opportunity cost of time as a fourth of annual income (against a third here) and consider that the Swiss work 2000 hours a year (against 1585 here). Also, our estimates represent the consumer surplus for the entire forest zone, from which the Pfyn pine forest only represents a tiny part.

While consumer surpluses per trip in Switzerland lie between CHF 25 and 113⁶², the meta-analysis of Zandersen and Tol (2009) finds a consumer surplus between EUR 0.66 and 112⁶³ per trip in European forests, with a median of 4.52⁶⁴, GDP per capita and population density playing a significant role. Because Switzerland is one of the richest European countries in terms of GDP per capita and is very densely populated, it is not surprising that our CS are higher than those of the international literature. We have also seen that Midland forests, the most densely populated area are highly valued, which confirms this intuition.

Costs related to recreation in forests depend on the intensity of recreational activities. Road maintenance and securing forests imply higher costs and economic shortfalls for the forest industry. According to Bernasconi et al. (2003), in the Canton of Bern,⁶⁵ these costs amounted from CHF 190 to CHF 3970 per inhabitant, per year depending on the forest's importance in terms of recreation and CHF 418 on average. We observe that estimated *CS* exceed the average costs, except for Jura forests, whose costs induced by recreational activities are higher. In Jura, forest management based on cost-benefit analyses for recreation would require either improving recreational infrastructure to

⁶²USD 19 to 88 in 2014 Purchasing Power Parity (PPP).

⁶³USD 0.82 to 139 in 2014 PPP

⁶⁴USD 5.62 in 2014 PPP

⁶⁵The Canton of Bern contains all types of forest we analyzed.

increase the associated benefits in some forests, or switching some forests status from recreational to biodiversity forest, which would decrease the cost associated with recreation infrastructure. For example, some recreational forests may be turned into natural reserves, in which access could be limited. This change would foster biodiversity and hence increase the non-use or option values of these forests (see Borzykowski et al., 2017b). In addition, costs of forest management would decrease.

3.7 Conclusion

We model the demand for recreation in Swiss forests using the individual TCM for different forest zones in Switzerland and derive travel costs elasticities and consumer surpluses. Our methodology takes into account a large number of non-visitors inherent from our off-site national phone survey, as well as over-dispersion thanks to the hurdle zero-truncated-negative-binomial model. Our results are in line with the recent TCM literature in Switzerland and Europe and show that recreation in Swiss forests provides large benefits to the population. Recreation in forest is travel cost inelastic, but its value differs across forest zones. We find that the most populated area is associated with greater consumer surpluses and observe that benefits from recreation in Jura forests are on average lower than management costs. For this zone, some forests could be turned from recreational forests to forest reserves, to foster biodiversity. In addition to reducing the costs of forest management, this policy would increase the non-use and option values of these forests.

Our methodology leads to a probable overestimation of consumer surplus because we were not able to account for close substitutes nor did we include recreational activities in bordering forests. In addition, the off-site nature of the survey could introduce some uncertainty: because observations are based on declarations regarding past visits and not actual visits, respondents may be subject to strategic issues or unable to remember. However, on-site surveys also ask this type of questions and hence suffer from this kind of uncertainty as well. As we also run a contingent valuation in the same survey, an extension of this Chapter would be to analyze differences across valuation methods for the same individuals.

Part III

Market methods

Chapter 4

Carbon offsets out of the wood? Acceptability of domestic vs. international reforestation programmes in the lab

Written with A. Baranzini and S. Carattini and published in the *Journal of Forest Economics* (Baranzini et al., 2018). This paper was presented at the Workshop on valuation of forest ecosystem services, held in 2016 at HEG-Geneva and at the 2017 EAERE conference in Athens. We thank two anonymous reviewers, as well as Matthew Kotchen, Michael Mendez and Alessandro Tavoni for useful comments and Anouk Curt for excellent assistance.

Abstract

Following the entry into force of the Paris Agreement in November 2016, governments around the world are now expected to turn their nationally determined contributions into concrete climate policies. Given the global public good nature of climate change mitigation and the important cross-country differences in marginal abatement costs, distributing mitigation efforts across countries could substantially lower the overall cost of implementing climate policy. However, abating emissions abroad instead of domestically may face important political and popular resistance. We ran a lab experiment with more than 300 participants and asked them to choose between a domestic and an international reforestation project. We tested the effect of three informational treatments on the allocation of participants' endowment between the domestic and the international project. The treatments consisted in: (1) making more salient the cost-effectiveness gains associated with offsetting carbon abroad; (2) providing guarantees on the reliability of reforestation programmes; (3) stressing local ancillary benefits associated with domestic offset projects. We found that stressing the cost-effectiveness of the reforestation programme abroad did increase its support, the economic argument in favour of offsetting abroad being otherwise overlooked by participants. We relate this finding to the recent literature on the drivers of public support for climate policies, generally pointing to a gap between people's preferences and economists' prescriptions.

Keywords: Forest policy; Climate policy; Carbon offsets; Reforestation; Acceptability

JEL classification: Q23, Q54, Q58

4.1 Introduction

Following the 2016 entry into force of the Paris Agreement, governments are now expected to turn their greenhouse gas emissions pledges into concrete climate policies. These policies need not only to be sufficiently effective to reach the emissions abatement objectives, but also to be as inexpensive as possible to leave some economic and political room for further policy tightening, in particular when it will come to set new ambitions in 2023. Only in this way, the long-term objectives of the Paris Agreement can be met. Since greenhouse gases mix uniformly in the atmosphere, and given the important differences in cross-country marginal abatement costs, distributing abatement efforts across countries could substantially lower the overall cost of implementing a global climate policy (Morris et al. 2012; Kriegler et al. 2014).

The choice of the policy instrument is crucial to ensure that the abatement objectives can be reached at a reasonable cost. Economists contend that carbon pricing represents the central pillar of the policy package necessary to transform emissions targets into effective abatements (Goulder and Parry 2008; Aldy and Stavins 2012). However, important political resistance opposes the use of carbon pricing, which explains the limited diffusion of carbon taxes and cap-and-trade programmes around the world (Baranzini and Carattini 2014; World Bank 2017b). The same resistance also applies to the use of carbon offsets resulting from activities or projects implemented abroad, but used to compensate domestic emissions, as well as, more generally, to the mechanisms permitting the compensation of emissions among countries (Monbiot 2007; Schneider 2009). For instance, the European Union (EU) Emissions Trading Scheme capped until 2013 the amount of carbon credits that firms could buy from emissions abatement projects taking place outside the EU. Since 2013, international credits are no longer accepted. Similarly, the use of international offsets is currently capped in the California cap-and-trade scheme, and international offsets may disappear altogether from this scheme as it enters the third compliance period in 2018. In the case of California, strong resistance to the use of offsets comes in particular from local environmental justice groups, which claim that firms should reduce their emissions locally, and provide co-benefits to local communities (Schatzki and Stavins 2009; Pastor et al. 2013). The 2009 Waxman-Markey bill also included a cap for the use of carbon offsets, related to the location of the abatement efforts. Domestic and international offset programmes were each capped at 1 billion metric tons, with the possibility for the US Environmental Protection Agency to shift part of the domestic cap to international offsets only if it

could be determined that the domestic supply was insufficient. The room for abating greenhouse gas emissions abroad is also limited by law in other contexts. In Switzerland, for instance, a minimum of 30% of the total emissions reduction must be achieved domestically. Stronger requirements may apply for some industries. For instance, fossil-thermal power plants are required to offset all of their emissions, 50% of which must be compensated domestically.

At the same time, some countries, such as Norway, Finland, Sweden or Costa Rica, plan to become carbon neutral over the next decades, an objective that potentially implies a large use of offsetting practices. While Costa Rica plans to undertake local measures to offset emissions through reforestation, reaching this objective in Scandinavian countries would very likely require the purchase of a substantial amount of carbon offsets from foreign countries. Sweden, for instance, plans to cut its domestic emissions by 85%, while offsetting the remaining amount. This paper is motivated by the conflict between the large potential cost savings associated with abating emissions through projects implemented abroad and the possible political resistance to such practice.

Some evidence already suggests that the public may not always favour the most efficiency-enhancing solution in climate policy, even when pay-offs are transparent (Cherry et al. 2012). People may not even pay attention to the provided quantity of public good, if their motivation is impurely altruistic and driven by the moral satisfaction of contributing (cf. Andreoni 1990). For instance, using stated preferences methods, Kahneman and Knetsch (1992) find that the willingness to pay for a public good may not be influenced by the quantity provided: Individuals may not necessarily understand that different quantities of public good can be provided with the same contribution. This difference can however be very large, especially for environmental goods such as carbon offsets, whose costs can vary greatly depending on location.

In addition, practical reservations have been raised to the purchase of international carbon offsets. Evidence of abuses in the additionality condition have clearly contributed to reduce the credibility of the UNFCCC's mechanisms to facilitate international emissions trading, such as the Clean Development Mechanism and Joint Implementation (see Schneider and Kollmuss 2015; Tirole 2012). In the light of these critiques, the preference that the general public seems to give to local projects, and to standards certifying projects generating emissions offsets abroad, should not be a surprise (see Blasch and Farsi 2014). However, beyond this, little is known on how to overcome these obstacles and increase the popularity of international carbon offsets.

A new literature analysing this question empirically is thus needed. Torres et al. (2015) use a choice experiment to test the effect of distance to the mitigation site on the propensity to support mitigation activities. This stated preference study finds a preference for local mitigation, which provides local co-benefits. All potential mitigation sites are however located in Mexico, where the survey takes place. The international dimension, and the related heterogeneity in abatement costs, is thus left for future research. Two other studies shed more light on the question of domestic versus international abatements. Anderson and Bernauer (2016) recruit participants on an online labour market and analyse the effect of different informational treatments on stated support for domestic versus international offsets. People seem to express higher support for international abatements when the argument of efficiency (versus e.g. ethicality) is raised, even though no real carbon offsets are proposed and no real monetary consequences are present. Diederich and Goeschl (2017) recruit German participants on an online survey platform to participate in an experiment in which, depending on the treatment, they may be offered the purchase of local (EU-based) versus developing country offsets. Inference is this time based on revealed preferences. In the local treatment, participants are reminded that it is in Germany, where they live, that they are generating emissions. In the developing country treatment, participants are informed that the offset projects are certified Gold Standard and will be realised in an environmentally-friendly way while providing benefits to the local population (such as jobs). The demand for these two offset options is compared to a neutrally-framed treatment (the control group), where the location of the abatement is also explicit (the EU), but no attempts to stimulate guilt or affect decisions are made. Diederich and Goeschl (2017) analyse the demand for carbon offsets across treatments and find that location does not matter. If anything, their informational treatments increase overall contributions with respect to the neutral framing. Note however that in all treatments, including the neutral framing, participants are informed that the climate is indifferent about where mitigation is carried out (that is, location does not matter).

Our paper also uses experimental methods, inferring from revealed preferences. We contribute to this nascent literature by focusing specifically on the allocation decision that determines how demand for domestic versus international offsets changes depending on the information provided. Our approach thus exploits a real situation, in which there is a real difference in location and abatement costs between two otherwise similar offsetting projects. In this setting, we analysed the role of informational treatments

in conjunction with the real difference in the offset price tag. In short, our experiment went as follows. We gathered about 300 students in the lab and observed how they allocated their endowment between two reforestation projects, one taking place domestically and one abroad. We provided three randomized informational treatments. The treatments mimicked the role of a political campaign trying to foster (or hamper) the political support for generating carbon offsets from reforestation projects implemented in a foreign country, instead of domestically. Two treatments played in favour of carbon offsets generated abroad by (1) emphasizing the cost-effectiveness related to international projects and (2) giving guarantees on the reliability of the reforestation programmes. The third treatment stressed the local ancillary benefits from domestic carbon offset projects in terms of biodiversity, recreational activities, protection from natural disasters and local employment. We compared these three treatment groups with a control group, subject to a neutrally-framed treatment.

We found that stressing the cost-effectiveness of the international reforestation programme led to a significant increase in contributions to the latter. That is, some participants seemed to overlook the price differential, absent any specific treatment leveraging it. We did not find any effect for the other treatments. Participants seemed to already factor in the existence of local co-benefits and seemed not to be questioning the credibility of the selected reforestation programmes.

The remainder of the paper is organized as follows. Section 4.2 introduces our hypotheses, the experimental design, and the econometric approach. Section 4.3 presents our data and results. Section 5.7 concludes.

4.2 Methodology

4.2.1 Economic background and hypotheses

In this paper, we focus on reforestation programmes. The potential for climate change mitigation of forest projects is considered substantial (Bellassen and Luyssaert 2014), given the generally low marginal costs of reforestation (van Kooten et al. 2004; Tavoni et al. 2007; Nielsen et al. 2014). In addition, it is estimated that 20% of global greenhouse gas emissions are caused by deforestation, twice as much as transportation (IPCC 2014). As a result, avoided deforestation and af-/re-forestation programmes may play an important role in climate change mitigation. For instance, Potter et al. (2007) estimate that up to 20% of US emissions could be offset through forests sinks. Forest

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offsets are encouraged since the Kyoto Protocol within the LULUCF (Land Use, Land Use Change, and Forestry) activities of the Clean Development Mechanism (UNFCCC 2007) and may also play an important role in the achievement of the recent agreement that the International Civil Aviation Organization reached in October 2016 to limit the growth of carbon emissions in the civil aviation sector. According to this voluntary agreement, from 2020 any increase in airline carbon emissions should be compensated through the purchase of carbon offsets.

The abundance of opportunities for carbon sinks in forests is only one of the reasons for focusing on forest offsets. From an experimental perspective, forests provide two additional benefits. First, forest-based offsets are cognitively easy to understand for participants. Second, while trees and forests may differ across countries in many characteristics, they can still represent the ideal of a homogeneous good in terms of CO₂ sequestration. Indeed, the effect on climate change mitigation of one ton of abated CO₂ is the same irrespective of the abatement location. In our experiment, relatively precise information on the CO₂ sequestration ability of each tree is available for both reforestation programmes in our study.

We are however aware of the concerns that have been raised about the limits of forest sinks. Unlike decarbonisation processes, such as the development of renewable energy, forests sinks are affected by the so-called “permanence problem” (Gren and Zeleke 2016). Indeed, uncertainties regarding climate change, the occurrence of wildfires or future anthropogenic activities, provide no guarantee that all new forests (and thus the stored carbon) will stand in the long run (Galik and Jackson 2009). Given that carbon sequestration in forests is potentially reversible (Watson et al. 2000), some national policies do not include international afforestation programmes in their eligible offset programmes (e.g. Swiss Federal Council 2016).

On top of these forest-specific concerns, one may have general reservations regarding the additionality, or ethical foundations, of offset programmes in general (Anderson 2012; Tirole 2012; Schneider and Kollmuss 2015; Carattini and Tavoni 2016b). Practical reservations may be related to the (in)effectiveness of carbon markets. Ethical considerations may be related to the “commodification” of nature, which is an argument often used by environmentalists to oppose the use of market-based solutions to environmental externalities (Baron and Leshner 2000; Sandel 2012; Braaten et al. 2015). In this paper, we analyse the demand for local and international forest offsets despite their potential weaknesses. While our main research question concerns the preference

for domestic versus international carbon offsets, in our experimental setting we also consider the general demand for carbon offsets and take care of potential concerns that our participants may have towards them.

From an economic perspective, purchasing carbon offsets is a real-life decision with a private cost to the individual. Individuals may be willing to voluntarily contribute to a public good such as climate change mitigation if, for instance, they derive some utility from the public good being provided (in case of pure altruism) or if they derive some utility from their contribution, due to warm glow (Andreoni 1990), or due to a positive self-image (Nyborg et al. 2006). In the case of offsets, individuals may also be willing to engage in the private provision of a public good if this may allow compensating other activities to which they contributed and that might have reduced the overall level of the same public good (Kotchen 2009). Following the environmental psychology literature, we would expect pro-environmental behaviour to depend positively on the following two arguments. First, the feeling of responsibility to contribute to the environmental public good at stake, the so-called “ascription of responsibility”. Second, the perception of the environmental impact that behaving in a pro-environmental way would generate, the so-called “awareness of consequences” (see e.g. Stern et al. 1999).

Concerning the preferences for domestic versus international carbon offsets, we considered three main drivers. Cost-effectiveness reasons justify international offsetting. However, experimental evidence from markets with externalities suggest that people may overlook efficiency gains, even with salient pay-off structures. This problem is particularly relevant for climate change mitigation. Kallbekken et al. (2011) show how tax aversion can affect Pigouvian taxes, hampering the implementation of instruments that would increase efficiency in the experiment, and allow for pay-off maximization (cf. also Kallbekken et al. 2010). When it comes to internalizing externalities, “half” measures such as subsidies may be preferred to “full” measures such as carbon taxes. That is, also in the lab, where the most cost-effective solution can be relatively easily identified, people may prefer sub-optimal solutions, even though these may imply lower pay-offs (Cherry et al. 2012).

People’s ethical and practical reservations to the use of carbon offsets, as described above, may also be influenced by the location of the offset project. We conjecture that these reservations, of practical character in particular, may be stronger in the case of projects undertaken in emerging economies. For instance, Gampfer et al. (2014) find that international climate transfers receive more public support if the donation is made

to a trustworthy government. Blasch and Farsi (2014) find that certifications by a trusted government agency or a United Nations body increase the willingness to pay for carbon offsetting. People may also have genuine preferences for local offsets. For instance, people could expect substantial local co-benefits from offsetting, which would increase the propensity to choose a domestic project (Torres et al. 2015).

Hence, we formulate the following hypotheses on the potential effect of each type of informational treatment applied in our experiment:

Efficiency hypothesis: Participants may pay attention to the amount allocated to carbon offsets, but not necessarily to the total quantity of emissions abated. Reminding them the cost differential between domestic and international reforestation programmes increases the amount allocated to foreign programmes and thus the overall abatement of carbon emissions.

Confidence hypothesis: Participants may not find projects abroad trustworthy. Providing guarantees on the trustworthiness of reforestation project providers increases the amount allocated to programmes abroad and thus overall abatement.

Local benefits hypothesis: Given that the main focus of the considered reforestation programmes is on greenhouse gas emissions, participants may neglect their local benefits. Reminding them the benefits of local forests increases the amount allocated to domestic reforestation programmes.

Most of the recent literature has examined the demand for carbon offsets relying on stated preferences, while only a few papers attempted to provide evidence based on revealed preferences by using lab and field experiments.⁶⁶ Since stated preferences are subject to several well-known biases (see e.g. Alberini and Kahn 2006), in this paper, we empirically address the acceptability of international carbon offsets using an experimental approach. Such an approach is arguably the best tool for inferring from revealed preferences, testing the effect of alternative policy designs that are not yet observed in reality, and causally identifying the effect of our treatments on people's preferences (Falk and Heckman 2009). In addition, the type of behaviour observed in the lab can be very similar to the one undertaken in a similar natural setting, and the

⁶⁶Stated preference studies include Brouwer et al. (2008), MacKerron et al. (2009), Carlsson et al. (2012), Blasch and Farsi (2014), Gampfer et al. (2014), Blasch and Ohndorf (2015) and Torres et al. (2015). Ovchinnikova et al. (2009), Löfgren et al. (2012), Diederich and Goeschl (2014; 2017), and Kesternich et al. (2016), are examples of revealed preference studies.

behavioural responses of student and non-student participants in lab experiments are often the same (cf. Alm et al. 2015). When it comes to analysing pro-social behaviour, or preferences over policies, one may argue that the likelihood that behavior in the lab differs from a real-life situation increases. While this can be true, pro-social behaviour in the lab remains strongly correlated with pro-social behaviour in the field (Benz and Meier 2008). That said, we are aware that each methodological decision involves a trade-off and we devote a section, below, to the external validity of our results, and how it may have implications for policy recommendations.

4.2.2 Experimental design

Following from the previous section, we selected two real reforestation programmes providing the same abatement per tree in both the domestic (developed) and the foreign (developing) country, but with a much lower price in the latter. The programme in the home country was located in Visp, Switzerland, while the programme in the developing country was located in Limay, Nicaragua. In these programmes, a tree in both Switzerland and Nicaragua captured 15 kg of CO₂ per year, while its price was 10 Swiss francs (CHF) in the former and only 3 in the latter country.⁶⁷ That is, given the price differential, with the same budget (e.g. with the same fiscal revenues from a carbon tax), emissions abatements could be three times larger in Nicaragua.

We ran the experiment in Geneva, Switzerland, in December 2015, with a sample of more than 300 undergraduate students in business administration (management) in their first or second year, all enrolled in mandatory microeconomics classes at the introductory or intermediate level⁶⁸. The experiment was conducted during class time, to prevent students self-selection. After entering the class, we briefly presented the experiment and instructed participants as per standard procedure in lab experiments.

The experiment was organized in two stages. A first stage determined participants' endowment, and their voluntary contribution to carbon offset projects. The allocation of this contribution between domestic and international projects was the focus of the second stage.

In the first stage, participants were randomly provided with 4 very general questions about microeconomics, whose answers determined their monetary endowment, along

⁶⁷1CHF≈1USD at the time of the study.

⁶⁸See the Appendix for the full questionnaire (translated from French).

Table 4.1: Reforestation programmes

	Programme 1	Programme 2
Place	Visp, Switzerland	Limay, Nicaragua
CO₂ / tree / year	15 kg	15 kg
Cost / tree	CHF 10	CHF 3

with a show-up fee of 2 Swiss francs. Each correct answer was rewarded with 2 francs, and so participants had the possibility to earn up to 8 additional francs.

Once the endowment was determined, participants were given the option to donate a share of it to the purchase of carbon offsets through reforestation programmes. At this stage, participants only decided how much money they wanted to spend on the purchase of carbon offsets and how much to keep for themselves, without further information on the specificities of the reforestation programme. Participants were informed about some basic facts of climate change; were introduced to the role of deforestation in increasing the stock of greenhouse gas emissions in the atmosphere; and were made aware of the role of reducing deforestation or increasing afforestation in helping mitigating climate change. All participants had also been informed that a nominal reforestation certificate could have been made available to all purchasers of carbon offsets, if they were willing to declare their identity once completed the experiment. This procedure might have reassured participants that the purchase of carbon offsets was really taking place, besides providing some reputational effects, which in general tend to have a significant positive impact on the contribution to a public good (Milinski et al. 2002).

In the second stage, once the amount dedicated to reforestation had been elicited, participants were asked to split it between the two specific programmes. This decision represented our outcome of interest, as it allowed understanding the preferences of people towards generating carbon offsets through a domestic or an international reforestation programme. Basic information about both reforestation programmes was provided to all participants as done in Table 4.1⁶⁹.

Furthermore, additional information was randomly provided in the form of the following three treatments. Treatment 1 (T1) stressed the price differential between a tree in Nicaragua and in Switzerland, emphasizing that funding the least-cost programme

⁶⁹Information on these reforestation programmes is available at <https://www.helvetia.com/ch/content/fr/qui-sommes-nous/engagement/foret-protectrice.html> (last accessed on November 26th, 2015) and <http://http://www.tree-nation.com/plant> (last accessed on November 26th, 2015).

would have resulted in higher emissions abatement, for a fixed contribution. T1 had thus been designed to test the efficiency hypothesis. Treatment 2 (T2) informed participants that both programmes had been guaranteed by reputable and independent institutions: the United Nations Environment Programme for the Nicaraguan project and the local government for the domestic programme. Hence, this treatment had been designed to test the confidence hypothesis. Treatment 3 (T3) introduced the role of local ancillary benefits of reforestation. We recalled to participants the recreational activities that the Swiss population uses to undertake in local forests, their importance for the local biodiversity, their benefits in terms of wood and non-wood products, as well as their contribution to local jobs and economic growth. T3 had been designed to test the local benefits hypothesis, favouring the domestic reforestation programme. A control group was assigned a very neutral messaging. Following the standard procedure, we administered a short debriefing survey to understand students' contributions and collected the usual socio-economic characteristics.

4.2.3 Econometric approach

We analysed separately the data from the two stages of our experiment. The first stage determined participants' contributions to the purchase of carbon offsets. The second stage captured the allocation decision between the domestic and international reforestation programmes. In the empirical analyses, the second stage addressed our main research question. In the first stage, given that our outcome variable, the ratio of contribution to forest programmes over endowment, was continuous and bounded between 0 and 1, we estimated both an ordinary least square (OLS) model and a specific generalised linear model for fractional outcomes (GLM), as recommended by Baum (2008).⁷⁰

In the econometric analysis of the second stage, we tested whether the differences among treatments were statistically significant, conditional on covariates, and assessed the magnitude of the treatment effects. We tested the following specification:

⁷⁰A tobit model could also be a potential candidate for a non-linear fit of our data. We thus followed Papke and Wooldridge (1993) and applied a specification link test to select the most appropriate model between the fractional logit GLM, and a tobit model. The specification test rejected the null hypothesis of good link specification for the tobit model ($p\text{-value}<0.001$), whereas it did not for the fractional logit GLM ($p\text{-value}>0.99$). Based on the test outcome, we selected GLM as our preferred non-linear specification. All additional estimations are available by the authors upon request.

$$Y_i = \alpha + \beta_1 T_1 + \beta_2 T_2 + \beta_3 T_3 + \gamma X_i' + \epsilon_i \quad (4.1)$$

in which our dependent variable Y is the percentage of participant i 's contribution allocated to the reforestation programme implemented abroad, α a constant and β_j the treatment effect for treatments $j = 1, 2, 3$. X_i is a vector of control variables and γ the vector of associated coefficients. Controls take into account the possible heterogeneity across individuals, along with ϵ_i , the heteroskedasticity-robust standard error.⁷¹ Since the dependent variable was bounded between 0 and 1, we also estimated this model with OLS and GLM.

We then checked whether the treatment effects occurred on the intensive or extensive margins. For each treatment, we could have observed the same proportion of participants contributing to the international programme as in the control group, but these could on average have been contributing a different amount (intensive margin). Alternatively, we could have observed a different proportion of participants contributing a positive sum to the international programme, without necessarily providing a different contribution, on average, than the control group (extensive margin).

To isolate the role of the extensive margin, we assessed, with OLS and logit models, the effect of the treatments on the proportion of individuals contributing a strictly positive amount to the international programme. We provided a further robustness test exploiting a two-parts model “à la Cragg”, which is appropriate for limited dependent variables and integrates both first stage and second stage decisions into a single two-parts model. Following Cragg (1971), we considered that the decisions to contribute and the level of this contribution might have been two different but simultaneous decisions, potentially driven by different factors. The first part of the model thus explained the probability to contribute to forest carbon offsetting with a probit model, and the second part explained the level of this contribution, conditional on strictly positive contributions.⁷²

⁷¹Due to the randomised allocation of the treatments, the inclusion of control variables did not affect the coefficients of the observed treatment effects, but it did increase the model's precision. Descriptive statistics for these variables are available in Table d.3 in the Appendix. The number of observations only slightly decreased when introducing control variables. The use of heteroskedasticity-robust standard errors was justified by standard heteroskedasticity tests such as modified Wald and Breusch-Pagan/Cook-Weisberg tests.

⁷²The Cragg model is intuitively similar to the Heckman two-stage model. However, our data did not suffer from a selection issue, as in Heckman (1979). In our experiment we indeed did not face missing data, but a “corner at 0” issue (see Wooldridge, 2010, chapter 16). That is, zeros were not present because of non-observable responses but were rather the result of an optimal choice made by

Table 4.2: Descriptive statistics

Variable	Contributors	Non-contributors
Endowment	7.15 (1.90)	7.34 (1.93)
Contribution	5.81 (2.59)	0 (0)
Contribution (% of initial endowment)	0.83 (0.30)	0 (0)
Observations	261	46

Standard deviations in parentheses.

4.3 Results

4.3.1 Descriptive statistics and first stage

Table 4.2 provides information on the first stage for the full sample. Descriptive statistics of the explanatory variables are available in Table d.1 in the Appendix. On average, participants contributed to climate change mitigation with about 6 francs each, i.e. about 80% of the average endowment of about 7 francs. Yet, 15% of them were not willing to contribute to reforestation at all.

In this stage, we analysed the propensity to contribute to a generic reforestation programme generating carbon offsets, relative to the initial endowment, and its determinants. To measure ascription of responsibility, we used two variables. The first variable was the standard measure of climate concern from the Gallup survey (cf. Lee et al. 2015) and the World Value Survey (WVS). Individuals were asked to answer on a 5 Likert scale from “I do not agree at all” to “I totally agree” to the following statement: “I consider that climate warming is a serious threat for the future”. We transformed this variable into a binary measure (called *climate concern*) taking the value 1 if an individual “pretty much agrees” or “totally agrees”, and 0 otherwise. As shown by the descriptive statistics in Table d.1 in the Appendix, the variable for climate concern scored particularly high, with 86% of the sample declaring to be concerned by climate change. For comparison, in the 2007 wave of the World Values Survey climate concern in Switzerland was about 89%. The second variable was a dummy taking value 1 if

the respondent. The Cragg model allows for two separate simultaneous decisions but does not correct for selection. It was thus the most appropriate approach for our context. It also allowed to have the same covariates in both parts of the model without risk of collinearity (Madden, 2008).

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participants felt morally obliged to contribute to climate change mitigation (we call it *moral obligation*). This variable resulted from the “pretty much agree” and “totally agree” answers to the following statement: “I feel morally obliged to protect climate.” Compared to climate concern, a relatively lower proportion (67%) stated to feel morally obliged to contribute to climate change mitigation.

To measure awareness of consequences, we used a variable capturing the belief that even small contributions to climate change can be important, such as the ones under examination in this study. This question was worded as follows: “How do you agree to the following statement? ‘In my opinion, even small contributions are useful to protect the climate’”. 85% of the sample considered that even small contributions can be important.

We note that considering a public good as important is a necessary, but not sufficient, condition for its voluntary provision (Nyborg et al. 2006). That is, people cannot contribute to the provision of all public goods that they deem important. Whether an individual is willing to contribute to a given good also depends on the descriptive norm concerning the provision of such good, i.e. what others do. Much evidence has been provided on conditional cooperation in local environments (cf. Fehr and Fischbacher 2003). However, conditional cooperation in the climate commons may appear less likely. Yet, according to Ostrom (2009), managing global dilemmas requires as much trust as managing local dilemmas does. Ostrom’s claim relies on the observed existence of reciprocity and trust at the local level, which may benefit the provision of any social good, regardless of its local or global characteristics. Supporting Ostrom’s intuition, Carattini et al. (2015) find for instance a negative correlation between trust and greenhouse gas emissions among European countries. Ostrom’s element of trust reconciles with the model of Nyborg et al. (2006): since the descriptive norm is not always salient, individuals may form expectations on other people’s contributions (see also Carattini et al. 2017b). This case applied to our experiment since communication was strictly forbidden between players. Hence, to estimate the effect of expected cooperation, we used a measure of participants’ belief of others’ contribution. This variable was based on the answers to the following question: “In your opinion, what share of their endowment other participants on average contributed to the reforestation programme?”.

We also added to the model a few variables that were related to the specificity of the public good under scrutiny. Since no details on the location of the reforestation programmes were provided at this stage, it is plausible that some individuals, especially

Table 4.3: Average marginal effects on contributions

	(1)	(2)
	OLS	GLM
Climate concern	0.039 (0.08)	0.016 (0.07)
Small contributions are important	0.13* (0.07)	0.11* (0.06)
Green member	-0.001 (0.05)	-0.008 (0.06)
Moral obligation	0.0099 (0.05)	0.016 (0.04)
Belief about others' contribution	0.71*** (0.06)	0.68*** (0.05)
Frequent forest user	0.071 (0.05)	0.070 (0.05)
Practical reservations w.r.t. reforestation	-0.069 (0.05)	-0.055 (0.04)
Ethical reservations w.r.t. the commodification of nature	-0.024 (0.04)	-0.016 (0.04)
Observations	299	299
Adjusted- R^2	0.347	

Heteroskedasticity-robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

those who were used to visit local forests, might have been more likely to contribute than others. Frequent usage is indeed a common determinant of contribution to the provision of ecosystem services in general (Czajkowski et al. 2014). We thus asked how often the participant used to visit forests, in general, and added to the model a dummy variable to account for regular or frequent visits.

Since no guarantee on the quality of the project was given at the first stage, we captured possible practical reservations to the use of forest carbon offsets. Our variable measured the degree of agreement with the following statement: “Reforestation is effective in reducing the stock of CO₂ in the atmosphere in the long run”. To capture general ethical considerations related to the commodification of nature, we exploited answers to the following statement: “I do not want to consider natural resources as a marketed commodity.”

Table 4.3 presents our estimates. Columns (1) and (2) show our coefficients for OLS and the average marginal effect of a fractional logit GLM, respectively. Since all es-

timates were statistically the same in both OLS and GLM models, and to allow for straightforward interpretation, we comment in what follows the estimated effects based on OLS.

All the coefficients had the expected sign, except the one associated with green membership, but the latter was not statistically significant. Our results suggest that the demand for carbon offsets generated by reforestation programmes is dominated, statistically speaking, by attitudinal variables, in particular, the belief that small contributions do help to make a difference, as well as the belief about others' contributions. Results about the belief of others' contributions match the recent evidence of Blasch and Farsi (2014), Blasch and Ohndorf (2015) and Schwirplies and Ziegler (2016). All these studies indeed find a positive effect on the demand for carbon offsets for variables very similar to our measure of beliefs about others' behaviour, namely, and respectively, "expected cooperation", "expected share of offset customers in society" and "expectation of society". Along with related literature showing similar patterns for other climate-friendly behaviours, this evidence can be used to support the existence of conditional cooperation in the climate commons (Carattini et al. 2017b).

Not surprisingly for a lab experiment, even for those with a relatively large sample, none of the other covariates reached the standard threshold for statistical significance, despite the expected sign. We note in particular that the frequent use of forests, or having practical reservations related to forest offsets, had no significant impact on the average contribution to reforestation programmes.

In the questionnaire, we also asked for participants' income. Given the non-negligible decline in observations that the inclusion of the income variable implied, we did not consider income differences in our model. Yet, we note that running additional estimations with such variable did not statistically affect the estimates of Table 4.3, while the coefficient for the income variable was found to be statistically insignificant. This result was unsurprising in our context, also because the private demand for environmental quality was likely to be only partially expressed, due to the (global) public good characteristics of climate change mitigation (cf. Roca 2003).

4.3.2 Second stage

The second stage included only participants providing a strictly positive monetary contribution to the generic reforestation programme. We examined the decision to allocate such contribution between the domestic and the international reforestation programme.

Table 4.4: Allocation of the monetary contributions to the programme abroad, per treatment

	T0	T1	T2	T3
Mean contribution to the international programme (% of total contribution)	0.63 (0.35)	0.73 (0.36)	0.64 (0.34)	0.59 (0.33)
Frequency of contributions to the international programme > 0	0.86 (0.35)	0.88 (0.33)	0.87 (0.34)	0.86 (0.35)
Observations	59	66	70	66

Standard deviations in parentheses.

Participants were randomly allocated to one of the three treatments or the control group, which resulted in 59 to 70 observations for each treatment. We created our variable of interest as a ratio, with the participant’s contribution to the reforestation programme abroad as numerator, and her total contribution as denominator. We expected this ratio to be affected by the informational treatments as discussed in Section 4.2.1. Table 4.4 shows some statistics for our dependent variable for each treatment group. Interestingly, 86% of all contributors who faced the neutral treatment accepted to contribute a positive amount to the international programme, with the average contribution at 63%. This suggests that participants to the experiment might not have opposed the principle of having emissions abatements taking place abroad. For comparison, Diederich and Goeschl (2017) find that when the cost of abating at home or abroad is (artificially) the same, people seem to have no preference for either one or the other location. Hence, a large proportion of our participants seemed to pay some attention to the price differential, even though they might have not fully internalized its implications for cost-effectiveness. A substantial part of the sample might have however been overlooking this differential, unless they had specific preferences or concerns in favour of one project or another. As expected, we observed some variation across treatments. In particular, contributions to the international reforestation programme were the highest with the efficiency treatment, and the lowest with the local benefits treatment.

As shown by Table 4.5, the estimates for the variables of interest were robust across OLS and GLM specifications. In what follows, we thus again interpret the results based on the OLS estimates.⁷³

⁷³The estimates for the control variables are displayed in Table d.4 in the Appendix. All coefficients had the expected sign, but most variables were not statistically significant. Declaring to be a frequent visitor of forests did not significantly affect the contribution to the local programme, nor did having previous experience with the domestic forest mentioned in the experiment. General ethical reservations such as being unwilling to consider natural resources as a marketed commodity, as well as other ethical

Table 4.5: Average treatment effects

	(1)	(2)
	OLS	GLM
Efficiency treatment (T1)	0.11*	0.12*
	(0.06)	(0.06)
Confidence treatment (T2)	0.026	0.025
	(0.06)	(0.06)
Local benefits treatment (T3)	-0.025	-0.024
	(0.06)	(0.05)
Covariates	Yes	Yes
Observations	256	256
Adjusted R^2	0.15	
AIC	148.5	1.08

Heteroskedasticity-robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Compared to the control group, the reference in the regressions, we found that all treatments have the expected sign. The informational treatment that reminded the importance of efficiency reasons (T1) and the treatment that provided guarantees on the quality of the offset programmes (T2) had both a positive impact on the relative allocation to the reforestation programme in Nicaragua. Likewise, the local benefits treatment (T3) increased the likelihood of funding the domestic programme. However, only the efficiency treatment had a statistically significant impact. This result suggested that participants tended to not completely factor in the efficiency argument supporting the use of international carbon offsets. Our causal estimate suggested that the efficiency treatment led to a 11 percentage point increase in the contribution to the programme generating carbon offsets abroad, compared to the neutral framing of the control group.

concerns related to international offsets, such as opposition to carbon markets or concerns on the fairness of offsetting domestic emissions abroad, did not reach statistical significance either. Given the relatively low number of observations and low variability of these variables, these results were not particularly surprising. Related to the previous discussion on conditional cooperation in the climate commons, we found that expectations about others' behaviour also shaped the allocation decision. Finally, a variable taking value 1 for second-year students was associated to higher contributions to the international reforestation programme. This result seemed consistent with Braaten et al. (2015), who maintain that students in economics are typically trained to focus on outcomes, i.e. on efficiency. A relatively large strand of literature on the behavior of economists tends to confirm this result. The main reference is, arguably, Marwell and Ames (1981), who find with lab experiments that graduate students in economics are more likely to respond to economic incentives than other subpopulations, in particular by free riding in the provision of public goods. Other notable studies on economists include Frey and Meier (2003) and O'Roark and Wood (2011).

The statistical insignificance of T2 suggested that a potential lack of credibility of the international programme was not a major concern for the individuals in the sample. Debriefing questions reported that only 12% of participants did not trust the Nicaraguan government for the implementation of the international reforestation programme, while no participant stated distrust in the Swiss government. Furthermore, we note that trust in the Nicaraguan government for the sub-sample having experienced T2 was not statistically different than the reported average for the whole sample, supporting this explanation. Other reasons could contribute to this result. It could be that the scepticism towards carbon offsets affected domestic and international reforestation programmes in the same way.

In the same spirit, we found that participants accounted already to a large extent for the potential benefits derived by the local programme, including how it might have supported the local biodiversity, which explained the limited effectiveness of T3 in boosting contributions to the local programme. It is worth noting that, in recent times, Swiss forests have been growing in both standing wood volume and surface and that their health is generally considered as good. The expectation of local co-benefits might thus have been limited in our context. In addition, in Switzerland the forestry sector contributes to only 0.1% of total employment and 0.06% of GDP (FSO 2017).

Our results showed that the efficiency treatment increased the average contribution to the international reforestation programme relative to the domestic reforestation programme. This increased contribution could take two forms. In the efficiency treatment, we could have either observed the same proportion of participants contributing to the international programme as in the control group, but these would have been on average contributing more. On the other hand, we could have observed a higher proportion of participants contributing a positive sum to the international programme, without necessarily having a different average contribution. That is, the change in behaviour could have taken place both on the intensive and extensive margins, respectively. To isolate the effect of the extensive margin, we looked at the treatment effects on the proportion of individuals contributing a positive amount to the international programme. In the same spirit, we also looked at heterogeneous treatment effects to determine whether responses to this treatment varied based on some of the participants' characteristics.

Table 4.6: Average treatment effects on the probability to contribute to the programme abroad (extensive margin)

	(1)	(2)
	OLS	Logit
Efficiency treatment (T1)	0.030 (0.058)	0.022 (0.058)
Confidence treatment (T2)	0.039 (0.059)	0.032 (0.056)
Local benefits treatment (T3)	0.018 (0.060)	0.0048 (0.055)
Covariates	Yes	Yes
Observations	256	256

Heteroskedasticity-robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Intensive vs. extensive margin

Descriptive statistics in Table 4.4 show that the proportion of strictly positive contributions to the international programme did not differ significantly across treatments. This is confirmed by the OLS and logit models presented in Table 4.6, showing that the effect of the treatments on this outcome variable is not statistically significant.⁷⁴

As presented in Table d.6 in the Appendix, the Cragg model provided very similar results to those in Tables 4.5 and 4.6. That is, it showed that T1 was not effective on the extensive margin, but it was on the intensive margin, and so increased average contributions to the international programme by about 11 percentage points.

Hence, while T1 had a positive impact on the average contribution to the international programme, this treatment did not affect the proportion of individuals contributing a positive amount to this programme, i.e. the extensive margin. That is, participants that were already predisposed to contribute to the programme abroad were likely to increase their contribution, whereas the remaining participants were likely to be unaffected. Hence, in presence of strong preferences for the local programme, the efficiency treatment may not be effective.

⁷⁴Results including covariates are presented in Table d.5 in the Appendix. Estimates from a probit model would lead to the same conclusion.

Heterogeneous effects

To disentangle the heterogeneous effects of our most effective treatment (T1) on different subgroups of the sample, we tested several extensions of equation (1), adding interaction terms. We expected some sub-samples to be particularly affected by the efficiency treatment. We tested the interaction between the efficiency treatment and the following dummy variables: *offsetting abroad is acceptable*; *ethical reservations with respect to the commodification of nature*; and *economic growth, rather than environmental protection, is the priority*. Similarly to the main model in the second stage, we estimated the coefficients with OLS. All the results were statistically the same if estimated with GLM. Column (1) shows the heterogeneous effect of T1 on individuals who think that it is morally acceptable to compensate CO₂ emissions abroad. Not surprisingly, as presented in Table 4.7, only those considering carbon offsets generated abroad as acceptable reacted to the informational treatment, whereas those expressing ethical concerns were more likely to remain on their positions. This supported the evidence provided on the treatment effect on the extensive margin. Relatedly, column (2) shows that only the participants that did not have ethical reservations related to the commodification of nature were affected by the efficiency treatment. Finally, we looked at whether “green” individuals were more or less responsive to the efficiency treatment than the rest of the sample. We used as proxy for greenness the WVS question “Economic growth and creating jobs should be the top priority, even if the environment suffers to some extent”. Interestingly, we found that, on average, “green” participants tended to react more than the average individual to the efficiency treatment. This suggested that, absent any external intervention, people caring for the environment might have been reticent to contribute in “large” proportions to the international programme, but stressing the higher environmental impacts achieved abroad with the same amount of money might have been effective in spurring participation to the international reforestation programme.

Discussion

We found that informational treatments emphasizing the cost-effectiveness of international offset programs could increase the demand for the latter. Our lab experiment suggested that there were information asymmetries, between our participants and economists, on the benefits of international abatements. In our context, an informational treatment was sufficient to address part of these asymmetries. We consider that our

Table 4.7: Heterogeneous treatment effects

	(1) Offsetting abroad is acceptable	(2) Ethical reservations w.r.t. commodification of nature	(3) Economic growth is the priority (vs. the environment)
T1 x Offset abroad	0.16* (0.08)		
T1 x NO offset abroad	0.096 (0.07)		
T1 x Ethical reservations		0.068 (0.08)	
T1 x NO ethical reservations		0.15** (0.08)	
T1 x Economy the priority			0.055 (0.13)
T1 x Economy NOT the priority			0.12* (0.06)
Confidence treatment	0.024 (0.06)	0.023 (0.06)	0.025 (0.06)
Local benefits treatment	-0.022 (0.06)	-0.023 (0.06)	-0.022 (0.06)
Constant	0.44*** (0.09)	0.422*** (0.09)	0.44*** (0.09)
Covariates	Yes	Yes	Yes
Observations	256	256	256
R^2	0.19	0.19	0.19
Adjusted- R^2	0.15	0.15	0.15

Heteroskedasticity-robust standard errors in parentheses. T1 represents the efficiency treatment. In all specifications we controlled for beliefs about others' contribution and frequent forest users, experience with the domestic site, acceptability of offsets abroad, ethical reservations against the commodification of nature, climate concern, green membership and economic growth as the priority (vs. the environment).

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

findings can have important implications for policy makers, with a caveat, related to their external validity. In what follows, we first discuss the policy implications, and then address the caveat.

Following the recent scandals related to Joint Implementation projects, most attention has been given to re-establishing the credibility of international offset programmes. Efforts in this direction are welcome, but our results seem to imply that credibility may not be the main concern for the general public. While for economists it is obvious that efficiency reasons would play in favour of abating emissions where it is cheapest, assuming that this is obvious also for lay people may be misleading. Information should thus be provided to make people understand why it is so important to undertake emissions abatements in developing countries. Other valid arguments oppose the use of international carbon abatements, but our results suggest that stressing the importance of providing a higher environmental benefit could lead an important share of contributions to switch from the local to the international programme. Even though our paper differs in perspective and results, we join Diederich and Goeschl (2017, p. 17) in their conclusion: “locational preferences need not stand in the way of realizing the gains from comparative advantage in climate change mitigation”. Our policy implications may also extend to linked carbon markets, an option that is currently receiving serious consideration in many jurisdictions having implemented emissions trading schemes. Besides the issue of reliability, linking carbon markets between developed and emerging countries would also require sufficient political support in the former, backing the purchase of carbon allowances from low- and middle-income countries. Therefore, reducing opposition to abatements taking place abroad may be highly beneficial for the prospect of future climate policy.

These policy implications depend on whether our findings can be applied to a broader context. Proving the external validity of our results is beyond the scope of this experimental investigation, hence the caveat. While the evidence covered in Section 4.2.1 supports the external validity of lab experiments, one can always argue that preferences for policy are context-specific. To put our results into perspective, we refer to the growing literature on public support for environmental policies, to which our paper is closely related. This literature has provided a set of recurrent findings, regardless of whether the methods used consisted in experimental approaches with students (e.g. Cherry et al. 2012, 2014; Kallbekken et al. 2011), qualitative surveys and focus groups (e.g. Dresner et al. 2006; Kallbekken and Aasen 2010), quantitative surveys and choice exper-

iments (e.g. Bristow et al. 2010; Sælen and Kallbekken 2011; Baranzini and Carattini 2017), survey panels in a quasi-experimental setting (Schuitema et al. 2010; Carattini et al. 2016a), or surveys combined with the observation of real ballots (Thalmann 2004; Carattini et al. 2017a). All these studies provide evidence of a gap between people's perceptions and economists' prescriptions, which contributes to explain an important part of the resistance to cost-effective environmental policies, such as carbon taxes.

This gap is very similar to that observed in our lab experiment. Hence, one could extrapolate to our context and support the external validity of our results. Furthermore, given that the participants in our study have some knowledge of economics, our experimental results are likely to provide lower-bound estimates. That is, if anything, asymmetries of information are likely to be larger with a fully representative sample. In our opinion, however, the main contribution of our paper relies on its novelty, rather than on its generalisability. We provide original findings and put forward a set of potential policy implications, whose relevance for other contexts may be investigated in future studies. Our paper, along with the concurrent studies by Anderson and Bernauer (2016) and Diederich and Goeschl (2017), represents indeed an initial investigation into a new research area on people's preferences for local and international abatements.

Several avenues for future research follow from our paper. While we consider reforestation programmes, the same research question applies also to other offset programmes, for which the difference in cost-effectiveness between programmes in developed and developing countries may be even larger. In addition, future research may include more than two countries, with varying costs and institutional features. Methodologically speaking, such analyses may not only be possible in the lab. Choice experiments, for instance, would be particularly suited to analyse the demand for carbon offsets, including location as one of many attributes and split designs to allow for randomized treatments. Researchers could also partner with companies offering carbon offsets, as in Kesternich et al. (2016), and analyse this question directly in the field. The larger and more representative the sample, with choice-experiment surveys or field experiments, the stronger the external validity. Qualitative studies could also offer a complementary perspective to this emerging literature, providing valuable information on how people's backgrounds and knowledge about efficiency and international carbon offsets may affect their preferences. Qualitative studies could also involve policy-makers, to understand the political economy of climate policies that restrict the use of international carbon offsets. Finally, further research could also extend the analysis to the role of local pol-

lution. The more international carbon offsets can be used, the lower the benefits of climate policy in terms of local air pollution and health. Especially in the presence of carbon trading schemes, and potential hot spots (cf. Fowlie et al. 2012), each additional unit of abatement that takes place abroad can have negative implications for the local population because of the co-generation of local and global pollutants.

4.4 Conclusion

Turning the Paris Agreement’s Nationally Determined Contributions into operational policies is the next challenge for policy makers. However, many political obstacles hamper the realisation of pledges in a cost-effective way. One of these is public resistance to the use of carbon credits and carbon offsets associated with greenhouse gas abatements in foreign countries. We addressed this issue in an experimental framework, in which participants were requested to allocate funding between a domestic and an international reforestation programme, the latter taking place in a developing country, where reforestation is cheaper.

We applied several informational treatments and found that the allocation decision was responsive to the provision of information on the cost-effectiveness of the reforestation programme implemented abroad. On the contrary, the decision was not particularly responsive to guarantees addressing a potential lack of credibility of the reforestation programme in the developing country and to information on the local benefits associated with the domestic programme. Our results suggest that stressing the potential for higher abatements in foreign countries is effective in changing participants’ priors in favour of international carbon offsets. Hence, individuals may be willing to increase their support for the use of international carbon offsets and related carbon markets, provided that they are in position to appreciate their environmental benefits.

Our novel findings contribute to the literature on the acceptability of climate policy instruments and on the emerging literature on carbon offsets. They suggest that some of the potential resistance to the use of carbon credits and carbon offsets generated in foreign countries may be, to some extent, spurious. Effective communication from policy makers could then address, and partly overcome, as in our experiment, such resistance. As policy-makers take their time to implement the required policies, the level of stringency requested to meet the climate targets increases. International carbon offsets could represent an important solution to ensure that the current pledges are met,

CHAPTER 4. CARBON OFFSETS OUT OF THE WOOD

thus supporting the Paris Agreement's ratchet mechanism, and the durability of the whole agreement.

Chapter 5

The Swiss construction wood market: CO₂ net emissions and actors responsiveness

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Abstract

Given the importance of wood products in CO₂ sequestration, an increase in the use of local wood in construction may help reduce the building sector's net emissions. Yet, the Swiss forest industry suffers from the low price of wood and is unwilling to produce more timber, despite the important potential of wood mobilization in Switzerland. Financial incentives may help to meet the goals of both environmental and economic sustainability, if actors respond to price changes. I thus use a rich yearly time series data set to estimate demand and supply price- and cross-elasticities on the market for roundwood in Switzerland, over the period 1949-2013. I consider both short term and long term relationships, thanks to a lagged adjustment model and correct for the price endogeneity using a supply-demand equations system estimated with the 3 Stage Least Squares approach. I find that both demand and supply are sensitive to price changes in the long and short run but that the simultaneous increasing demand for energy wood may have counterproductive impacts on the construction wood production.

Keywords: Roundwood; Simultaneous equations; Time series; Structural breaks; Construction

JEL classification: Q02, Q21, Q23, C31

5.1 Introduction

Wood is an important resource for the building industry. Indeed, although steel, concrete and cement have substituted timber to a large extent in the last century, the environmental advantage of wood in construction still makes a case in favor of the latter material. Wood sequesters carbon and, if used in buildings, prevents CO₂ to spill in the atmosphere (Lippke et al., 2010). Also, the production of timber requires less energy and wooden buildings are, on average, as energy-efficient as concrete buildings. Wooden buildings hence cause less emissions throughout their life than buildings made out of other materials such as cement or concrete (Gustavsson et al., 2006). As illustrated in Figure 5.1, walls in solid wood have a negative CO₂ emissions balance. One m² of solid wood wall is indeed able to sequester 200 kg of CO₂, while its production emits 10 kg of CO₂ only. In comparison, the production of one m² of concrete wall emits 60 kg of CO₂ and has no carbon storage ability. A more intensive use of wood in construction can therefore be useful as an additional tool to mitigate climate change. It is estimated that substitution of non-wood products by wood products could save up to 110 million tons of CO₂ up to the year 2096 in Switzerland (FOEN, 2007), which corresponds approximately to what Switzerland emits for two years as of today.

To encourage the use of wood and reach this goal, the Swiss government allows firms to domestically offset their CO₂ emissions through wood products (Swiss Federal Council, 2016). Also, since 2015, norms regarding fires prevention do not limit the use of wood in buildings anymore. These changes engender a renewed interest for the use of wood by the construction sector.

Swiss forests grow both in volume and surface since the 19th century. However, trees get older, which limit their ability to serve as carbon sinks. Given the relative environmental friendliness of wood, the sustainable aspect of an increase in wood production (Borzykowski and Kacprzak, 2017) and the potential of wood mobilization, the Swiss government decided to promote the use of this material within the framework of the Forest Policy 2020 (FOEN, 2013c) and the wood resource policy (FOEN, 2008). Yet, the Swiss forest industry has suffered from the low price of wood for decades and stakeholders claim that the current price does not give any incentive for more mobilization (FSO, 2017). Given the goal of the Swiss government and the financial bad health of the forest sector, understanding whether the Swiss forest industry responds to price changes is of particular importance. Indeed some doubts emerge regarding the responsiveness of wood market actors to financial incentives. With micro-data at the firm

level, Farsi and Krähenbühl (2015) have shown that the Swiss wood supply may not be profit driven but rather only target a given revenue. This result supports the view that financial incentives may be ineffective in increasing the wood production.

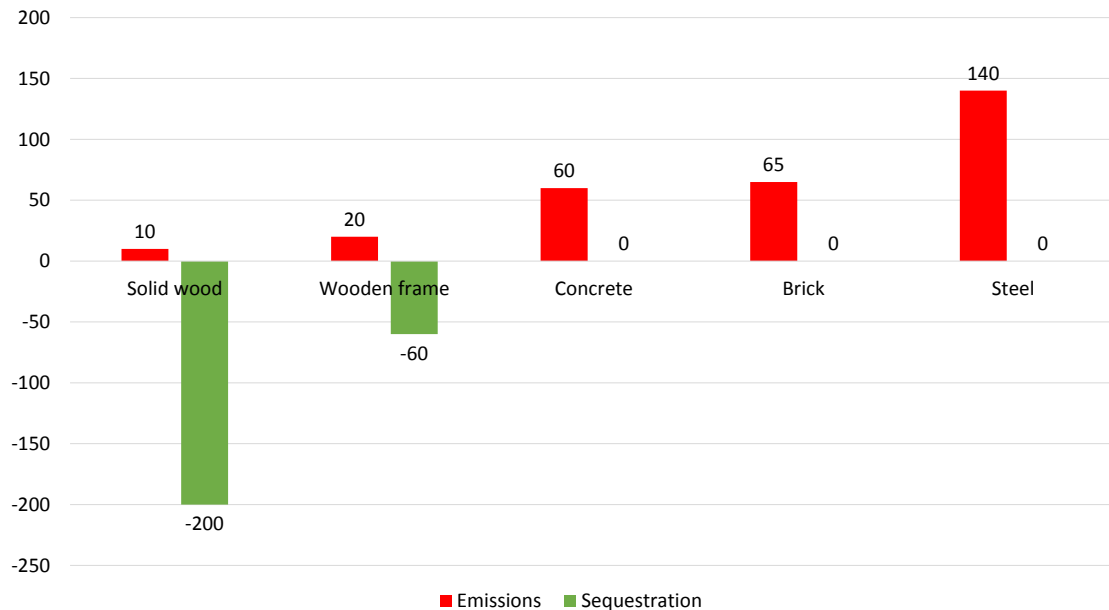


Figure 5.1: CO₂ emissions and sequestration in kg of CO₂ equivalent/m² of wall (Source: KBOB, 2009)

I use a rich yearly time series data set to estimate demand and supply price- and cross-elasticities on the market for roundwood in Switzerland. The analysis covers the period 1949-2013 and considers both short term and long term relationships, thanks to the Lagged Adjustment model (LAM) (Koyck, 1954). I present an approach that also corrects for the price endogeneity using a supply-demand equations system estimated with 3 Stage Least Squares (3SLS) and deal with structural breaks.

Section 5.2 presents the economic specificities of the Swiss wood market and Section 5.3 reviews the related literature in developed countries. Section 5.4 presents our data set and Section 5.5 explains our econometric approach. Results are available in Section 5.6. I discuss them and conclude in Section 5.7.

5.2 Economic context

The Swiss wood market is composed of a multitude of small decentralized actors such as forest owners, logging companies for the harvest, sawmills for the transformation and end-users, which can be institutional actors, private firms or households and hence respond to different factors. Represented by the two-way arrow in Figure 5.2, our interest market is comprised between forest owners and wood traders on the supply side and sawmills on the demand side. The demand for roundwood is therefore indirectly driven by the construction sector and marginally by the demand for other wood products.

With the exception of Brännlund (1989), scholars usually consider that markets are competitive (Toppinen and Kuuluvainen, 2010), and so do we. However, one needs to acknowledge that this is a strong simplifying assumption in Switzerland. In particular, wood markets are not completely integrated, given the substantial transportation costs. If they were, the Law of One Price (Richardson, 1978) should hold but some evidence reject it at the world level (Hänninen, 1998), acknowledging the lack of global competition (Kallio, 2001; Olsson, 2009). Anecdotal evidence also suggest that the Swiss wood market is far from the ideal perfect competition as prices are usually bargained over the counter on a case-by-base basis.

From raw wood, a large panel of products can be produced. Differences in the wood quality, assortment or essence increase the heterogeneity, which comes with heterogeneous prices (Kostadinov et al., 2014). In addition, there exists some complementarity and substitutability in the supply of wood products. Indeed, from a particular harvested tree, both energy wood and timber can be produced and wood waste from sawn wood can also be turned into valuable energy. Prices of energy wood may therefore have an impact on the production of construction wood. This effect may be positive, if energy wood is a complement to construction wood on the production side, or negative if producers substitute construction wood with energy wood. Indeed, the production of construction wood comes with a higher marginal cost than energy wood⁷⁵ and the profit may be higher with the production of energy wood rather than roundwood.

Another interesting specificity is the substantial externalities associated with the wood supply. Indeed, the exploitation of wood impacts the different forests functions such as recreation, protection against landslides, water and air purification and habitat for

⁷⁵At the exit of the forest, costs of energy wood do not include the costs of processing the wood. Also, transportation of energy wood is cheaper since it does not require as large trucks as construction wood.

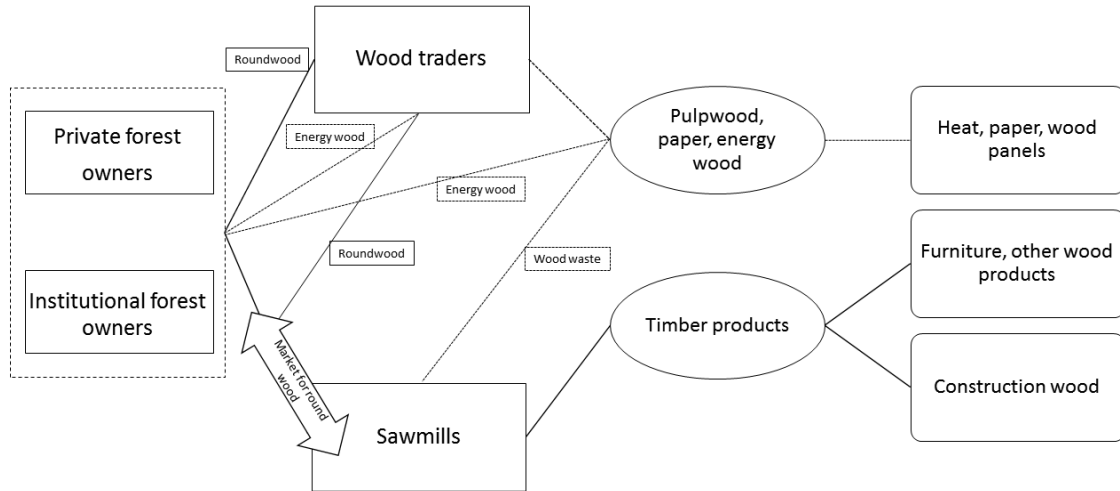


Figure 5.2: Swiss wood markets in a nutshell (Adapted from Kostadinov et al. 2014)

biodiversity. On the one hand, a reasonable forest exploitation has positive effects as it secures forest zones and gives more room to particular fauna and flora species. On the other hand, a too intensive exploitation reduces forest's ability to provide its other services. Given these external effects and the important deficit of forestry since the 90's, forest exploitation is usually subsidized or public owned in Switzerland.

Finally, wood is a storable good (Hendel and Nevo, 2004). Entrepreneurs may either choose not to harvest at time t and let the tree standing until $t + 1$ or cut it at time t and store the wood until $t + 1$ before the sales. Consumers may also choose to buy at time t and store it until the next period. This may impact the short vs. long term elasticities. However, since adaptation becomes easier with time, entrepreneurs and consumers reactions to a change in price (or in any other factor) should be higher in the long term than in the short term, and hence short term price-elasticities should be lower than long term price-elasticities. This is the Le Chatelier principle, first outlined by Samuelson (1948), which has been confirmed for US forestry markets (Daigneault et al., 2016).

5.3 Literature review

Time series analysis of wood markets may help to understand the reaction of the demand and supply to particular factors along time. Buongiorno (1979; 1996), Buongiorno et al.

(1988), Brännlund et al. (1985) and Brännlund (1989) extensively studied wood markets in developed countries in the 80's but time series analyses have become less common in Europe in the last decade, as highlighted by Toppinen and Kuuluvainen (2010). However, we observe a recent renewed interest in this type of approach, as shown by the number of very recent articles on wood products markets (Parajuli and Chang, 2015; Parajuli et al., 2016; Kristöfel et al., 2016; Daigneault et al., 2016; Kinnucan, 2016; Jochem et al., 2016; Sun and Niquidet, 2017; Parajuli and Zhang, 2017, among others). However, most of the studies are based on North American, Chinese (Wan et al., 2010; Zhang et al., 2015, 2017) and Scandinavian data (Mutanen and Toppinen, 2005) and the scarce papers about central Europe usually focus on energy wood only (Kristöfel et al., 2016; Sun and Niquidet, 2017)⁷⁶.

With time series on Great Britain, Iriarte-Goñi and Ayuda (2012) analyze the impact of wood use on economic development. These authors first calculate the apparent consumption of wood as the quantity produced minus net exports on the period 1871-1936 and find that the series are trend stationary. They then estimate price and income elasticities with OLS on 3 different periods: according to their results, income elasticity was particularly high ($\varepsilon_I^D = 6.23$) during the WW1 and lower ($\varepsilon_I^D = 1.22$) before and after that period. Wood can still be considered as a luxury good during the whole period. With respect to prices, these authors find that the demand for wood was relatively price-elastic during WW1 ($\varepsilon_P^D = -1.5$) and relatively price-inelastic after ($\varepsilon_P^D = -0.49$). They also find an interesting positive cross-relationship with iron, meaning that iron was a substitute to wood in the building and shipbuilding sector.

As reviewed in Daigneault et al. (2016), the literature before the year 2000 finds relatively low short run demand and supply price elasticities of softwood stumpage ($\varepsilon_P^D = -0.001$ to -0.85 ; $\varepsilon_P^S = 0.06$ to 0.63). We present a review of some price-elasticities found in the post 2010 developed countries literature in Table 5.1. Both supply and demand elasticities of wood products are found to be below 1, with the exception of wood pellets supply in Austria (Kristöfel et al., 2016). In general, we observe that elasticities are slightly higher in Europe than in the US.

With the same methodology as ours, Daigneault et al. (2016) find inelastic demand and supply, thanks to their model with data on the softwood market between 1950 to 2001. Their results are in line with those of the recent literature. In a study on softwood

⁷⁶See Jochem et al. (2016) and Zafeiriou et al. (2012) for analyses of roundwood markets in Germany and Greece, respectively.

lumber, Song et al. (2011) estimated a supply-demand system of equations with an Error Correction Model, using US monthly time series data from 1990 to 2006. Their results reveal relatively low demand and supply elasticities ($\varepsilon_P^D = -0.18$; $\varepsilon_P^S = 0.23$). Another interesting result of the latter study is the negative trend on the demand side, meaning that, *ceteris paribus*, technological progress reduces the demand for wood along time. Parajuli and Chang (2015) also found low price-elasticities on the softwood sawtimber stumpage market. Their result reveal that the market is significantly affected by natural calamities and the 2008 housing crisis.

To the best of our knowledge, the only econometric analysis of wood markets over time in Switzerland is Pauli et al. (2009). These authors regressed the supply on prices, costs, natural disasters and a time trend and the demand on prices, GDP, import prices and storage costs. Their results reveal low supply elasticities but very high demand elasticities (-8.26), which “do not seem realistic” (Pauli et al., 2009, p.84). However, their econometric analysis contains two major drawbacks: first, the price endogeneity is not correctly taken into account and supply and demand are estimated separately via a simple OLS regression. Second, the stationary nature of the series is not discussed, which casts doubts on the reliability of statistical inference from their results.

Table 5.1: Wood price-elasticities in developed countries in the post 2010 literature

Study	Wood product	Region	Period	ε_{SR}^D	ε_{SR}^S	ε_{LR}^D	ε_{LR}^S
Pauli et al. (2009)	All assortments	Switzerland	1995-2005			-8.36	0.73
Majumdar et al. (2010)	Softwood lumber	US	1959-2009				0.18 to 0.21
Song et al. (2011)	Softwood lumber	US	1990-2006	-0.14	0.16	-0.18	0.23
Zafeiriou et al. (2012)	Roundwood	Greece	1974-2008				0.97
Parajuli and Chang (2015)	Softwood sawtimber stumpage	Louisiana (US)	1955-2013	-0.38		-0.44	0.49
Daigneault et al. (2016)	Softwood sawlog	US	1950-2001	-0.08 to -0.18	0.15 to 0.26	-0.24 to -0.48	
Daigneault et al. (2016)	Softwood pulp	US	1950-2001	-0.07 to -0.12	0.15 to 0.49	-0.13 to -0.44	
Kristöfel et al. (2016)	Wood pellets	Austria	2000-2014			-0.66 to -0.76	1.03 to 1.18
Jochem et al. (2016)	Construction wood	Germany	1993-2013			-0.95	
Parajuli and Zhang (2017)	Hardwood sawtimber stumpage	Louisiana (US)	1955-2014			-0.85	0.73

5.4 Data description

Our time series analysis covers the period 1949-2013 on a yearly basis. The dependent variable (Q_t) is the quantity of roundwood produced from forests in Switzerland in millions of m³. Various data sources have been used and hence we had to make different assumption to make series consistent⁷⁷. In particular, Q_t corresponds to round lumber and industrial wood for construction purposes and a marginal part of Q_t is also used for

⁷⁷Data sources, units and variables description are available in Table e.1, in the Appendix. All assumptions and methods are listed in the Appendix.

the production of furniture. We assume that the market clearing condition is fulfilled, such that Q_t is the same on the demand side as well as on the supply side.

We consider different covariates, presented in Table 5.2, constrained by data availability:

P_t : The volume-weighted average real price of wood for construction purposes in 2011CHF/m³.⁷⁸

Given the lack of consistent data, aggregation and weighted averages had to be used. In general, those prices correspond to wood sold at the closest railway station or at the exit of the forest, Free On Board. This variable enters both supply and demand decisions. We expect it to take a negative sign on the demand side and a positive sign in the supply side, in line with classical economic theory.

P_{subs_t} : The average real import price of steel, iron and other metallic materials in 2011CHF/kg. We use this variable as an indicator for the price of a substitute in the building industry. If steel is indeed a substitute to wood, we expect the coefficient associated with this variable to be positive.

Px_t : An index of volume-weighted average production real prices of raw wood from all assortments and essence from publicly-owned forests in Germany (DESTATIS, 2017) (100=2011). This exogenous index is likely to proxy the price of foreign wood in Switzerland, since Germany is the biggest exporter of wood in Switzerland (about 45% of the value of all imported wood products come from Germany in 2013, followed by Italy with 11% (FOEN,2013)). This variable accounts for the exchange rates differentials by multiplying the raw data by an index of exchange rates between Germany and Switzerland (Swiss National Bank, 2017).

$Investment_t$: The real amount invested in construction in Switzerland in billion of 2011CHF. We use it as an indicator of the economic health in the building sector and of general business cycles. It enters the demand side and is expected to come with a positive coefficient.

$Wage\ in\ forestry_t$: The real wage paid to the logging crew in Switzerland in 2011CHF/hour (Niederer and Bill, 2015). We use this variable as an indicator of the cost of labor, the main input in the logging industry. We expect that this variable will have a positive impact on the marginal cost and thus a negative impact on the supplied quantity.

⁷⁸Prices were deflated thanks to the consumer price index (Source: FSO).

i_t : The real average interest rate on savings in %. This variable is used to account for the cost of capital. As in the case of the wage, we expect that this variable will have a positive impact on the marginal cost and thus a negative impact on the supplied quantity.⁷⁹

$Penergy_t$: The volume-weighted average real price of energy wood in 2011CHF/m³.⁸⁰ Again, given the lack of consistent data, aggregation and weighted averages had to be used. In general, those prices correspond to wood sold at the closest railway station or at the exit of the forest, Free On Board. We use this variable to test whether energy wood is a production substitute or complement to construction wood. We formulate no a priori assumption on the sign of this variable coefficient. Indeed, as wood can either be transformed into construction or energy wood, there are some substitution possibilities on the production side. However, the production of construction wood also causes wooden waste, which can only be used as energy provider. Therefore, energy wood and construction wood can be complementary as well as substitutes in production.

$Storm_t$: The volume of fallen wood due to major natural calamities in million of m³ (Usbeck, 2015). Two major events need to be noted: Vivian, a major storm that happened in 1990, and Lothar, which happened in December 1999 but whose effects were observable in 2000. These storms destroyed large parcels of forests. It is estimated that 10 million trees (13 million m³ (FOEN, 2014c)) fell because of Lothar. In 2000, the Swiss government decided to subsidize the forest industry in order to extract fallen trees from forests, which certainly had an impact on the supplied quantity.

T_t : A time trend that takes into account technological or preferences changes.

We do not include any indicator of household income because the demand is only indirectly driven by households. Investment in construction is probably a better driver of the demand for timber and mostly arises from firms or the public sector. The latter variable is also correlated with Gross Domestic Product (corr.=0.88).

Figure 5.3 shows both endogenous series, namely the quantity of roundwood (Q_t) and its associated price (P_t). The quantity produced has been increasing on average since

⁷⁹It is worth noting that the *user cost of capital* would be a better measure for this variable, since it also includes the depreciation rate. However, to the best of my knowledge, this variable is not available for Switzerland so far in time.

⁸⁰Prices were again deflated thanks to the consumer price index (Source: FSO).

Table 5.2: Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Q_t	3.25	0.92	1.74	7.61
P_t	254.46	143.81	71.17	498.74
$Psubst_t$	1.69	0.58	0.87	3.13
Px_t	75.22	16.84	31.52	111.40
$Investment_t$	39.54	14.68	7.69	61.88
$Wage\ in\ forestry_t$	15.14	10.57	1.96	32.53
i_t	6.47	4.25	0.20	11.97
$Penergy_t$	102.98	36.96	57.56	186.87
$Storm_t$	0.38	1.86	0	13.98
Observations	65			

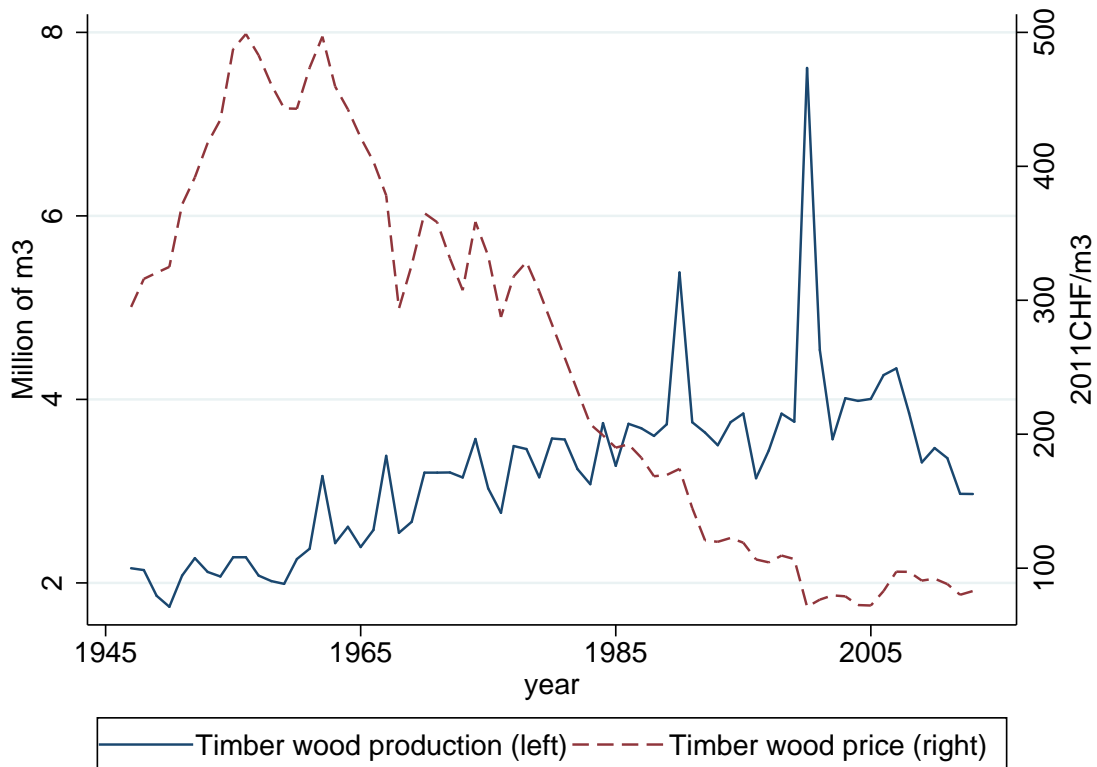


Figure 5.3: Timber wood production and price

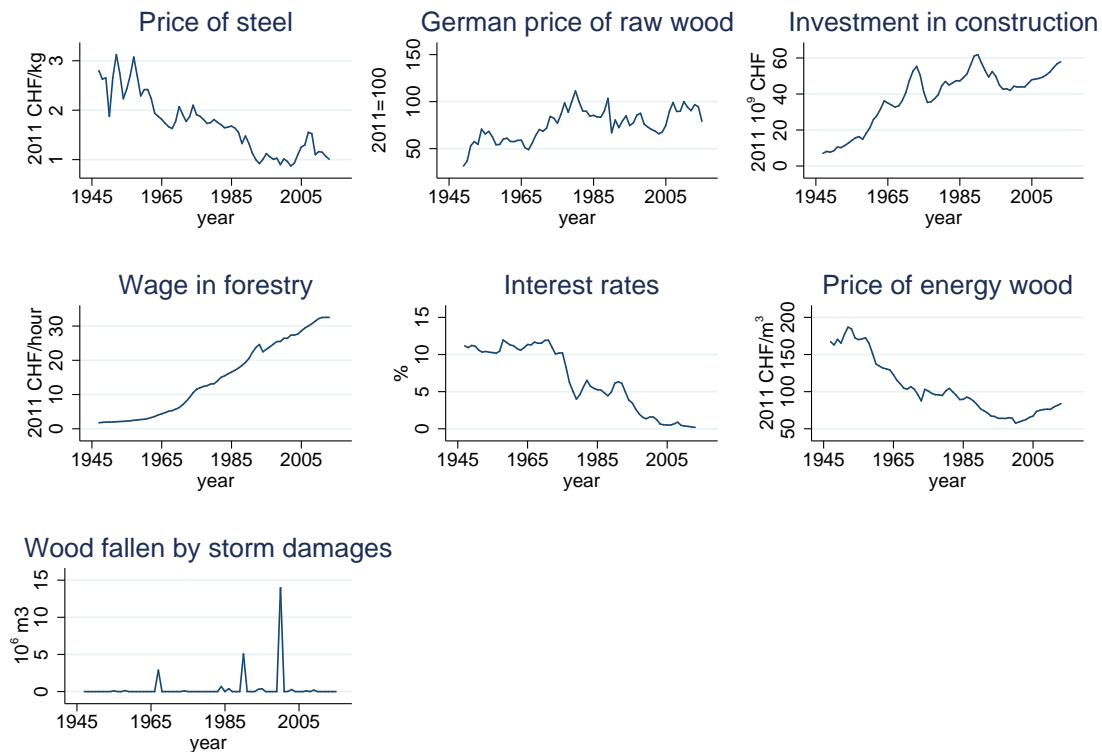


Figure 5.4: Annual time series

the beginning of the period but starts declining after 2008. We observe 2 main peaks: Vivian in 1990 and Lothar in 2000. These storms and the subsidies that followed Lothar increased the production of wood by roughly 44% for Vivian and 103% for Lothar (FOEN, 2014c). From 1949 to 2013, the production of construction wood has increased by 44%.

The real price of timber remained high until the mid 60's and started declining after that. This price in 2013 is 70% lower than in 1949 but has stabilized after 2000.

Figure 5.4 shows the evolution of our independent variables (not-log-transformed) for our period of interest. The real price of steel decreased since the beginning of the period until the 2000's. We then observe a slight rebound. The price of wood in Germany has been increasing over the whole period but there are some periods of slower growth from 1955 to 1965, 1980 to 2000 and 2005 to 2013. The economic crisis of the mid-70's caused by the oil shock caused a decrease of investment in construction, similarly to the burst of the Swiss housing bubble in the beginning of the 90's. This is visible in the third

graph. According to the fourth graph, wages in forestry increase on the entire period. The price of energy wood has decreased until 2000. It started increasing slowly since then, as shown in the sixth graph. On the last graph, three peaks of fallen wood are clearly observable and correspond to the three strongest storms in 1967, 1990 (Vivian) and 2000 (Lothar).

5.5 Econometric approach

Analyzing the whole market, it is important to deal with the issue of endogeneity. Indeed, at the equilibrium, prices and quantities are simultaneously determined by the market according to both demand and supply. Therefore, a system of simultaneous equations, accommodating both sides of the market, is necessary to instrumentalize the endogenous variables. This model can then be estimated using a Two Stage Least Squares (2SLS) or 3SLS approach. Contrary to 2SLS, 3SLS assumes that error terms of the equations system are correlated. 3SLS is usually more efficient for this kind of model and thus preferred in our case (AlDakhil, 1998). However, the main drawback of 3SLS is its sensitivity to misspecification (Hausman, 1978).

The use of Ordinary Least Squares (OLS) in a time series context is usually not recommended if series are not stationary. Indeed the non-stationary nature of series leads to the problem of spurious regressions and thus to unreliable statistical inference (Granger and Newbold, 1974). We thus observe two different types of model in the literature: variants of the Error Correction Model (ECM) developed by Engle and Granger (1987a) or the Lagged Adjustment Model (LAM) also called distributed lag model (Koyck, 1954; Jorgenson, 1966; Houthakker and Taylor, 1970) with simultaneous equations⁸¹. Hsiao (1997a; 1997b) have indeed demonstrated that the 2SLS and 3SLS estimators are consistent with cointegrated time series⁸² and that one may not worry about non-stationarity in a dynamic simultaneous equation context, as far as the estimation residuals are stationary (Hsiao and Fujiki, 1998)⁸³. In this case, short run and long run variable impacts

⁸¹Studies using the ECM include Song et al. (2011); Parajuli and Chang (2015); Parajuli et al. (2016); Parajuli and Zhang (2017) and LAM Polyakov et al. (2005); Mutanen and Toppinen (2005); Daigneault et al. (2016)

⁸²The current and lagged variables being trivially cointegrated (Hsiao, 1997b)

⁸³Although stationarity tests are not relevant in a dynamic simultaneous equation context (Hsiao, 1997a), we tested all series with Augmented Dickey-Fuller (Dickey and Fuller, 1979), Phillips-Perron (Phillips and Perron, 1988) and KPSS (Kwiatkowski et al., 1992) tests and found that all series are non-stationary on levels but stationary on first differences. Results of these tests are available in Table e.2, in the Appendix.

can be inferred straightforwardly from the estimations and their linear transformation (see Hsiao and Fujiki, 1998, p. 69). Parajuli et al. (2016), studying the sawtimber market in Louisiana, have also shown that both methods lead to similar results in terms of elasticities. In this Chapter, we thus follow Polyakov et al. (2005), Mutanen and Toppinen (2005) and Daigneault et al. (2016) and estimate a LAM on a simultaneous dynamic demand-supply equations system using 3SLS.

We tested up to 4 lags of the dependent (DV) and independent variables (IDV) on both supply and demand sides of the model and compute the Bayes information criteria (BIC) for each estimated model. The BIC selects the model with no lagged IDV but a single lagged DV. Hence the best model contains a single lagged DV (Q_{t-1}). This specification corresponds to the standard geometric lag function (Koyck, 1954), which assumes that the effects of lagged IDV decrease with a geometric pattern. The short run effect of a given variable thus correspond to its immediate effect at time t , while the long-run effect is the addition of the IDV lags on the whole period.

The inclusion of a lagged variable on the demand side increases the BIC, which indicates a worse model than without this lag. In addition, the coefficient associated with this variable is not significant. We therefore choose to add the lagged DV on the supply side only. This specification allows to understand the supply adjustment speed, while assuming that long term and short term elasticities are equal on the demand side (i.e. the demand adjusts immediately).⁸⁴

5.5.1 Structural breaks

Since our time series cover a long period of time, a number of structural breaks (SB) are expected (Toppinen and Kuuluvainen, 2010). We thus cautiously study structural breaks using a supremum Wald test⁸⁵ on the univariate regression $Q_t = \alpha + \beta P_t + \epsilon_t$ and using Gregory and Hansen (1996) approach (ghansen)^{86, 87}

⁸⁴Testing the residuals of the chosen model with a cumulative periodogram white-noise test (Bartlett, 1955), we do not reject that residuals are white noises, revealing no serious problem of autocorrelation. ($Prob > B = 0.06$ for the demand and $Prob > B = 0.33$ for the supply, with B the Bartlett's statistic. Adding up to 4 lagged DV on the demand side does not increase the probability $Prob > B$).

⁸⁵This command is provided by the `estat sbsingle` command on Stata14

⁸⁶Stata14 command: `ghansen`

⁸⁷A serie of tests for structural breaks exist in the literature, such as the cumulative sum of recursive residuals. Extending further this Chapter could require to use different tests for structural breaks and compare the results.

The supremum Wald test identifies a break in 1962. Except for the statistical reason, the year 1962 is marked by the adoption in the Swiss Constitution of the article on nature and landscape protection, which may have had an impact on the forest harvesting policy.

The ghasen approach identifies other breaks⁸⁸: level breaks in 1991 and 2001 that correspond to the storms Vivian and Lothar respectively and regime breaks in 1994. The fact that the storms produce structural breaks is not a surprise. However, our results tend to contradict the findings of Kinnucan (2016) that natural disasters cause a regime break (i.e. a rotation in the curves), since, in our case, the tests indicate a shift in levels only. Interestingly, the 1994 regime break follows the adoption of the Swiss forest law, which restricted the wood harvest, by, among other measures, forbidding clear cuts.

While level breaks are relatively easy to handle with a dummy, regime breaks are more difficult in a simultaneous equation context. As the price variable is endogenous, each regime break of price must come with its instruments. The lack of appropriate additional variable in our data set and the low number of degrees of freedom thus constrain the possibilities to account for regime breaks. Also, post-estimation tests for the instruments' strength are not available with more than one endogenous variable. We thus choose to only allow for a single regime break on the effect of price. For that purpose, we split the price variable in two, with the cut-off point in 1994, as suggested by the ghasen test. To take the level breaks into account, we add the dummy variables D_{1962_t} and D_{2000_t} , which take the value 1 for all years after 1962 and 2000 respectively. We do not account for the 1991 level break, since it came with non-significant coefficients in every model.

We add a time trend on the demand side, which accounts for preferences changes or technical progress in the construction sector. We do not include such a variable on the supply side, since the coefficients came insignificant in all tested models and to avoid issues related with overidentification.

We therefore end up with the following models without structural breaks (equation 5.1) and with structural breaks (equation 5.2):

⁸⁸It is worth mentioning that all tests of cointegration provided by the ghasen test reject the null hypothesis of no cointegration.

$$\begin{cases} Q_t^D = \alpha^D + \beta_1^D P_t + \beta_2^D P_{subs_t} + \beta_3^D P_{x_t} + \beta_4^D Investment_t + \beta_5^D T_t + z_t^D \\ Q_t^S = \alpha^S + \beta_1^S P_t + \beta_2^S Wage\ in\ forestry_t + \beta_3^S i_t + \beta_4^S P_{energy_t} + \beta_5^S Storm_t + \beta_6^S Q_{t-1}^S + z_t^S \end{cases} \quad (5.1)$$

and

$$\begin{cases} Q_t^D = \alpha^{D_{SB}} + \beta_1^{D_{SB}} P_{1949-1994_t} + \beta_2^{D_{SB}} P_{1994-2013_t} + \beta_3^{D_{SB}} P_{subs_t} + \beta_4^{D_{SB}} P_{x_t} \\ \quad + \beta_5^{D_{SB}} Investment_t + \beta_6^{D_{SB}} T_t + z_t^{D_{SB}} \\ Q_t^S = \alpha^{S_{SB}} + \beta_1^{S_{SB}} P_{1949-1994_t} + \beta_2^{S_{SB}} P_{1994-2013_t} + \beta_3^{S_{SB}} Wage\ in\ forestry_t + \beta_4^{S_{SB}} i_t \\ \quad + \beta_5^{S_{SB}} P_{energy_t} + \beta_6^{S_{SB}} Storm_t + \beta_7^{S_{SB}} D_{1962_t} + \beta_8^{S_{SB}} D_{2000_t} + \beta_9^{S_{SB}} Q_{t-1}^S + z_t^{S_{SB}} \end{cases} \quad (5.2)$$

With the exception of i_t , $Storm_t$, the trend and the dummies⁸⁹, we transform all variables in the natural logarithm form.

5.6 Results

We present the estimation results of equations 5.1 and 5.2, hence respectively without and with structural breaks in column (1) and (2) of Table 5.3. All coefficients except $Storm_t$ and i_t can be directly interpreted as short run (SR) elasticities.

Coefficients in Table 5.3 all have the appropriate signs on the demand side estimation. In particular, we observe that the SR price-elasticity of demand is negative. The magnitude of this effect is 1.9 in absolute value and indicates that the demand for construction wood is rather highly price-elastic. The addition of regime breaks does not result in any statistically significant change in slope, as shown by model (2). A 1% increase in price should therefore lead to 1.8 to 1.9% decrease in demanded quantity in the short run.

As expected, the cross-elasticity between construction wood and steel is positive. Steel is thus a substitute to wood in the construction sector. Indeed, if the price of steel increases, the latter becomes less attractive, which causes an increased demand for construction wood of 0.9% for a 1% increase in steel prices. The German price of wood is positively correlated with the demanded quantity. Indeed, if foreign prices increase by 1%, the Swiss wood becomes relatively more attractive and the demanded

⁸⁹As $Storm_t$ contains many 0, a log-transformation would cause an important loss of observations. Also a logarithmic transformation is not suitable for percentage variables such as i_t .

Table 5.3: Results of the lagged adjustment model estimation

		(1)	(2)	
		SR relationships No breaks	SR relationships With breaks	
Demand	P_t	-1.89*** (0.44)		
	$P_t(1949 - 1994)$		-1.85*** (0.42)	
	$P_t(1994 - 2013)$		-1.83*** (0.41)	
	P_{subst}	0.85*** (0.28)	0.86*** (0.27)	
	Px_t	0.40* (0.22)	0.40* (0.23)	
	$Investment_t$	1.00*** (0.20)	1.04*** (0.22)	
	T_t	-0.064*** (0.017)	-0.065*** (0.017)	
	$Constant$	131.90*** (33.99)	133.50*** (35.18)	
Supply	P_t	0.28*** (0.067)		
	$P_t(1949 - 1994)$		0.41*** (0.11)	
	$P_t(1994 - 2013)$		0.40*** (0.12)	
	$Wage\ in\ forestry_t$	0.11** (0.050)	0.18** (0.082)	
	i_t	-0.022** (0.0095)	-0.019 (0.011)	
	$Penergy_t$	-0.39*** (0.13)	-0.56*** (0.18)	
	$Storm_t$	0.058*** (0.0061)	0.057*** (0.0067)	
	$D1962_t$		-0.13* (0.068)	
	$D2000_t$		0.093* (0.055)	
	Q_{t-1}	0.26*** (0.081)	0.23*** (0.091)	
	$Constant$	1.03* (0.63)	1.05 (0.13)	
	$Demand\ Residuals\ ADF^a$		-4.81**	-4.96**
	$Supply\ Residuals\ ADF^a$		-6.38***	-5.70***
Observations		64	64	
BIC		-99.4	84.8	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

^a Augmented Dickey-Fuller test for residuals stationarity (Engle and Yoo, 1987)

quantity increases by 0.4%. Investment in construction also has a positive impact on the demand, which is an expected result. For the latter variable, a 1% increase in investments comes with a 1% increase in wood consumption. Finally, similarly to Song et al. (2011), we observe a negative trend. That may mean that, thanks to technological changes, construction became more efficient in using wood or that preferences changes have diminished the attractiveness of wood with time.

On the supply side, we observe a positive but relatively small SR price-elasticity between 0.3 and 0.4, which indicates a price-inelastic supply. Again, structural breaks do not result in any significant changes in slope, which tends to show that the adoption of the Swiss law on forest did not significantly impact the supply responsiveness to prices. The price of energy wood negatively affects the supply of construction wood. This result means that suppliers may have some room to substitute the production of construction wood with energy wood if it becomes more profitable. An increase of 1% in the price of energy wood leads to a 0.4 to 0.6% decrease in construction wood production. We also observe a significant effect of the fallen wood caused by storms that increased the wood supply. A million m³ of fallen wood comes with an increase of 0.06% in the construction wood supply⁹⁰. The effect of the labor cost (*Wage in forestry*) is surprisingly positive⁹¹. This may indicate a problem of reverse causality, since wages in the logging industry may be driven by the logging crew productivity rather than exogenously given. The cost of capital has the expected negative impact. An increase of 1 percentage point in the interest rates, leads to a decrease of 0.02% of the supplied quantity.

The level break in 1962 has an interesting impact. Indeed, years following the adoption of the constitutional law on landscape and nature conservation have a lower intercept, suggesting that this policy has had a negative impact on the output. Daigneault et al. (2016) also found a significant impact of the inclusion of the Northern spotted owl in the Endangered Species list in the US in 1989, which completely stopped the production in some forests.

⁹⁰This effect is surprisingly low, given the large impacts of Lothar and Vivian on the production. Indeed, a rough look at the data indicates between 1990 and 2000, the production increased by 3.9 millions m³, while the fallen wood reached 14 millions m³. The expected impact of one m³ of fallen wood would therefore be around 0.28 for the year 2000 and we observe approximately the same expected impact in 1990 and 1967. However, this coefficients indicates an average effect on the whole period and some relatively small storms may have had no effects on the wood supply. Also, it is possible that part of the effects may be integrated in the $D2000_t$ variable.

⁹¹The inclusion of a lag gives similar results.

Contrarily, years following 2000 and the storm Lothar have a higher intercept, probably because of the higher subsidies that were allocated after the storm Lothar and the relative ease to extract fallen wood from forests.

In general, given the values of the Bayes Information Criteria (*BIC*), our preferred model is model (1), without structural breaks.

After estimating the short run relationships, we predict the residuals and test them for stationarity with an Augmented Dickey-Fuller test (ADF). For both models, residuals are found to be stationary, which confirms the cointegration relationship of the series⁹².

It is worth noting that first stage OLS regressions from the 3SLS come with a much higher F-statistic than the usual rule of thumbs of 10 for strong instruments (Staiger and Stock, 1997). Also, the Cragg-Donald F-statistic provided by the `ivreg2` command on Stata14, equation by equation, and presented in Table e.3 in the Appendix show that the maximal IV relative bias is 5% on the demand side. Moreover, the Anderson canonical correlation statistics presented in the same Table reject the hypothesis that equations are underidentified. However, results from the Sargan statistic for overidentifying restrictions show that our models may be overidentified. However, excluding exogenous variables does not affect the Sargan statistic for the demand side.

We observe a significant impact of the lagged quantity variable, which suggests that the supply side adapts over time. Its magnitude is relatively low, indicating relatively quick adjustment. Long run (LR) elasticities must therefore be computed by taking into account this adjustment. This is done by dividing the coefficients by 1 minus the coefficient of the lag variable (see Daigneault et al., 2016). Long run elasticities are presented in Table 5.4. It is worth reminding that, since we did not include the lagged DV in the demand equation, SR elasticities are equal to LR elasticities on the demand side.

Supply long run elasticities are larger than short run elasticities, which confirms Le Chatelier principle that agents have more time to adapt in the long run. However, supply elasticities remain low on the long run as well. The supply price-elasticities resulting from our estimations are in the same order of magnitude as those from recent studies presented in Table 5.1. In contrast, we find higher price-elasticities on the demand side. This result suggests that the Swiss construction wood may have several substitution possibilities on the demand side, either with other material or by importing foreign wood.

⁹²Plots of the residuals are available in Figure e.1 in the Appendix.

Table 5.4: Long run elasticities

		(1)	(2)
		LR relationships No breaks	LR relationships With breaks
Demand	P_t	-1.89*** (0.44)	
	$P_t(1949 - 1994)$		-1.85*** (0.42)
	$P_t(1994 - 2013)$		-1.83*** (0.41)
	P_{subst_t}	0.85*** (0.28)	0.86*** (0.27)
	Px_t	0.40* (0.22)	0.40* (0.23)
	$Investment_t$	1.00*** (0.20)	1.04*** (0.22)
	T_t	-0.064*** (0.017)	-0.065*** (0.017)
Supply	P_t	0.37*** (0.097)	
	$P_t(1949 - 1994)$		0.53*** (0.16)
	$P_t(1994 - 2013)$		0.53*** (0.18)
	$Wage\ in\ forestry_t$	0.14** (0.064)	0.23** (0.11)
	i_t	-0.029** (0.013)	-0.024* (0.015)
	$Penergy_t$	-0.53*** (0.17)	-0.73*** (0.21)
	$Storm_t$	0.078*** (0.012)	0.074*** (0.014)
	$D1962_t$		-0.16* (0.092)
	$D2000_t$		0.12* (0.069)

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.7 Discussion and conclusion

The commitment of the Swiss government to encourage the production of Swiss wood and its use in buildings is a step towards a more carbon neutral economy. Achieving this goal requires to mobilize more wood from Swiss forests, what the forest industry is currently unwilling to do given the lack of financial incentives. Encouragements through subsidies would be useful only if suppliers and consumers react to price changes. We analyze the effect of the price on construction wood supply and demand thanks to a rich annual time series data set on the period 1949-2013. The use of the Lagged Adjustment Model allows to derive long run and short run elasticities, while correcting for price endogeneity thanks to a simultaneous supply-demand equations system estimated with the 3 Stage Least Squares approach.

This Chapter and its results, however, have a number of limitations. First, the low number of observations and the difficulty to find reliable historical data reduces the ability to complexify the model. For this reason, we do not consider imperfect competition. The international competition is also imperfectly accounted for and domestic wood and imported wood are thus considered as very imperfect substitutes⁹⁴. Finally, given the lack of consistent data, the storage capacity on the supply, as well as on the demand side, could not be included in the model. In the same spirit, Solow residuals could have been used to account for technological changes (Solow, 1957). This would, however, imply an important data collection regarding the construction sector and is beyond the scope of this Chapter.

Our results are generally in line with the international literature but show that the demand is quite sensitive to prices changes both in the long run and in the short run. This is not very surprising, given the numerous substitutes to Swiss wood in construction. On the other hand, the supply is rather price-inelastic and its responsiveness is lower in the short run than in the long run. This could be explained by steeply increasing marginal costs or by the public ownership of forest zones, since public owners may not only be profit driven.

The structural breaks in our series correspond to changes in the legal context. Although indispensable, the tight regulation might thus break the Swiss wood provision, leading to forests' ageing. Since old forests are less able to serve as carbon sinks, adapting the Swiss forest management to face the climate change challenges might be necessary. The wood

⁹⁴This assumption is consistent with the findings of Borzykowski and Kacprzak (2017), which reveals that 55% of the Swiss population prefers Swiss wood rather than imported wood.

production should thus be financially fostered to fully integrate the positive externalities brought by rejuvenation of forests on CO₂ sequestration. Given the positive supply responsiveness to prices, a subsidy might indeed help to meet the goals of the Forest Policy 2020 and increase the production of Swiss wood to the desired level. In addition, financial incentives may increase the use of Swiss wood in construction and thus reduce the CO₂ emissions of the construction sector.

Finally, given the carbon neutrality of energy wood, the wood policy (FOEN, 2008) encourages the use of wood for energy purposes as well. The latter policy may however be counterproductive to increase the production of construction wood. Indeed, our results show that construction wood and energy wood can be substitutes on the supply side. If the demand and thus the price of energy wood increases, suppliers may switch from construction wood to energy wood, the marginal cost of the latter being lower. This would reduce the available Swiss wood quantity and thus increase the CO₂ emissions of the construction sector.

The data collection and results from this Chapter open room for new research questions. First, analyses of structural breaks' welfare effects could provide interesting information on the total economic surpluses created by the Swiss wood markets. Second, since data on energy wood had also been collected, one could analyze the energy wood market with the same kind of method. Finally, a link between the energy wood market and the roundwood market could be studied. The spatial dimension could also be studied with a panel data approach, since cantonal data on wood production are available since 2004⁹⁵. This would allow to confirm our results with less concerns about the time series nature of the data.

⁹⁵This would lead to a dataset of 26 cantons during 9 years and thus 234 observations. However, independent variables are only available at the national scale.

Conclusion

The Swiss forests provide highly valuable services to the population. While they have generally grown, both in surface and standing wood volume, some forest zones are under pressure because of climate change or demographic development. Swiss forests' ageing also diminishes their ability to provide some services such as carbon sequestration. On the other side, the forest industry stands in a financially difficult situation and needs the support of public administrations to cover their deficits. Indeed, wood harvesting is generally not a profitable activity in Switzerland because of the important harvest restrictions arising from the multifunctional management practices, among other reasons. However, because of its CO₂ neutral aspect, wood is expected to take a growing importance in energy provision. In addition, the demand for wood from the construction sector may increase in the future, since wood products can offset some CO₂ and thanks to less restrictive fire norms. Furthermore, the potential for a (reasonable) increase in forest harvest in Switzerland is acknowledged by all parties: thanks to strict regulations, more harvesting would create some positive externalities on other forest ecosystem services, in particular biodiversity and carbon sequestration. Along with the creation of unexploited forest reserves, the increased forest rejuvenation could also diversify the types of Swiss forests and thus improve their resilience to climate change and their resistance to wildfires.

This thesis shows that Swiss people, in particular city-dwellers, are willing to pay a substantial amount for the conservation of their forests (Chapter 2). This amount is largely higher than the actual costs of creating new forest reserves and restricting access to some forests is also relatively well accepted. Since forest recreational activities are found to be travel costs inelastic (Chapter 3), these restrictions should only slightly decrease the forests recreational benefits, in particular if access-restricted reserves are created in less densely populated regions. With respect to forest carbon sequestration (Chapter 4), international forest carbon offsets are not particularly frowned upon but

CONCLUSION

making salient the price differential with domestic forest carbon offset increases their acceptability.

Since the forest industry does respond to financial incentives (Chapter 5) and creates indispensable positive externalities on other FES, a better integration of these external benefits may profit both environmental and economic sustainability of Swiss forests. To improve the Swiss forest policy, I thus suggest deepening the existing federal convention-programs and designing a new framework, which, in parallel to the creation of forest reserves, should include some Payments for Ecosystem Services, directly linked with the wood harvest. This could take the form of a pigouvian subsidy per m³ of wood produced and would integrate the positive externalities and thus push the equilibrium wood quantity closer to its socially optimal level (Pigou, 1920). The amount of the financial incentives could vary depending on the region. Indeed, external benefits of the wood exploitation are probably lower in the Swiss Central Plain than in mountainous areas. Demographic development puts the Central Plain's forests under pressure and the higher accessibility already imply lower marginal costs. Therefore, the subsidy should be close to zero in this region and the priority should go to the creation of new forests reserves instead. The incentive should also give priority to construction wood rather than energy wood. From an environmental point of view, the use of wood as energy provider makes sense at the end of its life cycle only. The subsidies should therefore rather foster the "cascade" use of wood (Steubing et al., 2015). Since benefits of cantonal forests spill over other Cantons (Chapter 1), they should preferably be entirely financed by the Confederation rather than by Cantons.

However, there are political resistances to subsidies in general and for the wood production in particular. A debate on how to promote the production of Swiss wood has already been held at the Swiss Parliament during the revision of the Law on Forest in 2015⁹⁶ and subsidies have been rejected.

Despite these resistances, this thesis shows that both economic and environmental sustainability are two tied birds and killing one at the expense of the other is senseless. Two birds, one stone: a direct subsidy to the wood production could give the right incentives to forest owners and improve the economic and environmental sustainability of Swiss forests

⁹⁶See <https://www.parlament.ch/fr/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20140046>
Accessed: 12.01.2018

Limitations

These recommendations should be considered with caution, since results from this thesis suffer from several limits. First, the national scale of this study does not take into account the regional heterogeneity. There might be differences linked with the topography and hence the costs of harvesting, the population density, the proximity to the borders and hence the international competition. Central plain forests indeed do not face the same issues as Alpine forests and so do the forests owners.

The low level of production might also be due to structural inefficiencies, leading to high marginal costs. Mack (2015) indeed finds an important degree of technical inefficiency in the production of wood and Mack and Schoenenberger (2008) suggest that subsidies even decrease the efficiency. However, the subsidies under scrutiny in this study are not linked to the quantity produced but rather to the (stated) costs of other direct services provided by the forest industry, while the efficiency is measured in terms of the quantity produced. A direct subsidy by m³ of wood is more likely to give the right incentives than existing subsidies. However, structural inefficiencies should also be tackled, in particular by better exploiting potential scale economies and reducing potential monopsonistic power within the wood processing sector.

The development of new wooden products, by stimulating the demand for wood, might also help foster the production (Rey and Thalmann, 2017). Prices could rise and hence increase the incentives to produce more.

Potential for future research

This thesis and the rich data sets created leave room for future research. The survey used in Chapter 2 and 3 elicited both travel cost estimates and contingent valuation estimates for the same individuals. While the former correspond to use values and the latter to non-use values, there certainly exists a link between them, which deserves to be analyzed, as shown by the recent work of Jeon and Herriges (2017).

The time series collected and used in Chapter 5 also deserve more attention: welfare effects could provide interesting information on the total economic surpluses created by the Swiss wood markets and the energy wood markets could also be studied. In addition, a link between the energy wood market and the roundwood market could be analyzed.

CONCLUSION

Finally, an extensive analysis of the relationships between forest ecosystem services and their values would be of great interest. A better understanding of these conflicts and synergies would indeed improve the credibility of the total economic value framework and the comprehensibility of ecosystem services assessment.

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Appendix

A Chapter 1

Descriptive statistics

Table a.1: Summary statistics of covariates for Swiss (CH) and Geneva (GE) sub-samples

	Variable	Mean	Std. Dev.	Min.	Max.	N
CH	<i>Age</i>	39.070	14.448	18	81	228
	<i>Green member</i>	0.158	0.365	0	1	228
	<i>Members in household</i>	2.996	1.349	1	6	227
	<i>Urban</i>	0.732	0.444	0	1	228
	<i>Visit frequency</i>	2.412	1.492	0	4	228
	<i>Distance</i>	6.722	17.201	0	150	228
	<i>Forest concerned</i>	1.232	1.166	0	3	228
	<i>Swiss wood</i>	0.118	0.324	0	1	228
	<i>(Income)^a</i>	76'108	40'599	17'500	180'000	88
GE	<i>Age</i>	42.089	13.231	19	81	191
	<i>Green member</i>	0.164	0.371	0	1	189
	<i>Members in household</i>	2.555	1.208	1	6	191
	<i>Urban</i>	0.801	0.400	0	1	191
	<i>Visit frequency</i>	2.251	1.629	0	4	191
	<i>Distance</i>	7.191	14.028	0	110	191
	<i>Forest concerned</i>	1.419	1.193	0	3	191
	<i>Swiss wood</i>	0.0524	0.223	0	1	191
	<i>(Income)^a</i>	76'250	34'326	17'500	140'000	74

^a We provide the descriptive statistics of the income variable but do not include it in the final model.

Age represents the age of the respondent. We included this variable because it is statistically different across sub-samples. Also, as this variable is usually correlated with income, it may affect WTP. *Green member* is a binary variable taking the value

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1 if the individual is member of or donates to an environment friendly association. The proportion of members is similar in both sub-sample. We expect this variable to be positively correlated with WTP. *Members in household* is the number of persons that composes the household. Households in the CH sub-sample are composed of a significantly higher number of individuals, which is why we included this variable in the model. *Urban* is a binary variable taking the value 1 if the individual lives in an urban area within the Canton of Geneva; *Visit frequency* is a categorical variable representing the annual frequency of visits in a forest; *Distance* is the distance in kilometers from respondent's home to the most visited forest; *Forest concerned* is an index representing the perception of the state of Swiss forests⁹⁷. We added these variables because of their potential effect on WTP for our program. Finally, *Swiss wood* is a dummy indicating whether the respondent favors more expensive Swiss wood rather than cheaper imported wood. This variable is significantly higher in the Swiss forest sub-sample. *Income* corresponds to the middle point of the income class proposed.

Estimations

Ceteris paribus, respondents accept more often the bid if they are older, member of environment friendly associations and concerned about the state of Swiss forests. The number of household's member is negatively correlated with the bid acceptance for the Swiss program and positively for the Geneva program. Since larger households usually recreate more often in forests and do it in the closest forest, they may put a higher value on the closer Geneva forests and consider their income constraints when asked for Swiss forests. This point is also reflected in the coefficients associated with the *Visit frequency* variable. Indeed a frequent forest visitor is more likely to accept the bid for the Geneva program but less likely for the Swiss program, which tend to highlight that the higher the usage, the higher the value attributed to Geneva protected forests. Preferences for Swiss wood rather than imported wood is positively correlated with the bid acceptance for the Swiss program: an unsurprising result since domestic wood is considered as environmentally more friendly than imported wood (only 30% of respondents think that the exploitation of wood may threaten biodiversity).

⁹⁷This index is created from answers to the following questions: "According to you, in the last 20 years, the general health of Swiss forests has: a) improved, b) stayed the same, c) degraded", "According to you, in the last 20 years, the surface of forests in Switzerland has: a) increased, b) stayed the same, c) decreased", "According to you, in the last 20 years, biodiversity in Swiss forests has: a) improved, b) stayed the same, c) degraded". This index ranges from 0 to 3, the higher the index, the more concerned the respondent is about the state of Swiss forests.

Table a.2: Results from the plain parametric estimations

	Logistic			Log-normal			Log-logistic			
	CH	GE	GE	CH	GE	GE	CH	GE	GE	
<i>Bid</i>	-0.00311*** (0.000749)	-0.00717** (0.00314)	-0.00364*** (0.000832)	-0.00801** (0.00328)						
<i>ln(Bid)</i>					-0.427*** (0.0754)	-0.673*** (0.115)	-0.460*** (0.0828)	-0.723*** (0.135)	-0.721*** (0.140)	-0.777*** (0.159)
<i>Age</i>			0.0186 (0.0166)	0.0273* (0.0155)		0.00793 (0.00843)	0.0149 (0.0105)	0.0149 (0.0105)	0.0152 (0.0149)	0.0286 (0.0189)
<i>Green member</i>			0.902* (0.514)	0.242 (0.527)		0.363 (0.296)	0.238 (0.330)	0.238 (0.330)	0.571 (0.496)	0.318 (0.575)
<i>Members in household</i>			-0.243 (0.153)	0.280 (0.174)		-0.191** (0.0844)	0.211** (0.107)	0.211** (0.107)	-0.307** (0.149)	0.369** (0.187)
<i>Urban</i>			-1.259*** (0.407)	0.177 (0.526)		-0.562** (0.241)	0.148 (0.329)	0.148 (0.329)	-0.936** (0.410)	0.367 (0.605)
<i>Distance</i>			0.0155 (0.00953)	-0.00619 (0.0126)		0.00971 (0.00662)	-0.00276 (0.00771)	0.00971 (0.00771)	0.0161 (0.0105)	-0.00456 (0.0126)
<i>Visit frequency</i>			-0.0954 (0.132)	0.238* (0.125)		-0.0708 (0.0788)	0.141* (0.0785)	0.141* (0.0785)	-0.112 (0.140)	0.229* (0.138)
<i>Forest concerned</i>			0.119 (0.176)	0.0405 (0.177)		0.106 (0.100)	0.0246 (0.102)	0.0246 (0.102)	0.177 (0.175)	0.0815 (0.182)
<i>Swiss wood</i>			1.405** (0.652)	-0.182 (1.254)		0.708** (0.352)	-0.404 (0.561)	-0.404 (0.561)	1.284** (0.604)	-0.633 (1.020)
Constant	0.859*** (0.223)	1.313*** (0.364)	1.656* (0.977)	-1.126 (0.920)	2.084*** (0.396)	3.169*** (0.546)	2.787*** (0.622)	1.742*** (0.663)	3.541*** (0.738)	4.598*** (1.107)
<i>N</i>	183	152	183	150	183	152	183	150	183	150
Pseudo- <i>R</i> ²	0.142	0.204	0.271	0.247	0.165	0.283	0.277	0.331	0.167	0.274
<i>AIC</i>	221.6	170.1	204.9	175.4	215.8	153.6	203.4	158.0	215.3	152.6

Heteroskedasticity-robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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Table a.3: Results from the spike model

	CH	GE	CH	GE
<i>ln(Bid)</i>	-0.743*** (0.120)	-1.124*** (0.223)	-0.875*** (0.145)	-1.850*** (0.358)
<i>Age</i>			0.00812 (0.0119)	0.0348* (0.0179)
<i>Green member</i>			0.172 (0.385)	-1.220*** (0.468)
<i>Members in household</i>			-0.167 (0.112)	-0.00859 (0.166)
<i>Urban</i>			-0.657** (0.306)	0.0647 (0.519)
<i>Distance</i>			0.0441 (0.0340)	-0.0140 (0.0186)
<i>Visit frequency</i>			-0.219* (0.123)	0.232* (0.129)
<i>Forest concerned</i>			-0.0000585 (0.135)	-0.564** (0.258)
<i>Swiss wood</i>			0.482 (0.480)	0.878 (1.056)
Constant	4.324*** (0.654)	5.946*** (1.091)	5.958*** (0.980)	9.060*** (2.190)
<i>N</i>	134	122	134	120
Pseudo- <i>R</i> ²	0.317	0.484	0.410	0.613
<i>AIC</i>	119.9	81.28	120.1	77.31

Heteroskedasticity-robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table a.4: Data used in the non-parametric model

		10	60	100	250	500	1000	Total
CH	Yes	26	22	18	12	6	6	90
	% of Yes	0.79	0.81	0.56	0.41	0.18	0.21	
	PAVA % of Yes		0.80	0.56	0.41		0.19	
	No	7	5	14	17	27	23	93
	N	33	27	32	29	33	29	183
GE	Yes	34	25	19	3	3	1	85
	% of Yes	0.92	0.76	0.58	0.11	0.30	0.09	
	PAVA % of Yes	0.92	0.76	0.58		0.16	0.09	
	No	3	8	14	25	7	10	67
	N	37	33	33	28	10	11	152

This data can be derived from Table 1.1 when excluding protesters

B Chapter 2

Table b.1: Explanatory variables

Variable	Description
<i>R35</i>	Gross annual income class of the household: 0-35'000 CHF
<i>R35_50</i>	Gross annual income class of the household: 35'000-50'000
<i>R50_80</i>	Gross annual income class of the household: 50'000-80'000
<i>R80_120</i>	Gross annual income class of the household: 80'000-120'000
<i>R120_160</i>	Gross annual income class of the household: 120'000-160'000
<i>R160_200</i>	Gross annual income class of the household: 160'000-200'000
<i>R200</i>	Gross annual income class of the household: 200'000 and +
<i>FR</i>	French speaker
<i>IT</i>	Italian speaker
<i>Jura</i>	Lives in the Jura region
<i>Rural</i>	Lives in a rural area or small and isolated town
<i>Often</i>	Goes “often” in forest (as opposed to “sometimes” or “never”)
<i>Member</i>	Member of an environmental friendly association
<i>Swiss Wood</i>	Prefers Swiss wood over cheaper imported wood
<i>Reserve</i>	Agrees to create forest reserves
<i>Number of children</i>	Number of children in the household

Table b.2: Determinants of protest answers

	Selection probit
<i>R35</i>	0.247 (0.188)
<i>R35_50</i>	0.102 (0.150)
<i>R50_80</i>	0.113 (0.131)
<i>R120_160</i>	-0.00669 (0.175)
<i>R160_200</i>	0.689 (0.240)
<i>R200</i>	-0.0474 (0.247)
<i>FR</i>	0.199* (0.111)
<i>IT</i>	0.215 (0.135)
<i>Jura</i>	-0.0840 (0.329)
<i>Rural</i>	0.00147 (0.109)
<i>Age</i>	0.0103*** (0.00376)
<i>Female</i>	-0.260** (0.101)
<i>Often</i>	0.200* (0.101)
<i>Member</i>	-0.135 (0.103)
<i>Swiss Wood</i>	0.148 (0.988)
<i>Reserve</i>	-0.363*** (0.0986)
<i>Number of Children</i>	0.104** (0.509)
<i>Constant</i>	-1.511*** (0.250)
Observations	987
Pseudo- R^2	0.0526

Heteroskedasticity-robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Questionnaire

- La durée de l'enquête est d'environ 15 minutes.
- La confidentialité et l'anonymat des données sont absolument garantis
- Cette enquête récolte des informations sur la perception des forêts suisses par ses habitants. Elle a pour but de constituer une base, utile pour faciliter la prise de décision en matière de gestion forestière et de politique environnementale.

Question filtre: Avez-vous plus de 18 ans et habitez-vous en Suisse?

- Oui Non (fin de l'entretien)

LA NOTION DE FORÊT MENTIONNÉE DANS LES QUESTIONS SUIVANTES
COMPREND TOUTES LES SURFACES COUVERTES D'ARBRES OU
D'ARBUSTES EN SUISSE D'UNE SUPERFICIE AU MOINS ÉQUIVALENTE À
CELLE D'UN TERRAIN DE FOOTBALL.

1. Selon vous, au cours de ces 20 dernières années, la surface forestière suisse: (une seule réponse possible)

- a augmenté est restée identique a diminué

2. Par rapport à vos expériences personnelles, vos souvenirs vis-à-vis de la forêt sont: (une seule réponse possible)

- Négatifs Mitigés Positifs

3. À quelle fréquence vous rendez-vous généralement en forêt ? (une seule réponse possible)

- Souvent Parfois Jamais (Rendez-vous directement à la question 7)

4. En forêt, pratiquez-vous les activités suivantes?

- | | | |
|--|------------------------------|------------------------------|
| Flâner (promenade, détente, respirer l'air frais, pique-niquer) | <input type="checkbox"/> Oui | <input type="checkbox"/> Non |
| Pratiquer du sport (randonnée, jogging, VTT, équitation, accrobranche) | <input type="checkbox"/> Oui | <input type="checkbox"/> Non |
| Observer la nature (la faune, la flore) | <input type="checkbox"/> Oui | <input type="checkbox"/> Non |
| Chasser, cueillir des champignons ou des fruits, collecter du bois | <input type="checkbox"/> Oui | <input type="checkbox"/> Non |
| Votre activité professionnelle est en forêt | <input type="checkbox"/> Oui | <input type="checkbox"/> Non |

4.a. Parmi les activités que vous avez sélectionnées, quelle est l'activité que vous pratiquez le plus souvent ? (une seule réponse possible)

- Flâner (promenade, détente, respirer l'air frais, pique-niquer)
- Pratiquer du sport (randonnée, jogging, VTT, équitation, accrobranche)
- Observer la nature (la faune, la flore)
- Chasser, cueillir des champignons ou des fruits, collecter du bois
- Votre activité professionnelle est en forêt .

5. D'une manière générale, dans quelle mesure êtes-vous satisfait de vos visites en forêt ?

- Satisfait
- Indifférent
- Insatisfait

6. Dans les 12 derniers mois, dans quel type de forêts vous êtes-vous rendu en Suisse? (plusieurs réponses possibles; vous pouvez vous référer à la carte envoyée dans la lettre que vous avez reçu à la maison)

- Forêt urbaine (située à l'intérieur d'une ville/village)
- Forêt du Jura (sans les forêts urbaines)
- Forêt de plaine ou du Plateau (sans les forêts urbaines)
- Forêt des Alpes, Préalpes ou Sud des Alpes (sans les forêts urbaines)

(En fonction des réponses, poursuivre avec les questions suivantes pour chaque type de forêts indiqué et compléter le tableau)

- Pour une forêt (soit urbaine, de plaine, du Jura, des Alpes) : combien de fois vous y êtes-vous rendu dans les 12 derniers mois ? (approx.)
- Quelle distance parcourez-vous généralement depuis votre lieu de départ pour vous rendre dans ce type de forêt ? (kilomètres) [*Attention: il s'agit bien du lieu de départ pour visiter la forêt, pas nécessairement le lieu de domicile. Exemple : si je vais à Zermatt en vacances et que, entre autres, je me promène dans une forêt, je dois indiquer les kilomètres parcourus depuis Zermatt jusqu'à l'entrée de cette forêt*]
- Quel moyen de transport utilisez-vous généralement pour effectuer l'essentiel du trajet ? (3 propositions, une seule réponse possible) [*même remarque indiquez le moyen de transport entre le lieu de départ et la forêt*]
- Combien de temps mettez-vous généralement pour vous y rendre ? (minutes) [*même remarque: depuis le lieu de départ et la forêt*]

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- Combien de temps passez-vous en moyenne dans cette forêt ? (minutes)
- A quel moment visitez-vous généralement cette forêt ? (3 propositions, plusieurs réponses possibles)

Type de forêt	Nombre de visites dans les 12 derniers mois	Distance depuis le lieu de départ et jusqu'à l'entrée de la forêt	Moyen de transport utilisé pour l'essentiel du trajet (une seule réponse possible)	Temps de parcours depuis le lieu de départ et jusqu'à l'entrée de la forêt	Durée moyenne de la sortie en forêt	Moment habituel de la sortie en forêt (plusieurs réponses possibles)	Nombre de personnes vous accompagnant généralement
Forêt urbaine	-- fois	-- km	<input type="checkbox"/> A pied, à vélo <input type="checkbox"/> En voiture, moto, scooter <input type="checkbox"/> En transports publics	-- min	-- min	<input type="checkbox"/> la semaine <input type="checkbox"/> le week-end <input type="checkbox"/> en vacances	-- pers
Forêt de plaine	-- fois	-- km	<input type="checkbox"/> A pied, à vélo <input type="checkbox"/> En voiture, moto, scooter <input type="checkbox"/> En transports publics	-- min	-- min	<input type="checkbox"/> la semaine <input type="checkbox"/> le week-end <input type="checkbox"/> en vacances	-- pers
Forêt du Jura	-- fois	-- km	<input type="checkbox"/> A pied, à vélo <input type="checkbox"/> En voiture, moto, scooter <input type="checkbox"/> En transports publics	-- min	-- min	<input type="checkbox"/> la semaine <input type="checkbox"/> le week-end <input type="checkbox"/> en vacances	-- pers
Forêt des Alpes, Préalpes et Sud des Alpes	--- fois	-- km	<input type="checkbox"/> A pied, à vélo <input type="checkbox"/> En voiture, moto, scooter <input type="checkbox"/> En transports publics	-- min	-- min	<input type="checkbox"/> la semaine <input type="checkbox"/> le week-end <input type="checkbox"/> en vacances	-- pers

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7. Lorsque vous achetez des produits en bois, achetez-vous en priorité des produits réalisés à partir de bois suisse?

- Oui Non Je ne sais pas
 Je n'achète pas de produits en bois (Passer à la question 9)

8. Achetez-vous en priorité des produits en bois labélisés (par exemple FSC, PEFC, COBS)?

- Oui Non Je ne sais pas

9. Êtes-vous d'accord avec les affirmations suivantes ?

Affirmations	D'accord	Pas d'accord	Sans avis
La forêt suisse fait partie de l'identité et du patrimoine du pays.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Le bois des forêts suisses n'est pas assez exploité.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
L'exploitation du bois joue un rôle important dans l'économie suisse.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
L'exploitation du bois contribue à l'entretien des forêts.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
L'exploitation forestière gâche le paysage et gêne l'accès aux forêts.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
L'exploitation du bois en Suisse menace la biodiversité.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Il y a trop d'activités de détente et de loisirs dans les forêts suisses.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Certaines zones forestières, abritant des animaux sauvages, devraient être interdites d'accès à la population.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
L'État devrait autoriser plus souvent le dézonage de forêts pour y construire des logements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

10. Parmi les deux alternatives proposées, laquelle privilégiez-vous ? Vous pouvez être indifférent.

(Lisez la question de la manière suivante : « A : Augmentation de l'exploitation du bois suisse contre B : Protection accrue de la faune et la flore forestière »)

- A : Augmentation de l'exploitation du bois suisse
 B : Protection accrue de la faune et la flore forestière
 Indifférent / ne se prononce pas
- A : Création de lieux d'activités récréatives en forêt
 B : Création de réserves forestières pour protéger la faune et la flore
 Indifférent / ne se prononce pas
- A : Augmentation de l'exploitation du bois suisse
 B : Création de lieux d'activités récréatives en forêt

Indifférent / ne se prononce pas

11. Un tiers du territoire suisse est couvert de forêts dont 5% sont protégées. Celles-ci abritent un écosystème riche et varié, permettent d'atténuer les effets du changement climatique et protègent contre certains dangers naturels (avalanches, glissements de terrain, érosion...). Afin de préserver et développer de manière durable la forêt suisse et la diversité de ses fonctions, la Confédération envisage de doubler la surface des réserves forestières protégées d'ici à 2030. La protection de nouvelles surfaces a pour avantages :

- Une meilleure protection de la biodiversité
- Une réduction du nombre de catastrophes naturelles (avalanches, glissements de terrain)
- Une plus forte atténuation des changements climatiques

Mais ce programme engendrerait également des inconvénients:

- Une augmentation des coûts logistiques pour la mise en place du programme
- La baisse de revenus des exploitations forestières
- La mise en place de limitations d'accès aux zones forestières

On envisage de financer la hausse des dépenses par un impôt spécifique consacré au financement du programme. La Confédération a besoin de connaître l'avis de la population sur ce sujet afin d'orienter sa politique environnementale et évaluer la manière dont cette mesure pourrait être instaurée.

Vous pourriez être amené à contribuer concrètement à ce programme. De ce fait, il est important que votre réponse reflète bien votre disposition à contribuer à la création de nouvelles réserves forestières. Ainsi, avant de répondre, soyez attentif au fait que votre revenu est limité et que vous pourriez être sollicité pour contribuer à d'autres causes, mais que la réussite du programme dépend principalement de son financement.

Par conséquent, est-ce que votre ménage serait prêt à payer un montant de [Random in Sample] 12.- / 30.- / 60.- / 120.- / 240.- / 480.- / 780.- / 1000.- CHF par an (soit 1.- / 2.50 / 5.- / 10.- / 20.- / 40.- / 65.- / 83.- CHF par mois) pour soutenir la création de nouvelles réserves forestières en Suisse?

Oui Non

Dans ce cas, combien votre ménage serait-il prêt à payer au maximum par an pour soutenir le programme? _____ CHF/an

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(Si montant > 0, allez à la question 11.b. ; si montant = 0 ou refus de répondre, allez à la question 11a. puis 12

11.a. Pour quelle raison n'êtes-vous pas disposé à contribuer au programme? (une seule réponse possible)

(Laisser le sondé répondre et ensuite classer la réponse, en lui demandant de bien confirmer. Une seule réponse possible)

- Financièrement, je ne peux pas me le permettre, mais si je pouvais je le ferais.
- Il existe d'autres problèmes plus urgents à régler. Les problématiques liées aux forêts ne sont pas une priorité.
- Je ne me sens pas concerné par les problématiques liées à la forêt
- La forêt, pour moi, n'a aucune valeur
- Je souhaiterais avoir plus d'informations à ce sujet.
- Il s'agit d'un bien appartenant à la collectivité, ce n'est pas raisonnable de me demander de payer pour cela.
- J'estime que ce n'est pas à moi de payer pour protéger la forêt, mais à la collectivité publique, aux propriétaires de forêt et/ou aux utilisateurs des forêts.
- Je paie déjà assez d'impôts.
- Je ne fais pas confiance à l'État. Rien ne me garantit que l'argent sera bien employé pour financer le programme.

11.b. Cette somme sera partagée entre les quatre éléments suivants:

- 1) La compensation de la baisse de revenus des exploitants forestiers
- 2) La protection de la biodiversité (faune, flore) en forêt
- 3) La création de nouveaux lieux d'activités récréatives pour compenser les limitations d'accès
- 4) L'amélioration de la capacité des forêts à protéger contre les dangers naturels

Quel pourcentage de la somme indiquée au préalable attribueriez-vous à chacun des quatre éléments, que je vous répète ?

- La compensation de la baisse de revenus des exploitants forestiers _____%
- La protection de la biodiversité (faune, flore) en forêt _____%

- La création de nouveaux lieux d'activités récréatives pour compenser les limitations d'accès _____%
- L'amélioration de la capacité des forêts à protéger contre les dangers naturels _____%

11.c. Voulez-vous modifier le montant maximum indiqué à la question précédente?

Oui _____CHF/an Non

Informations générales

12. Vous êtes : une femme un homme

13. Quelle est votre année de naissance ? _____

14. Code postal : _____

15. De combien de personnes se compose votre ménage (vous compris)?

Nombre d'adultes (plus de 18 ans) : _____ Nombre d'enfants (moins de 18 ans) : _____

16. Etes-vous membre et/ou versez-vous régulièrement des dons à une ou plusieurs organisations environnementales ?

Oui Non

17. Par votre travail ou vos activités associatives, êtes-vous en lien direct avec les intérêts du milieu forestier ?

Oui Non

18. En plus de votre résidence principale, disposez-vous d'une résidence secondaire ou d'une location à la saison ou à l'année en Suisse ?

Oui Non

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19. Quel est votre profil professionnel actuel ? (une seule réponse possible; indiquez l'activité principale)

- | | |
|---|---|
| <input type="checkbox"/> Femme – Homme au foyer | <input type="checkbox"/> Cadre supérieur(e) |
| <input type="checkbox"/> Étudiant(e) | <input type="checkbox"/> Indépendant(e) |
| <input type="checkbox"/> Employé(e) | <input type="checkbox"/> Retraité(e) |
| <input type="checkbox"/> Cadre | <input type="checkbox"/> Sans emploi |

20. Quel niveau d'étude avez-vous atteint ? Si vous êtes en train d'étudier, mentionnez le niveau qui correspond aux études que vous avez achevées.

- École obligatoire
- Apprentissage
- École post-obligatoire (École de commerce, maturité ...)
- Formation professionnelle supérieure
- Université, École polytechnique, HES

21. Quel est le revenu brut annuel de votre ménage ?

- | | |
|--|---|
| <input type="checkbox"/> Moins de CHF 35'000.- | <input type="checkbox"/> Entre CHF 120'000.- et 160'000.- |
| <input type="checkbox"/> Entre CHF 35'000.- et CHF 50'000.- | <input type="checkbox"/> Entre CHF 160'000.- et 200'000.- |
| <input type="checkbox"/> Entre CHF 50'000.- et CHF 80'000.- | <input type="checkbox"/> Plus de 200'000.- |
| <input type="checkbox"/> Entre CHF 80'000.- et CHF 120'000.- | <input type="checkbox"/> Pas de réponse |

Table b.3: Indicators of representativity

		Survey	Switzerland
Females		51% ^c	51% ^a
Age		18%	27% ^b
		42%	38% ^b
		40%	35% ^b
Cantons	ZH	12%	18% ^a
	BE	10%	12% ^a
	VD	11%	9% ^a
	AG	7%	8% ^a
	SG	5%	6% ^a
	GE	6%	6% ^a
	LU	3%	5% ^a
	TI	16%	4% ^a
	VS	4%	4% ^a
	FR	4%	4% ^a
	Others	22%	24% ^a
Annual gross income	mean ^d	83'349	120'624 ^a
Education level		8%	12% ^c
		35%	39% ^c
		12%	9% ^c
		21%	14% ^c
		25%	26% ^c
Member		37%	23% ^e

^aOFS 2013^bOFS 2009^cOFS 2014^dMean calculated with the central point in each class^eWorld Value Survey 2007

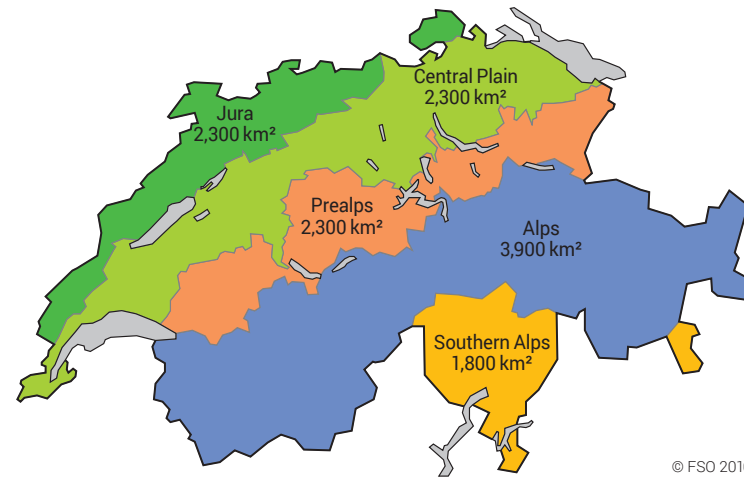


Figure c.1: Map of the Swiss forest zones. Source: FSO (2016b) (Central Plain and Midland are used interchangeably within the Chapter)

Table c.1: Description of forest zones. (Source: FOEN, 2014b and FSO, 2015b)

Forest zone	Total <i>km</i> ²	Forest <i>km</i> ²	Forest %	Pop. 1000 <i>hab</i>	Forest/cap <i>a/hab</i>	Private %	Conifers %	Forest dens. <i>m</i> ³ / <i>ha</i>	Prod. intens. <i>m</i> ³ / <i>ha</i>
Switzerland	41'285	12'582	30	7'204	18	29	67	350	3.8
Jura	4'766	2'341	49	1'023	23	22	53	378	4.7
	(11.5)	(18.6)		(14.2)					
Midland	9'836	2'262	23	4'304	5	45	51	386	7.5
	(23.8)	(18.0)		(59.7)					
Alps, Prealps and Southern Alps (Alps)	26'684	7'979	30	1'880	42	27	75	332	2.5
	(64.6)	(63.4)		(26.1)					

Percentage of total in parentheses

Pooled model

Table c.2: Descriptive statistics for the second step (pooled)

Variable	Mean	Std. Dev.	Min.	Max.	N
<i>NV</i>	45.32	70.58	1	400	1'073
<i>TC_{Urban}</i>	1.06	4.73	0	78.11	1'073
<i>TC_{Midland}</i>	2.89	10.96	0	150.21	1'073
<i>TC_{Jura}</i>	3.01	12.31	0	127.58	1'073
<i>TC_{Alps}</i>	9.94	31.44	0	352.57	1'073
<i>Relaxes</i>	0.93	0.25	0	1	1'073
<i>Does sport</i>	0.60	0.49	0	1	1'073
<i>Observes nature</i>	0.71	0.453	0	1	1'073
<i>Collects resource</i>	0.38	0.49	0	1	1'073
<i>Age</i>	50.31	14.5	18	93	1'073
<i>Economic interest</i>	0.25	0.43	0	1	1'073
<i>Bad memories</i>	0.028	0.17	0	1	1'073

The pooled model differs from the separated models by the inclusion of the dummy variables *Urban*, *Midland* and *Jura*, to indicate the specific forest zone and by the absence of the *Residence* variable. We select the following specification for the pooled model:

$$\begin{aligned} \ln(\lambda_i) = E[NV_i] = & a + \beta_{TC_{Urban}} TC \times Urban_i + \\ & \beta_{TC_{Midland}} TC \times Midland_i + \beta_{TC_{Jura}} TC \times Jura_i + \\ & \beta_{TC_{Alps}} TC \times Alps_i + \beta_{X_2} X_{2i} + u_i \end{aligned} \quad (5.5)$$

With a a constant; $TC \times s$ the interaction variables with each forest zone s and β_{TC_s} the associated coefficients; X_{2i} the explanatory variables for the second step, β_{X_2} the associated coefficients and u an error term.

We handle the data as a panel, since we have 4 observations per individual (one observation per forest zone). After dropping non-complete observations, the pooled data contains 829 individuals, who visit 1.3 forest zones in average. We therefore analyze the results from 1073 observations that passed the hurdle. We run the usual Hausman test to decide between fixed or random effects and do not reject random effects (p-value = 0.13). To test for random effects, we then apply the Breusch-Pagan LM test and do not

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reject the null hypothesis of no random effects. A simple pooled model (i.e. without random, nor fixed effects), presented in Table c.3, is therefore the most appropriate.

Table c.3: Results of the HZTNB estimation for the pooled model

<i>Visits_s</i> (Participation)	Coef.	(Std. Err.)
<i>Urban</i>	-0.76***	(0.063)
<i>Midland</i>	-0.18***	(0.059)
<i>Jura</i>	-0.81***	(0.064)
<i>French</i>	0.0646	(0.051)
<i>Italian</i>	-0.18***	(0.067)
<i>Children</i>	0.10*	(0.052)
<i>Member</i>	0.12**	(0.047)
<i>Age</i>	0.0070	(0.0081)
<i>Age²</i>	-0.000068	(0.000080)
<i>Secondary Residence</i>	-0.0021	(0.067)
<i>Well informed</i>	0.10**	(0.048)
<i>Constant</i>	-0.45**	(0.20)
<i>NV_s</i> (Frequency)		
<i>TC_{Urban}</i>	0.0011	(0.014)
<i>TC_{Midland}</i>	-0.0099**	(0.0046)
<i>TC_{Jura}</i>	-0.041***	(0.0038)
<i>TC_{Alps}</i>	-0.015***	(0.0018)
<i>Relaxes</i>	0.11	(0.19)
<i>Does sport</i>	0.39***	(0.10)
<i>Observes nature</i>	0.19*	(0.11)
<i>Collects resource</i>	0.16*	(0.093)
<i>Age</i>	0.0094***	(0.0034)
<i>Economic Interest</i>	0.27***	(0.10)
<i>Bad Memories</i>	0.18	(0.31)
<i>Constant</i>	2.77***	(0.28)
Observations (total)	3800	
Non-zero observations	1073 ^a	
<i>ln(α)</i>	0.55***	
Vuong stat. for ZTNB over ZINB	-6.79***	
Accuracy	53%	

^a 829 individuals, 1.3 observations per individual on average

Heteroskedasticity-robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table c.4: Travel costs elasticities from the pooled model

	Urban	Midland	Jura	Alps
ε_s^{TC}	0.0012 (0.02)	-0.03** (0.01)	-0.12*** (0.01)	-0.14*** (0.02)
Mean TC_s	6.5	9.0	19.8	27.1
Observations	1073			

Standard errors calculated with the Delta method in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table c.5: Individual Consumer Surpluses from the pooled model

	Urban	Midland	Jura	Alps
CS per visit	n.a.	101.3** [8;194]	24.6*** [20;29]	69.01*** [52;86]
Observations	1073			

95% confidence intervals calculated with the Delta method in brackets

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

NB: Since the travel cost elasticity is positive for urban forests, we do not provide the consumer surplus for urban forest.

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Table c.6: Results of the ZINB estimation

	Urban	Midland	Jura	Alps
<i>Visits_s</i> (Participation)				
<i>Residence_s</i>	-0.69*** (0.13)	-0.59*** (0.099)	-1.26*** (0.12)	-1.33*** (0.15)
<i>French</i>	0.10 (0.12)	0.35*** (0.10)	-0.67*** (0.12)	-0.21* (0.12)
<i>Italian</i>	0.23* (0.15)	0.78*** (0.15)	0.58* (0.30)	0.15 (0.18)
<i>Children</i>	-0.19* (0.12)	-0.22** (0.11)	-0.43*** (0.14)	0.22* (0.11)
<i>Member</i>	-0.21** (0.10)	0.019 (0.095)	-0.38*** (0.12)	-0.15 (0.10)
<i>Age</i>	0.031* (0.017)	-0.011 (0.016)	-0.017 (0.021)	-0.060*** (0.018)
<i>Age²</i>	-0.00028 (0.00017)	0.00014 (0.00015)	0.000051 (0.00020)	0.00066*** (0.00018)
<i>Secondary Residence</i>	0.14 (0.15)	0.18 (0.14)	0.15 (0.18)	-0.60*** (0.16)
<i>Well informed</i>	0.042 (0.11)	0.053 (0.096)	-0.19 (0.12)	-0.46*** (0.11)
<i>Constant</i>	0.71* (0.42)	0.68* (0.39)	2.87*** (0.56)	2.04*** (0.44)
<i>NV_s</i> (Frequency)				
<i>TC</i>	-0.0021 (0.0099)	-0.0070** (0.0034)	-0.033*** (0.0038)	-0.011*** (0.0013)
<i>Relaxes</i>	0.77* (0.42)	0.31 (0.27)	-0.45 (0.39)	0.63** (0.27)
<i>Does sport</i>	0.53** (0.24)	0.51*** (0.14)	0.29 (0.23)	0.41*** (0.14)
<i>Observes nature</i>	0.089 (0.26)	0.031 (0.16)	0.27 (0.26)	0.49*** (0.16)
<i>Collects resource</i>	-0.16 (0.23)	0.28* (0.15)	0.13 (0.22)	0.27** (0.14)
<i>Age</i>	0.021** (0.0086)	0.014*** (0.0047)	0.0026 (0.0076)	0.00015 (0.0052)
<i>Economic Interest</i>	0.076 (0.27)	0.15 (0.17)	0.47** (0.24)	0.41*** (0.15)
<i>Bad Memories</i>	-1.78** (0.75)	0.34 (0.47)	0.28 (0.46)	0.23 (0.40)
<i>Constant</i>	1.77*** (0.65)	2.36*** (0.35)	3.62*** (0.60)	2.35*** (0.40)
<i>ln(α)</i>	0.62*** (0.16)	0.40*** (0.10)	0.41*** (0.16)	0.54*** (0.10)
Vuong stat. for ZINB over NB	2.44***	8.38***	8.17***	8.57***
<i>N</i>	1038	1010	1034	973

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

D Chapter 4

Table d.1: Descriptive statistics (1st stage)

Variable	Mean	Std. Dev.	Min.	Max.	N
Endowment CHF	7.2	1.87	2	10	299
Contribution >0 0/1	0.86	0.35	0	1	299
Contribution (% of initial endowment)	0.70	0.4	0	1	299
Climate concern 0/1	0.86	0.34	0	1	299
Small contributions are important 0/1	0.85	0.36	0	1	299
Green member 0/1	0.09	0.29	0	1	299
Moral obligation 0/1	0.67	0.47	0	1	299
Belief about others' contribution (% of initial endowment)	0.53	0.30	0	1	299
Frequent forest user 0/1	0.19	0.39	0	1	299
Practical reservations 0/1	0.27	0.45	0	1	299
Ethical reservations w.r.t. the commodification of nature 0/1	0.48	0.5	0	1	299

Table d.2: Average marginal effects on contributions (Tobit model)

	Tobit
Climate concern	0.083 (0.27)
Small contributions are important	0.50** (0.24)
Green member	-0.021 (0.22)
Moral obligation	0.028 (0.16)
Belief about others' contribution	2.71*** (0.30)
Frequent forest user	0.24 (0.21)
Practical reservations	-0.24 (0.16)
Ethical reservations w.r.t. the commodification of nature	-0.064 (0.14)
Observations	299
Pseudo- R^2	0.24

Heteroskedasticity-robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

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Table d.3: Descriptive statistics (2nd stage)

Variable	Mean	Std. Dev.	Min.	Max.	N
Belief about others' contribution abroad 0/1	0.70	0.46	0	1	256
Second-year student 0/1	0.43	0.520	0	1	256
Frequent forest user 0/1	0.19	0.39	0	1	256
Experience with domestic site 0/1	0.35	0.48	0	1	256
Offsetting abroad is acceptable 0/1	0.29	0.45	0	1	256
Ethical reservations w.r.t. the commodification of nature 0/1	0.49	0.50	0	1	256
Carbon markets are acceptable 0/1	0.21	0.41	0	1	256
Green member 0/1	0.10	0.30	0	1	256
Economy the priority 0/1	0.11	0.31	0	1	256

Table d.4: Average treatment effects

	(1)	(2)
	OLS	GLM
Efficiency treatment (T1)	0.11*	0.12*
	(0.06)	(0.06)
Confidence treatment (T2)	0.026	0.025
	(0.06)	(0.06)
Local benefits treatment (T3)	-0.025	-0.024
	(0.06)	(0.05)
Belief about others' contribution abroad	0.26***	0.24***
	(0.05)	(0.04)
Second-year student	0.068*	0.067*
	(0.04)	(0.04)
Frequent forest user	0.033	0.034
	(0.06)	(0.06)
Experience with domestic site	-0.043	-0.043
	(0.04)	(0.04)
Offsetting abroad is acceptable	0.019	0.023
	(0.04)	(0.04)
Ethical reservations w.r.t. to the commodification of nature	-0.031	-0.032
	(0.04)	(0.04)
Carbon markets are acceptable	0.0083	-0.0069
	(0.05)	(0.05)
Green member	0.10	0.11
	(0.06)	(0.07)
Observations	256	256
Adjusted R^2	0.15	

Heteroskedasticity-robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table d.5: Average treatment effects on the probability to contribute (extensive margin)

	(1)	(2)
	Logit	OLS
Efficiency treatment	0.022 (0.058)	0.030 (0.058)
Confidence treatment	0.032 (0.056)	0.039 (0.059)
Local benefits treatment	0.0048 (0.055)	0.018 (0.060)
Belief about others' contribution abroad	0.19*** (0.029)	0.22*** (0.054)
Second-year student	0.029 (0.039)	0.025 (0.041)
Frequent forest user	0.042 (0.059)	0.040 (0.048)
Experience with domestic site	-0.024 (0.040)	-0.022 (0.042)
Offsetting abroad is acceptable	0.068 (0.051)	0.056 (0.042)
Ethical reservations w.r.t. to the commodification of nature	0.013 (0.039)	0.010 (0.040)
Carbon markets are acceptable	-0.040 (0.049)	-0.030 (0.051)
Green member	0.13 (0.11)	0.081 (0.051)
Covariates	Yes	Yes
Observations	256	256

Heteroskedasticity-robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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Table d.6: Average marginal effects from Cragg model: 2nd stage

Contributions to the international programme > 0 (0/1)	
Efficiency treatment (T1)	0.021 (0.056)
Confidence treatment (T2)	0.029 (0.054)
Local benefits treatment (T3)	0.0038 (0.054)
Belief about others' contribution abroad	0.18*** (0.037)
Second-year student	0.033 (0.039)
Frequent forest user	0.030 (0.054)
Experience with domestic site	-0.026 (0.039)
Offsetting abroad is acceptable	0.052 (0.046)
Ethical reservations w.r.t commodification of nature	0.013 (0.038)
Carbon markets are acceptable	-0.021 (0.048)
Green member	0.092 (0.088)
Contribution to the international programme (% of total contribution)	
Efficiency treatment (T1)	0.11** (0.046)
Confidence treatment (T2)	-0.0050 (0.047)
Local benefits treatment (T3)	-0.044 (0.047)
Belief about others' contribution abroad	0.13*** (0.040)
Second-year student	0.059* (0.032)
Frequent forest user	0.0070 (0.047)
Experience with domestic site	-0.027 (0.037)
Offsetting abroad is acceptable	-0.018 (0.034)
Ethical reservations w.r.t commodification of nature	-0.046 (0.033)
Carbon markets are acceptable	0.024 (0.041)
Green member	0.052 (0.051)
Observations	256

Heteroskedasticity-robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Questionnaire

Welcome and thank you for participating to our experiment on climate policy!

Please read questions and texts carefully and answer sincerely without communicating with your classmates. By participating to this experiment, you can earn up to CHF 10 if you answer all questions until the end of the survey. Your answers will be treated anonymously. Your participation and answers have no impact on your final grade.

You will now have to answer 4 true/false questions. We give you CHF 2 for your participation and every correct answer will be rewarded by other CHF 2. You have 90 seconds to answer all 4 questions.⁹⁸

1. **The demand curve for a good/service is generally downward sloped.**
 True False
2. **The income-elasticity of demand for an inferior good is negative.**
 True False
3. **Macroeconomics analyses households and firms' decisions.** True
 False
4. **“It is unfair that poor households pay the same amount for their health insurance as a billionaire .” This is a normative statement.** True
 False
5. **Economists generally assume that individuals are irrational and altruist and maximize the welfare of the society (homo oeconomicus).** True
 False
6. **In 2014, Switzerland exported more coffee than chocolate, in monetary value.** True False
7. **Perfect competition refers to a market where a firm has no influence on prices.** True False
8. **Monopoly is an imperfect competition market structure, wherein a single buyer will push the price downward.** True False

⁹⁸Students were randomly provided 4 questions among the following 10.

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9. **The opportunity cost of an activity represents the value of the best alternative.** True False
10. **The “invisible hand” described by Adam Smith is a metaphor to illustrate the State’s intervention in the economy.** True False

Congratulations! You have earned CHF _____ . We remind you that you must finish answering the questionnaire to receive this amount. Instructions on how to be paid are given at the end.

Please read the following text:

Climate warming is a phenomenon of increasing temperature at the world level. It is partly caused by greenhouse gas (GHG) emissions from human activities. Main consequences on the environment and humankind predicted by the IPCC (Intergovernmental Panel on Climate Change) are the following:

1. Polar glaciers melting and increasing sea level
2. Extinction of numerous vegetal and animal species
3. Lower land productivity
4. More difficult access to water resources
5. Increasing number of extreme meteorological phenomena (heavy rains, storms, drought, etc.)
6. Increasing mortality linked with heat, extension of zones infested by diseases such as cholera, malaria, allergies...
7. Mass migration by people who have lost their land
8. Risk of global geopolitical destabilisation and civil wars

Carbon dioxide (CO₂) is the main greenhouse gas responsible for climate warming. CO₂ emissions are mainly caused by the combustion of fossil fuels such as coal, oil or natural gas, for energy production or industrial activities. However, deforestation across the world has contributed to GHG emissions to a larger extent than transportation.

Indeed trees absorb CO₂ from the atmosphere and are thus important carbon sinks, so that increasing reforestation or reducing deforestation are effective and efficient tools to reduce CO₂ emissions.

Part 1:

You now have the opportunity to participate in a real reforestation programme, which will allow taking CO₂ out from the atmosphere. Thanks to your contribution, we will finance tree planting, which would offset CO₂ emissions linked with all economic activities, including your own activities.

The funding to reforestation programmes will be taken from the amount that you have earned in the previous questions. You can freely decide which amount you wish to give to tree planting, without exceeding the amount that you have earned.

The money will really be used to finance reforestation. We will receive a certificate attesting the tree planting. If you participate and wish it, your name can be added on the reforestation certificate. Otherwise, you can keep complete anonymity.

Please note again that your participation to this experiment is not mandatory and will have no impact on your final grade.

What amount of your earnings do you want to (total must be equal to your earnings - otherwise an error message is displayed):

Give to the reforestation programme: CHF _____

Keep for you: CHF _____

At the end of the survey you will receive CHF _____ and CHF _____ will be used to finance reforestation.

Among the following reasons, which one is the main reason why you did not contribute more to the reforestation programme?

- I prefer using the money for things that are more valuable to me
- I have the feeling that I legitimise a bad behaviour

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- I disagree with individual CO₂ offsetting
- I do not want to consider natural resources as a marketed commodity
- I do not agree to be asked to buy something within the framework of this survey
- I would like more information

In your opinion, what share of their endowment other participants on average contributed to the reforestation programme? _____%

Part 2:

You now have the choice to split your contribution between two different reforestation programmes. You can freely allocate your amount between the two programmes. Please notice that we will collect all participants' contributions and finance trees from the overall amount. We will complete the missing fraction of a tree, if needed. Hence there is no problem if you cannot finance an entire tree.^{99,100}

Table d.7: Reforestation programmes

Programme 1	Programme 2
Place: Visp, Switzerland	Place: Limay, Nicaragua
CO ₂ sequestration / tree / year: 15kg	CO ₂ sequestration / tree / year: 15kg
Cost / tree: CHF10	Cost / tree: CHF3

Neutral treatment (T0): The above programmes are very similar, but differ according to the place where they are implemented: Programme 1 plans to plant trees in Wallis, Switzerland and programme 2 in Limay, Nicaragua.

Efficiency treatment (T1): The above programmes are very similar, but differ according to the place where they are implemented: Programme 1 plans to plant trees in Wallis, Switzerland and programme 2 in Limay, Nicaragua. A new tree in Switzerland has the same CO₂ sequestration potential as a new tree in Nicaragua but the same amount of money allows to plant more trees in Nicaragua than in Switzerland, the price per tree being lower in Nicaragua. As the place of emission reduction has no importance for the stock in the atmosphere, it is more efficient

⁹⁹After this point, each individual randomly received one of the following treatments.

¹⁰⁰To avoid order effects, programmes are randomly numbered 1 or 2.

to plant trees where it is the cheapest: with the same amount it is possible to buy more trees in Nicaragua and thus to further reduce CO₂ emissions.

Confidence treatment (T2): The above programmes are very similar, but differ according to the place where they are implemented: Programme 1 plans to plant trees in Wallis, Switzerland and programme 2 in Limay, Nicaragua. Both programmes are strictly controlled by external institutions. In Switzerland, local authorities are directly taking part in the programme while in Nicaragua, the United Nations Environmental Programme (UNEP) oversees the projects to avoid any abuses. These institutions guarantee that the money sent will indeed be used to implement reforestation programmes, in Switzerland as in Nicaragua.

Local benefits treatment (T3): The above programmes are very similar, but differ according to the place where they are implemented: Programme 1 plans to plant trees in Wallis, Switzerland and programme 2 in Limay, Nicaragua. A new tree in Switzerland has the same CO₂ sequestration potential as a new tree in Nicaragua but reforestation in Switzerland implies a series of advantages for the local population. The Swiss population indeed enjoys forest to recreate: it is estimated that Swiss people spend more than 80 hours per year in forests, for leisure such as hiking, mushrooms picking, etc. Forests also allow to protect the Swiss population against natural hazards such as avalanches, landslides or rock slides. Moreover, Swiss forests are home to numerous local species, in particular amphibians and lichens, under the threat of extinction. Finally, forests are also a source of income for part of the population. In 2014, the gross income from the forest industry in Switzerland amounted to CHF 900 millions.

How much of your contribution do you wish to allocate to (total must be equal to your contribution - otherwise an error message is displayed):

The Swiss programme: CHF _____

The Nicaraguan programme: CHF _____

Among the following reasons, which one is the main reason why you did not contribute more to the Nicaraguan programme?

- Local benefits are more important in Switzerland than in Nicaragua

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- It is unfair to compensate Swiss CO₂ emissions abroad
- I do not trust the Nicaraguan government for the implementation of this programme
- It is not my duty to pay for a programme in Nicaragua
- None of the above

Among the following reasons, which one is the main reason why you did not contribute more to the Swiss programme?

- Populations in Nicaragua need more financial help than in Switzerland
- Local benefits are more important in Nicaragua than in Switzerland
- The price of a tree is lower in Nicaragua and hence, for the same amount, I can reduce more CO₂ if I buy trees in Nicaragua rather than in Switzerland
- It is not my duty to pay for this programme
- None of the above

In your opinion, for which programme did your classmate contribute the most?

- The programme in Switzerland
- The programme in Nicaragua
- Their contribution is, on average, the same for both programmes

It is possible to offset GHG emissions by other means than reforestation (renewable energy, methane recuperation, etc.). If the programme proposed to contribute to another type of project instead of reforestation, would your contribution have been:

- The same

- Higher
- Lower

If the reforestation programme abroad had not been in Nicaragua but in an industrialised country, would your contribution have been:

- The same
- Higher
- Lower

Please answer the following questions:

	Never	Sometimes	Regularly	Often
Have you ever been to the Visp region?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you ever been to Nicaragua?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
How often do you go to forests?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

How do you agree with the following statements?

	Not at all	Pretty not	Neutral	Pretty much	Totally
I consider that climate warming is a serious threat for the future	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Protecting the environment should be given priority, even if it causes slower economic growth and some loss of jobs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Economic growth and creating jobs should be the top priority, even if the environment suffers to some extent	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I feel morally obliged to protect the climate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
In my opinion, even small contributions are useful to protect the climate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reforestation is effective in reducing the stock of CO ₂ in the atmosphere	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The creation of carbon markets is an acceptable solution to reduce GHG emissions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It is morally acceptable to offset domestic CO ₂ emissions abroad	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Every country should offset the major part of its CO ₂ emissions on its own territory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I do not want to consider natural resources as a marketed commodity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I disagree with individual CO ₂ offsetting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Are you member of or donate to an environmental friendly organisation?

- Yes
- No

Are you:

- Male
- Female

How old are you? _____ years old

What is your ZIP code? _____

Is your mother tongue Spanish or are you originally from Latin America?

- Yes
- No

What type of diploma have you earned?

What type of study did your parents complete?

Please indicate the interval that best represents your personal monthly budget (without rents nor insurances).

We thank you for your participation to this survey!

Table e.1: Data sources, units and description

Variable	Unit	Description	Sources
Q_t	Millions of m ³	Quantity of roundwood produced	Siegenthaler and Ritzman-Blickenstorfer (1996) FSO (1990), FOEN, (1996; 2014g)
P_t	2011CHF/m ³	Volume-weighted average price of roundwood	FSO (1976; 2015c)
P_{subs_t}	2011CHF/kg	Average import price of steel, iron and other metallic material	FSO (2015c)
Px_t	Index 2010=100	Average producer price of raw wood from German public forests accounting for exchange rate differentials	DESTATIS (2017) Swiss National Bank (2017)
$Investment_t$	Mio of 2011CHF	Investment in building infrastructure	FSO (2015c)
$Wage\ in\ forestry_t$	2011CHF/hour	Average wage paid to forest workers	Niederer and Bill (2015)
i_t	%	Real average interest rate on savings	Swiss National Bank (2017)
$Penergy_t$	2011CHF/m ³	Volume-weighted average price of energy wood	FSO (1990), FOEN, (1996; 2014g) FSO (1976; 2015c)
$Storm_t$	1000m ³	Quantity of fallen wood due to natural calamities	Usbeck (2015)

Table e.2: Stationarity tests

Variable	ADF			Phillips-Perron			KPSS		
	Z_t	lags	form	Z_ρ	lags	form	η	lags	form
Q_t	-0.88	2	no t	-11.01*	2	no t	0.97***	5	no t
ΔQ_t	-7.78***	1	no t	-81.50***	1	no t	0.25	5	no t
P_t	-1.62	0	t	-10.50	0	t	0.18**	6	t
ΔP_t	-7.05***	1	t	-57.82***	1	t	0.16**	8	t
P_{subs_t}	-0.41	1	no t	-4.13	1	no t	1.03***	5	no t
ΔP_{subs_t}	-2.80***	1	no t	-68.26***	1	no t	0.07	8	no t
Px_t	-2.14	0	t	-13.68	0	t	0.17**	5	t
ΔPx_t	-7.74***	0	t	-66.24***	0	t	0.08	5	t
$Investment_t$	-1.37	1	t	-5.51	1	t	0.26***	5	t
$\Delta Investment_t$	-4.61***	1	t	-36.48***	1	t	0.12	5	t
$Wage\ in\ forestry_t$	-0.78	1	t	0.93	1	t	0.27***	5	t
$\Delta Wage\ in\ forestry_t$	-3.56**	0	t	-27.58***	0	t	0.15**	5	t
i_t	-0.31	2	no t	-0.65	2	no t	1.09***	5	no t
Δi_t	-5.27***	1	no t	-36.40***	1	no t	0.09	4	no t
$Penergy_t$	-0.63	0	no t	-4.06	0	no t	0.90***	6	no t
$\Delta Penergy_t$	-3.38***	0	no t	-64.21***	0	no t	0.36*	4	no t
$Storm_t$	-8.16***	0	no t	-66.71***	0	no t	0.22	6	no t
$\Delta Storm_t$	-13.65***	0	no t	-64.21***	0	no t	0.04	4	no t

***p<0.01, ** p<0.05, * p<0.1

t: trend, no t: no trend

For augmented Dickey-Fuller tests (ADF) (Dickey and Fuller, 1979) and Phillips-Perron tests (Phillips and Perron, 1988), lags and functional forms have been chosen thanks to the Bayesian Information criteria. H0: The series is non-stationary. For KPSS (Kwiatkowski et al., 1992) test, the number of lags was selected by automatic bandwidth selection and autocovariances weighted by Bartlett Kernel. H0: The series is stationary

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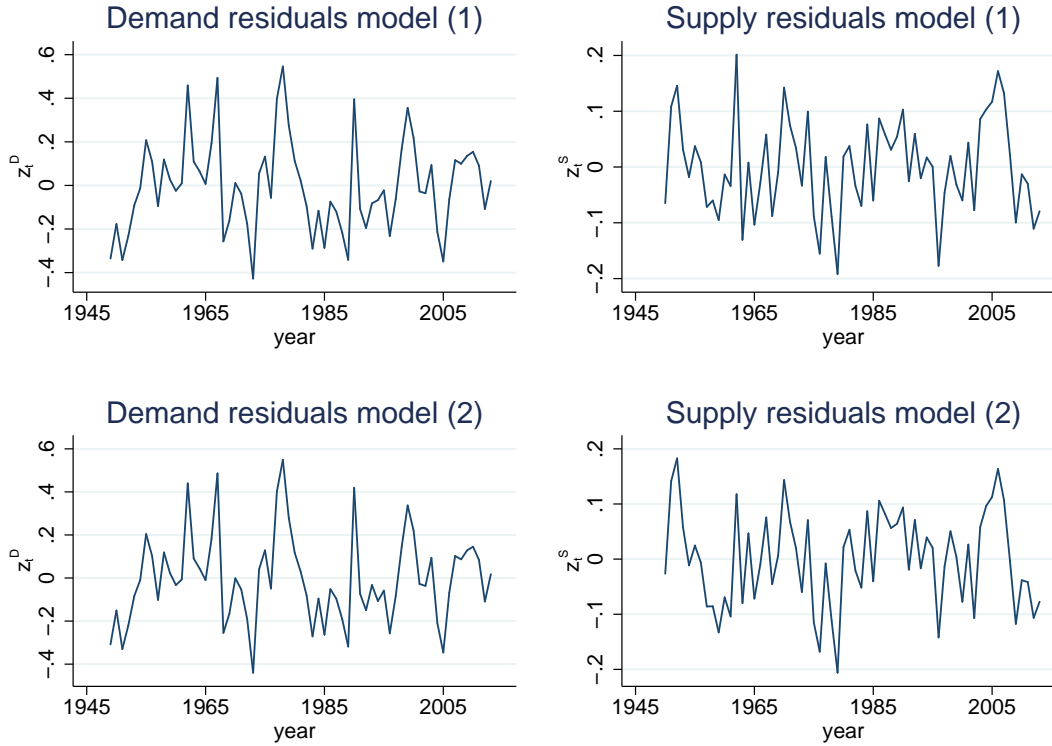


Figure e.1: Plots of the residuals

Table e.3: Post-estimation tests

Demand	Anderson canon. corr. stat. ^b	46.19***
	Cragg-Donald F-stat. ^c	35.01+++^^^
	Sargan statistic ^d	9.12**
Supply	Anderson canon. corr. stat. ^b	16.97***
	Cragg-Donald F-stat. ^c	3.90
	Sargan statistic ^d	6.88

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

+ 20% maximal IV relative bias, ++ 10% maximal IV relative bias, +++ 5% maximal IV relative bias

^ 20% maximal IV size, ^^ 15% maximal IV size, ^^ 10% maximal IV size

^b Underidentification test (H0: Equations are underidentified)

^c Weak identification test (Stock and Yogo, 2005)

^d Overidentifying restrictions test (H0: instruments are valid and excluded instruments are correctly excluded)

Description d'une base de données en vue d'établir la demande de bois en Suisse

Production de bois en Suisse : 1851-2012

Nous avons construit la série temporelle retraçant la production à partir de de trois sources.

- **(1851-1960)** : De 1851 à 1990 : Statistique historique de la Suisse, de Hansjörg Siegenthaler et Heiner Ritzman-Blickenstorfer, pp.576-577 (ci-après Siegenthaler and Ritzman-Blickenstorfer, 1996), disponible à la bibliothèque de l'Office Fédéral de la Statistique (OFS) à Neuchâtel. Ce document contient la production totale de *bois à brûler* et de *bois de construction* en 1000m³.
- **(1961-2001)** Entre 1961 et 1990, l'Annuaire La forêt et le bois de 2002 (ci-après FOEN, 2002) produit par l'OFS et l'Office Fédéral des Forêts et disponible sur internet permet le recoupement avec Siegenthaler and Ritzman-Blickenstorfer (1996) et fournit des données jusqu'en 2001 sur la récolte totale de bois, par groupe d'essences et d'assortiments, en 1000 m³. De cette source, on peut obtenir la récolte totale par essence (résineux/feuillus) et par groupe d'assortiments (grumes / bois d'industrie / bois de feu). Entre 1961 et 1990, on constate que Ritzman a construit la série bois de construction en additionnant la quantité de bois de grume avec celle de bois d'industrie et que la terminologie « bois à brûler » dans Siegenthaler and Ritzman-Blickenstorfer (1996) équivaut au bois de feu dans l'annuaire (2002). Il faut noter que Siegenthaler and Ritzman-Blickenstorfer (1996) a probablement fait une erreur, car la comparaison avec annuaire 2002 révèle une différence systématique : en effet, Siegenthaler and Ritzman-Blickenstorfer (1996) est toujours 10x inférieur à l'annuaire 2002 alors que les deux utilisent la même mesure en 1000m³. FOEN (2002) comportant une décimale supplémentaire et donc plus de précision, nous optons pour ces données entre 1961 et 2001.
- **(2002-2014)** Entre 1970 et 2014, l'Annuaire La forêt et le bois de 2015 (ci-après FOEN, 2015) disponible sur internet permet de compléter la série. La classification est identique, si ce n'est que le bois de feu est maintenant appelé bois-énergie et que celui-ci est séparé en bûches et plaquettes à partir de 2004. Ces dernières sont incluses dans la série car « jusqu'à la révision de la statistique forestière en 2004,

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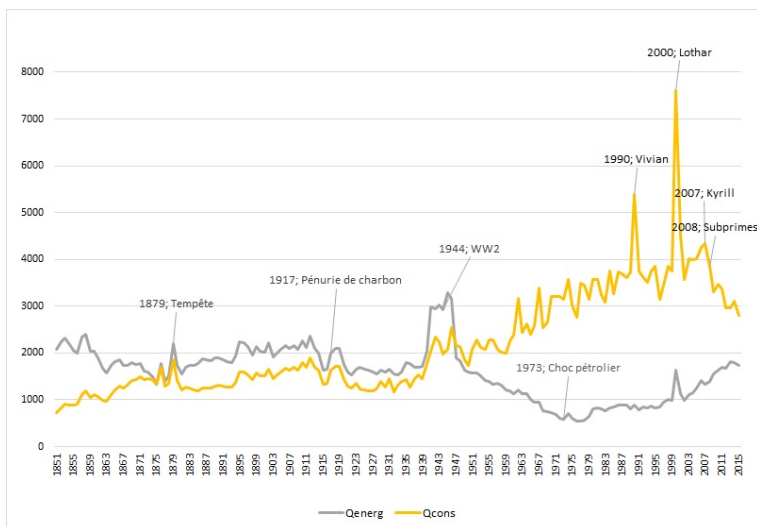


FIGURE e.2 : Série temporelle de la production de bois de construction (Q_{cons}) et de bois énergie (Q_{energ}) en Suisse en 1000m^3 (1851-2012)

les plaquettes n'ont pas été recensées séparément ». À partir de 2004 également, une rubrique autres assortiments apparaît et correspond à « bois résineux et feuillu sous forme de piquets, petites perches, plots à fendre à tavaillons, etc. ». Cette dernière rubrique n'est pas incluse dans la série. Enfin, une différence entre FOEN (2002) et FOEN (2015) est à remarquer. Dans FOEN (2015), la récolte est exprimée en $100\text{m}^3\text{p}$ (milliers de mètres-cube-produit). En l'occurrence, on constate que, pour ces assortiments et ces essences, un millier de mètre cube est équivalent à un millier de mètre-cube-produit.

- **(2015)** Nous complétons cette série avec les données de l'OFS consultables sur le site FSO (2015a).

Dans la Figure e.2, nous avons alors reporté les séries temporelles du bois énergie et du bois de construction sur la période 1851-2015, en adoptant les définitions suivantes :

Bois de construction = bois d'industrie + bois de grumes

Bois à brûler = bois de feu = bois-énergie = bûches + plaquettes

$$1000\text{m}^3 = 1000\text{m}^3\text{p}$$

Si on se concentre premièrement sur le bois énergie, à la lecture de la Figure e.2, nous constatons que son importance relative ne cesse de diminuer jusque dans les années 2000. La production de bois énergie reste toutefois relativement stable jusqu'à la fin de la deuxième guerre mondiale, sans tendance particulière. Celle-ci devient baissière, jusqu'au premier choc pétrolier en 1973 où elle s'inverse fortement. Une première lecture grossière de cette tendance semble donc indiquer que la production de bois énergie suit le chemin inverse de l'augmentation des prix du pétrole et du mazout montrant que ces produits peuvent être substitués l'un avec l'autre. L'avènement récent du pellet et des plaquettes pousse à la hausse la production de bois énergie, car elle permet notamment l'utilisation de bois de moindre qualité. Nous pouvons aussi constater que cette série est plus stable que celle du bois de construction, les variances étant de 560 et 1094 milliers de m³, respectivement. C'est uniquement pendant la deuxième guerre mondiale que la production de bois-énergie est supérieure à celle pour la construction, afin de répondre à la pénurie des substituts énergétiques importés. Le bois de construction, reste relativement stable, mais gagne en importance relative jusqu'à la deuxième guerre mondiale. À partir de ce moment, nous assistons à une forte croissance de la production jusqu'en 2007. La production de bois de construction semble sujette à de fortes variations suite à des événements particuliers. Ainsi, les ouragans Vivian et Lothar en 1990 et 1996 ont eu un impact notable sur la production. Ceci peut s'expliquer par le fait que le bois est subitement devenu plus accessible, son exploitation ne nécessitant plus l'abattage d'arbres. De plus, la Confédération a versé des subventions pour le nettoyage des forêts touchées par ces tempêtes. Le bois de construction étant majoritairement composé de résineux, plus sensibles aux vents, il est logique que la production de ce type de bois soit plus impactée par les ouragans que celle de bois-énergie. La série de production du bois de construction semble également plus impactée par l'évolution conjoncturelle. En effet, la construction fait partie des secteurs annonciateurs d'une crise économique et subit relativement fortement les récessions, avec pour corollaire, la diminution de demande de bois par ce secteur. On le voit tout particulièrement entre 2008 et 2012 où la crise économique a eu un effet important sur la production de bois en Suisse.

Les prix du bois en Suisse : 1928-2012

Nous avons dû faire appel à différentes sources pour construire la série des prix nominaux.

- (1898-1921) (T0) Il existe une série de prix pour les « bois de sciages et de

construction » et les « bois de feu » dans les forêts cantonales uranaises (*der Holzmarkt*, 1922). Cette série peut être éventuellement ajoutée aux données ultérieures décrites plus bas. Nous mettons cependant en évidence que les hypothèses qui en découlent sont nombreuses. Il faudrait ainsi notamment supposer que les forêts du Canton d'Uri soient représentatives de la Suisse et la composition des bois qui en sont extraits soit identique et que la méthodologie d'agrégation des prix soit la même que celle utilisée dans les tableaux nationaux suivants. Par souci de cohérence, nous avons décidé de ne pas intégrer ces données dans la série des prix.

- **(1928-1934)** (T1) L'Office Fédéral de la Statistique propose, sur son site internet, une section « Statistique et histoire » (FSO, 2015c). Dans la sous-section « Prix » on trouve un « indice des prix de gros par marchandises » pour les « matériaux de construction » et les « combustibles et papier ». Il est ainsi possible de faire le lien avec les prix des années suivantes mais des données manquent entre 1928 et 1934 pour le bois-énergie. Cependant, pour ces années, l'Indice des Prix à la Consommation (IPC), disponible sur le site de l'OFS, et l'indice des prix de gros sont extrêmement corrélés (0.93 pour IPC et l'indice bois de feu). Il est ainsi possible de lier T1 et T2, sous l'hypothèse que l'évolution des prix du bois-énergie durant cette période est uniquement due à l'inflation. La série de prix peut ensuite être étirée jusqu'en 1806 grâce à l'indice des prix de gros. Les informations concernant ces mesures sont peu nombreuses. Pour le bois de construction, il est indiqué : « bois de construction FM » et pour le bois de feu, « Bois de chauffage hêtre » et « bois de chauffage sapin ». Comme pour T2, une moyenne pondérée pour le bois de feu a été considérée pour agréger les essences. (31% de sapin et 69% de hêtre)
- **(1934-1955)** (T2) Entre 1934 et 1949, le tableau *Tabelle der gewogenen Durchschnittspreise von inländischem, rohem unverarbeitetem Nutz- un Brennholz 4. Quartal 1934 bis Ende 1949* (Tableau des prix moyens pondérés du bois d'œuvre et du bois à brûler indigènes, bruts et non-travaillés) (ci-après T1), disponible dans la revue *der Holzmarkt* (1955) à la bibliothèque HBD de l'ETHZ retrace les prix moyens trimestriels du bois en Suisse par essence et par assortiment. Le bois à brûler (Brennholz) consiste en deux catégories : sapin/épicéa (résineux) et hêtre (feuillus). Le bois d'œuvre (Nutzholz) est, lui, séparé en : résineux (Nadelholz)¹⁰¹

¹⁰¹Résineux s'entend ici par : sapin/épicéa, pin, mélèze

et feuillus (Laubholz)¹⁰². Les prix s'entendent « nächste Bahnstation unverladen » (prochaine gare non-chargé) ou pour le bois d'œuvre (pas dans tous les cas) « nächste Säge » (prochaine scierie). L'assortiment de bois d'œuvre, résineux correspond aux bois de dimensions I à III et l'assortiment de bois à brûler, de « Sagklötze Normalqualität von 40-49cm Mittendurchmesser » (billes de sciages de qualité n de 40-49 cm de diamètre). Pour obtenir une moyenne annuelle, nous avons fait la moyenne des trimestres. Afin d'agrèger les prix de la même façon que les quantités (bois de construction et bois à brûler), nous avons appliqué une moyenne pondérée des essences. Pour le bois de feu, nous avons pris 31% (max. à 50% en 2000 suite à l'ouragan Lothar et min. à 16% en 2012) de résineux et pour le bois d'œuvre 85% (max à 91% en 1968 et min 79% en 1975). Ces pourcentages correspondent à la moyenne des proportions de résineux entre 1965 et 2012 calculée à partir des annuaires 2002 et 2013. Il faut noter que les prix de 1934 ne sont observés que sur la période octobre-décembre 1934.

- (T3) Entre 1947 et 1951, le tableau Prix moyens pondérés des bois d'œuvre et des bois de feu bruts indigènes de la période allant du 4e trimestre 1947 au 2e trimestre 1951 (ci-après T3) est également disponible dans la revue *der Holzmarkt* (1955) à la bibliothèque HBD de l'ETHZ. Ces prix s'entendent « station ferroviaire la plus proche, marchandise non-envagonnée ». Les prix entre 1947 et 1949 permettent de faire la comparaison avec T2 et indique que la même méthodologie a été utilisée. Une précision supplémentaire est apportée : le bois de feu est mesuré en quartier. La même méthodologie que pour T2 a été utilisée.
- (T4) Entre 1949 et 1953, le tableau Prix moyens pondérés des bois d'œuvre et des bois de feu bruts indigènes de la période allant de 1949 au 1er trimestre 1953 (ci-après T4) est disponible dans la revue *der Holzmarkt* (1955) à la bibliothèque HBD de l'ETHZ. Les prix entre 1949 et 1951 permettent de faire la comparaison avec T3 et indique que cette série suit celle issue de T3. La même méthodologie que pour T2 et T3 a été utilisée.
- (T5) Entre 1951 et 1954, le tableau Prix moyens pondérés des bois d'œuvre et des bois de feu bruts indigènes de la période allant de 1939 au 4e trimestre 1954 (ci-après T5) suit également la même série que les tableaux précédents.

¹⁰²Feuillus s'entend ici par : hêtre, chêne

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- **(1956-1978/79)** (T6) Entre 1952 et 1963/1964, le tableau Prix moyens pondérés des bois d'œuvre et des bois de feu bruts indigènes de la période allant de 1939 à la 3e période 1963/1964 (ci-après T6) est également disponible dans la revue *der Holzmarkt* (1979) à la bibliothèque HBD de l'ETHZ. La comparaison des moyennes annuelles effectuées par nos soins pour les années 1939 et 1952-1955 et celle de T6, indique que T6 suit également la même série. Une précision est apportée : le prix du bois d'œuvre est mesuré en CHF par m³ et le prix du bois de feu (en quartier) est mesuré en CHF par stère. Un changement de méthodologie est constaté puisque les prix sont maintenant agrégés en année forestière comportant 3 périodes de 4 mois et allant de septembre à août. T6 n'est donc pas strictement comparable avec les données précédentes. La même méthodologie d'agrégation que pour les données précédentes a été utilisée.
- (T7) Entre 1963/64 et 1978/79, Prix moyens pondérés des bois d'œuvre et des bois de feu bruts indigènes (ci-après T7) suit la même série que T6. La méthode d'agrégation est la même que précédemment jusqu'à l'année 1964/65. Dès 1965/66, nous avons utilisé les pondérations découlant des statistiques de FOEN (2002) et FOEN (2015), pour chaque année.
- **(1980-1984)** (T8) Entre 1980 et 1984, le tableau Prix moyens du bois de grumes et du bois de feu suisses, de 1979 à 1984 (ci-après T8) est disponible à l'OFS sur demande. Il n'est pas noté de changement de méthodologie significatif, mais la continuité avec les données précédentes n'a pas pu être assurée, car les dates ne pouvaient pas être recoupées. Contrairement à T2-T7, le bois d'œuvre est séparé en bois de grumes (résineux=sapin/épicéa et feuillus=hêtre) et bois d'industrie (sapin/épicéa seulement). Le bois de grumes résineux correspond à la moyenne de tous les assortiments, alors que le bois de grumes feuillu reste de la même qualité que T2-T7. Le bois d'industrie correspond à du bois à papier, 1ère classe, non écorcé, 1m, chargé sur wagon. Les prix sont annoncés par tiers de l'année forestière, ce qui rend possible, la transformation en prix sur l'année civile. Pour le bois de feu, la même méthodologie que T2-T7 a été utilisée. Pour le bois d'œuvre, ne disposant pas des prix du bois d'industrie, feuillu, le calcul du prix du bois d'œuvre est impossible. Il faut noter que le prix du bois de feu de 1980 est basé uniquement sur les prix de mai à décembre.
- **(1983-1992)** (T9) Entre 1983 et 1991, le tableau Prix moyens pondérés, en francs,

du bois brut suisse vendu aux bords des routes forestières praticables pour des camions (ci-après T9) est disponible à l'OFS sur demande. Il convient tout d'abord de noter le changement de lieu où les prix sont constatés par rapport à T2-T8. De plus, la période du relevé n'est que de janvier à avril pour cette période. Les assortiments sont classifiés de la même manière que T8, à la différence près que le bois d'industrie, feuillus, apparaît dans les statistiques comme bois pour la fabrication de panneaux de particules, feuillus, ces bois correspondent à des bois de feuillus de 1ère classe. Pour l'agrégation, il a fallu procéder en deux temps. Premièrement, un prix regroupant le bois d'œuvre, pour les feuillus et les résineux séparément était nécessaire. Pour les résineux, nous avons procédé à une moyenne pondérée des prix des grumes et du bois à papier, en utilisant les pondérations (pourcentage de grumes résineux dans le bois d'œuvre résineux, en moyenne 84% mais les pondérations varient chaque année) découlant des annuaires 2002 et 2013. Pour les feuillus, nous avons procédé à une moyenne pondérée des prix des grumes et du bois pour panneaux de particules, en utilisant les pondérations (pourcentage de grumes feuillus dans le bois d'œuvre feuillus, en moyenne 64% mais les pondérations varient chaque année) découlant des annuaires 2002 et 2013. Puis, afin de regrouper les essences, nous avons utilisé les moyennes créées et y avons appliqué la même méthodologie que T7 (dès 1965)-T8.

- **(1992-2012)** (T10) Entre 1992 et 1996, le fichier Prix à la production des bois bruts est disponible sur le site web de l'OFS. Il faut noter le lieu de mesure des prix : «Prix de vente moyens du bois brut indigène non façonné, à port de camion (y compris les chablis).» Ce fichier est bien plus détaillé que les tableaux précédents, ce qui implique un travail d'agrégation conséquent. Tout d'abord, nous avons calculé des moyennes annuelles avec les prix trimestriels fournis. Ensuite, pour les grumes de résineux, nous avons procédé à une moyenne simple de tous les assortiments, pour garantir la continuité avec les tableaux précédents. Pour les grumes de feuillus, nous avons utilisés les prix des billes de sciage de qualité n, 40-49cm de diamètre comme dans T2-T9. Le bois d'industrie résineux est constitué de bois de classe 1, long. Il faut noter que le bois à papier n'a pas pu être pris en compte. Le bois d'industrie étant indiqué en CHF par tonnes, le facteur de conversion de l'annuaire 2013 propose de multiplier par 0.9 pour obtenir la mesure en CHF m³, ce qui a été fait. Le prix des grumes est ici en CHF/Fm La même méthodologie d'agrégation que T7-T9 a ensuite été appliquée. Concernant le bois-

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énergie, la même méthodologie que T7-T9 est appliquée.

- (T11) Entre 1996 et 2000 le fichier Prix à la production des bois bruts est disponible sur le site web de l'OFS (FSO, 2015). Il est identique à T10, mais il est plus détaillé et précise que ces prix ne comprennent pas la TVA. Pour les grumes de résineux, il s'agit d'une moyenne de tous les assortiments de sapins et d'épicéas. Les prix étant désagrégés dans le fichier source pour la première fois. Pour les grumes de feuillus, nous continuons sur les prix des billes de sciage de qualité n, 40-49cm de diamètre. Pour les bois d'industrie et énergie, le processus est identique à T10 et les méthodes d'agrégation également.
- (T12) Entre 2000 et 2013, le fichier Prix à la production des bois bruts est disponible sur le site web de l'OFS (FSO, 2015). Il est encore plus détaillé que T11. Pour les grumes de résineux, la méthode est identique à T11. Pour les grumes de feuillus, la nomenclature a changé et les billes de sciages de hêtre de qualité n, 40-49 cm de diamètre deviennent des billes de sciages 4B, 40-49 B, min. 3m mais ces deux catégories sont identiques (cf. Jan Boni). Les méthodologies sont ensuite identiques à T11. Il convient de noter que le prix des plaquettes n'a pas été pris en compte dans le prix du bois énergie, mais qu'il devrait l'être puisque les quantités incluent les plaquettes (le prix des plaquettes est disponible à partir de 1992 mais les quantités produites seulement depuis 2004).

Du fait des nombreux changements et transformations et de la non-exhaustivité de certaines données, cette série de prix doit plutôt être considérée comme un indicateur plutôt que comme une série de prix effectif. Dans la Figure e.3, nous avons alors reporté les séries temporelles du prix du bois énergie et du prix du bois de construction sur la période 1934-2012, en adoptant les définitions suivantes :

$$P \text{ Bois d'œuvre} = P \text{ bois de construction} = x\% P \text{ bois de grumes} + (1-x\%)P \text{ bois d'industrie}$$

$$P \text{ Bois d'industrie} = P \text{ bois à papier (résineux)} + P \text{ bois pour panneaux de particules (feuillus) (jusqu'en 1992)}$$

Pour la construction de la Figure e.4, les prix nominaux sont déflatés par l'Indice des Prix à la Consommation (base de 2011). À partir de la Figure e.4, nous constatons que les prix réels du bois-énergie baissent constamment depuis 1934, avec une stabilisation

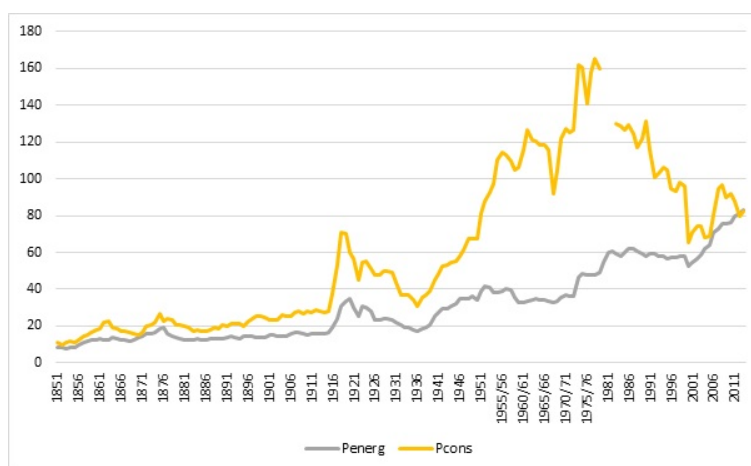


FIGURE e.3 : Série temporelle des prix nominaux moyens du bois de construction et du bois énergie en Suisse en CHF par m³ (1851-2013)



FIGURE e.4 : Série temporelle des prix réels moyens du bois de construction et du bois énergie en Suisse en CHF par m³ (1914-2013) aux prix de 2011

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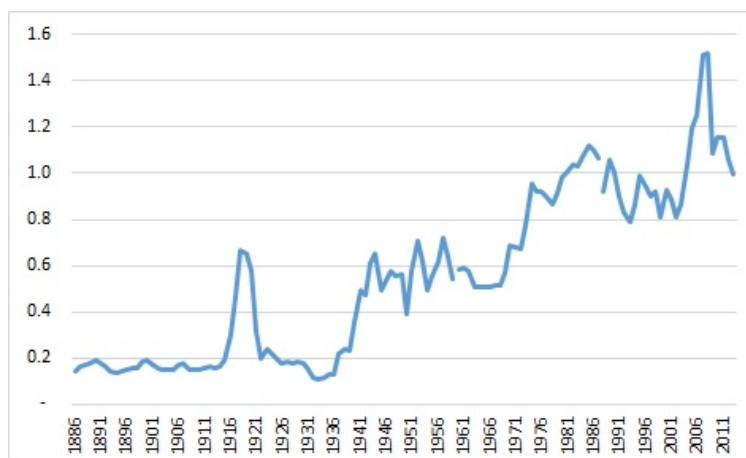


FIGURE e.5 : Prix moyens à l'importation de l'acier, du fer et de la ferraille en CHF/kg(1886-2013)

dans les années 2000. Les prix du bois de construction ont par contre d'abord augmenté jusque dans les années 60 puis diminué jusqu'au début des années 2000.

Prix de l'acier

Le prix de l'acier correspond aux prix à l'importation de l'acier, du fer et de la ferraille. Ces données proviennent de FSO (2015a) de 1886 à 1987 puis de 1988 à 2013 de AFD (2014).

Salaire dans l'industrie forestière

Le salaire moyen dans l'industrie forestière de 1939 à 2014 est donné par Niederer and Bill (2015) en CHF/heure.

Dégâts dus aux catastrophes naturelles

Pour tenir compte du bois tombé lors de catastrophes naturelles, nous utilisons les données de Usbeck (2015) fournies par le Professeur Thomas Wohlgemuth, en milliers de m³. Ces données sont disponibles de 1865 à 2014.