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INCENTIVOS ECONÓMICOS Y MOTIVACIONES INTERNAS EN EL COMPORTAMIENTO DE PRODUCTORES AGRÍCOLAS Y FORESTALES

ECONOMIC INCENTIVES AND INTERNAL MOTIVATIONS ON THE BEHAVIOR OF AGRICULTURAL AND FOREST PRODUCERS

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Resumen

El uso sostenible de los recursos naturales en el ámbito agrícola depende de las decisiones de producción y conservación ambiental en tierras privadas. Esto pone de relieve el rol de las políticas agrarias y los programas de incentivos para guiar los comportamientos de inversión y manejo de recursos naturales que realizan los productores. En esta tesis, se analizan varios sistemas de incentivos enmarcados en políticas agrícolas ambientalmente relevantes que han sido implementados en Chile. El primer capítulo consiste en una evaluación del subsidio forestal Decreto Ley n ° 701 (DL701) sobre el aumento de las plantaciones forestales y su efecto sobre los cambios en el uso de la tierra y la dependencia del ingreso fuera del predio. El segundo capítulo comprende el estudio del efecto del Sistema de Incentivos para la Sustentabilidad Agroambiental de los Suelos Agropecuarios (SIRSD-S) en la adopción de prácticas agrícolas sostenibles, y cómo este estímulo exógeno se relaciona con las motivaciones intrínsecas de los productores. Finalmente, el tercer capítulo explora la relación entre el desempeño de cooperación grupal en Comunidades del Agua y los atributos de los presidentes, el capital social y los sistemas de sanciones.

En el primer capítulo, que tiene como objetivo evaluar el impacto del DL701, se utilizó el enfoque de Sistema de Ecuaciones Estructurales (SEM). SEM permite el estudio de relaciones complejas entre diferentes eventos, la existencia de perturbaciones en cascada o la importancia relativa de diferentes influencias sobre ciertos resultados. Dado que la naturaleza de los datos utilizados en este capítulo es observacional, lo que significa que los individuos en la muestra no comparten las mismas características iniciales, se implementó un procedimiento de “matching” antes del análisis para construir un contrafactual apropiado que ayude a lograr estimadores insesgados. La hipótesis es que el DL701 aumentó efectivamente las plantaciones forestales en detrimento de los usos tradicionales de la tierra, al tiempo que generó un aumento en los ingresos fuera del predio para cubrir el ingreso general a corto plazo.

Aunque los siguientes capítulos también tratan sobre incentivos (i.e., SIRSD-S y sanciones), no se consideró el uso de “matching” o métodos causales ya que el análisis es más correlacional. En el segundo capítulo, que evalúa la interacción entre el incentivo SIRDS-S y las motivaciones intrínsecas, se estimó un modelo de conteo para comprender la intensidad de la adopción de

prácticas sostenibles por parte de los productores de cultivos anuales. La hipótesis es que la adopción de prácticas agrícolas sostenibles se asocia positivamente con el incentivo, siendo especialmente decisivo cuando las motivaciones intrínsecas de los productores son bajas y no significativas cuando estas últimas son altas.

Finalmente, el tercer capítulo utilizó un análisis de “clusters” en dos etapas para explorar cómo las sanciones y los atributos de los presidentes se relacionan con la cooperación grupal en el uso de agua de riego. Sobre la base de tasas de cooperación demostradas por Comunidades de Agua, la muestra fue agrupada en varios grupos que comparten características comunes. La hipótesis es que las Comunidades de Agua caracterizadas por sistemas de sanciones y líderes con alto liderazgo y capital social afectan positivamente la cooperación grupal y, por tanto, promueven el logro de acciones colectivas.

Abstract

The sustainable use of natural resources in the agricultural sphere depends on both production and environmental conservation decisions undertaken in private lands. This fact highlights the relevance of agricultural policies and incentive programs to guide the producers' investment behaviors and natural resource management. In this thesis, various incentive systems framed as Environmentally Relevant Policies (ERPs) implemented in Chile are analyzed. The first chapter consists of an evaluation of the forestry subsidy Decree Law n° 701 (DL701) on the increase of forest plantations and its effect on land use changes and off-farm income dependence. The second chapter comprises the study of the effect of the System of Incentives for the Agro-environmental Sustainability of Agricultural Soils (SIRSD-S) on the adoption of sustainable agricultural practices, and how this exogenous stimulus is related to the producers' intrinsic motivations. Finally, the third chapter explores the relationship between cooperation performance in Water Communities in light of presidents' attributes, social capital, and sanctions systems.

In the first chapter, which aims at assessing the impact of the DL701, the Structural Equation Modeling (SEM) approach was used. SEM allows the study of complex relationships between different events, the existence of cascading disturbances, or the relative importance of different influences on certain results. Since the nature of the data used in this chapter is observational, meaning that the individuals in the sample do not share the same initial characteristics, a matching procedure was implemented before the analysis to construct an appropriate counterfactual that helps to achieve unbiased estimators. The hypothesis is that the DL701 effectively increased forest plantations to the detriment of traditional land uses, while generating an increase in off-farm income to cover the overall income in the short term.

Although the following chapters also deal with incentives (i.e., SIRSD-S and sanctioning), no matching or causal methods were considered since the analysis is more correlational. In the second chapter, which evaluates the interplay between the SIRDS-S incentive and intrinsic motivations, a count model was estimated to understand the intensity of adoption of sustainable practices by annual crop producers. The hypothesis is that the adoption of sustainable

agricultural practices is positively associated with the incentive, being especially decisive when the producers' intrinsic motivations are low, and not significant when the latter are high.

Finally, the third chapter used a two-stage cluster analysis to explore how sanctioning and presidents' attributes relate to group cooperation in the use of irrigation water. Based on cooperation rates demonstrated by Water Communities, the sample was grouped into several clusters sharing common characteristics. The hypothesis is that Water Communities characterized by sanction systems and leaders with high leadership and social capital positively affect group cooperation, and thus promote the achievement of collective actions.

Palabras clave:

Acción colectiva, Agricultura sostenible, Chile, Comportamiento, Incentivos, Plantaciones forestales, Toma de decisiones.

Keywords:

Behavior, Chile, Collective action, Decision making, Forest plantations, Incentives, Sustainable agriculture.

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1. Comprehensive introduction of the thesis

Intensive production systems, either in agricultural or forestry contexts, tend to exert strong pressure on the use of natural resources, generating a negative impact on their quality, biodiversity, and the provision of ecosystem services (Daloğlu et al., 2014; Home et al., 2014). This is reflected in negative externalities such as excessive water extraction, unsustainable soil management, leaching of fertilizers, or alteration of habitats, which are among the most important (Godfray and Garnett, 2014). Since the motivation of farmers does not always go hand in hand with the social interests to preserve nature and avoid the degradation of natural resources (de Krom, 2017), in recent decades the agricultural approach called 'sustainable intensification' has gained importance as an objective of agro-environmental policies (Ward et al., 2016). This concept refers to the promotion of agricultural production with less impact on the environment, guaranteeing food security and ecosystem functions (Batáry et al., 2015; Garnett et al., 2013; Tittonell, 2014).

However, the generation of pro-environmental changes at the agricultural level usually represents an opportunity cost for producers since it limits the flexibility to optimize production and thus maximize benefits (de Krom, 2017; Hanley et al., 2012; Pannell et al., 2014). Moreover, the adoption of sustainable practices implies making adjustments in the management of the exploitation that may face important cultural and social barriers (FAO, 2003). Therefore, to motivate farmers to implement sustainable practices, it is necessary to create appropriate incentive programs and subsidies to make them more appealing and thus guide their adoption (Bhaskar and Beghin, 2007; Burton and Schwarz, 2013; de Snoo et al., 2013; Hanley et al., 2012; Home et al., 2014; Malawska et al., 2014; Pretty and Bharucha, 2014; Siebert et al., 2006; Ward et al., 2016).

Various incentive systems have been used within the framework of ERPs, which are not limited to the implementation of conservation agriculture but also include other dimensions, such as those of productive development that also have an impact on the environment (OECD, 2017). In the field of forestry, policymakers from different regions of the world have incentivized forest plantations through subsidies, tax benefits, or preferential access to credit, for both the ecosystem and economic benefits that forests provide (Heilmayr et al., 2020). As for conservation agriculture, programs ranging from economic incentives to long-term technological packages have been launched by many countries to foster the adoption of sustainable agriculture by farmers (de Snoo et al., 2013). In the case of water resources for agricultural irrigation, negative incentives such as internal sanction systems are common to adjust consumption or withdrawals among water users for equitable access within a context of shared common pool resource (Ostrom, 1990).

1.1. Approaches to explain farmers' behaviors.

Understanding the determinants of behaviors is key to creating incentive systems seeking to foster specific decisions or to modify farmers' behavior (Home et al., 2014; Poppenborg and Koellner, 2013). Financial incentives, based on the assumption that producers behave in an economically rational way, have been the main instrument of public policy to promote better environmental management in conventional production systems (Birge et al., 2017; Burton and Paragahawewa, 2011), drawing on the premise that effective targeting is enough to positively influence pro-environmental behaviors (Hanley et al., 2012). The mode of operation of economic incentives on farmers' pro-environmental decision-making processes consists of linking present behaviors to future awards (Bhaskar and Beghin, 2007; Hanley et al., 2012).

However, according to de Krom (2017), explaining behavior based purely on the economic approach is indeed limited since it dismisses social factors of decisions, such social capital formation and cultural preferences. Numerous authors have pointed out that monetary incentives would not be sufficient to generate a sustainable behavioral change and that non-economic factors are also relevant in this regard, especially in the case of long-term decisions where internalizing environmental degradation and biodiversity loss is crucial (Birge et al., 2017; Burton and Paragahawewa, 2011; de Krom, 2017; de Snoo et al., 2013; Home et al., 2014; Kits et al., 2014). For example, payments for protecting birds, arachnids, and plants in different countries of Europe showed a limited effect on the richness and abundance of these species (Whittingham, 2007).

De Martino et al. (2017) points out that external monetary incentives do combine and interact with the intrinsic motivations of producers, such as pro-environmental attitudes and pre-existing subjective norms, leading to action or non-action that is sometimes inexplicable from the economic rationale. Furthermore, some authors have pointed out that monetary incentives could even reduce people's intrinsic motivation by making them dependent on an exogenous stimulus (De Martino et al., 2017; Deci et al., 1999), and that this displacement would be difficult to reverse once the incentive is removed (Chan et al., 2017; Kits et al., 2014). In this light, payments aimed at the realization of certain actions create an opportunistic financial motivation rather than a real motivation (Burton and Paragahawewa, 2011; de Snoo et al., 2013; Greiner et al., 2009), making behavior a conjunctural situation that depends on the continuity of the incentive (Birge et al., 2017; de Snoo et al., 2013; Olafsen et al., 2015; Siebert et al., 2006).

The recent literature on farmers' conservation behavior, despite recognizing the importance of financial motivations, has paid more attention to the socio-psychological dimensions guiding producers' behavior (Burton and Paragahawewa, 2011; Home et al., 2014; Poppenborg and Koellner, 2013). According to de Krom (2017), the growing recognition of the importance of social factors and values in farmers' behavior, such as pro-environmental attitude and pre-existing subjective norms, has played a corrective role to the reductionist view that economic capital is the only driving force of participation in incentive programs. Moreover, Malawska et al. (2014) argues that there is an alternative rationality as important as the economic one, based on cultural, social, or altruistic preferences. The underlying assumption is that producers will adopt a practice or technology only if there are expectations that it will help them to achieve their general objectives, including those of a financial, social, and environmental nature, which are among the most relevant (Greiner et al., 2009).

Furthermore, Burton (2014) conceptualizes a 'behavioral approach' that integrates motivational and structural/economic aspects of decisions and makes it suitable for investigating the response of producers to agricultural policy incentives, jointly considering economic, sociological, and psychological influences in the decision-making process of farmers (Siebert et al., 2006). On the other hand, Kits et al. (2014) studying the effect of monetary payments on pro-environmental behavior distinguished between internal and social motivations to explain behavior, where the former are based on utility, altruism, or commitment, while the latter are based on social norms and reciprocity. Other recent studies have also shown that personal norms play an influential role in long-term behavior (Bamberg and Moser, 2007; Burton and Paragahawewa, 2011; Kiatkawsin and Han, 2017) because they would be driven by inner convictions for carrying out certain behaviors considering others' opinions or socially desirable behaviors fostered by public incentives (de Snoo et al., 2013). In this regard, Pretty (2003) observed that if an incentive fails to generate changes at the level of social norms, people will tend to adopt the original behavior once the intervention ends.

From the social sciences, the concept of Social Capital and the Theory of Planned Behavior (Ajzen, 1991) also regard personal norms as an important driver of behaviors, and have been widely used in the agricultural incentive literature (Blackstock et al., 2010; Chouinard et al., 2016; Malawska et al., 2014; Mills et al., 2017). The quantity and quality of social networks, trust, and reciprocity norms from the social capital literature, as well as the attitudes, subjective norms, and self-efficacy to carry out certain actions as described by the Theory of Planned Behavior, represent individuals' intrinsic motivations within the decision-making process.

This thesis aims to analyze the role of different agricultural incentives within the context of ERPs, examining producers' decisions in three different sectors of Chilean agriculture.

1) First, the impact of the forestry incentive to establish forest plantations (DL701) on land use changes and the decision to seek income off-farm is estimated. The hypothesis is that an increase in forest plantations as result of the DL701 displaces traditional land uses and generates two effects: a) a greater availability of time since it is a non-labor-intensive activity, and b) a need to cover income in the short term. Therefore, the decision to change the use of land to forest plantations should result in a change of the income ratio from outside and within the property.

2) Next, the impact of the soil conservation incentive (SIRDS-S) on the adoption intensity of sustainable agricultural practices is analyzed. In this case, the hypothesis is that the incentive (extrinsic motivation) favors the adoption of practices, an effect that will be more pronounced in a scenario of low intrinsic motivation of producers, and not significant in the opposite case of high intrinsic motivation of producers.

3) Finally, the relationship is explored between group cooperation of irrigation users sharing a common water source and the characteristics of their Water Communities and leaders. The hypothesis in this case is that WUAs exhibiting high cooperation are characterized by having sanction systems and leaders with better personal characteristics, thus incentivizing collective actions.

Each of these incentives in the field of natural resources corresponds to a particular thesis chapter, which is organized in the modality of a scientific publication. Thus, the three scientific articles arising from each of the chapters are attached sequentially following the order indicated above. In the case of Chapter 1 and Chapter 2, they were published in the journals *Land Use Policy* (https://doi.org/10.1016/j.landusepol.2019.104308) and *Journal of Environmental Management* (https://doi.org/10.1016/j.jenvman.2019.04.107), respectively. In the case of Chapter 3, it was sent to *Water Resources Research* and is under peer review (reception e-mail is attached at the end of the chapter).

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2. First chapter

Are forest plantation subsidies affecting land use change and off-farm income? A farm-level analysis of Chilean small forest landowners

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Abstract

Forest plantations have increased rapidly in the last three decades, to a large extent due to direct and indirect financial incentives. At the farm level, forestry incentives can affect the investment decisions of small forest landowners and bring socioeconomic externalities or unintended effects associated with farm management. The purpose of this study is to assess the ex post impacts of a forestry subsidy on land use changes and off-farm income experienced by Chilean small forest landowners. A structural equation mediation model (SEM) was estimated using a time frame of 15 years (1998 – 2013). To reduce the selection bias, propensity score matching (PSM) was performed prior to the estimation of the SEM. Results indicate that the subsidy had a significant effect on land use changes, as it increases forest plantations and replaces pastures primarily, but also crops and native forest to a lesser extent. In addition, beneficiaries of the subsidy had a marginal increase in off-farm income not explained by the increase in forest plantation.

Keywords: Chilean forest policy, Forestry subsidy, Land use change, Off-farm income, Structural equation models.

2.1. Introduction

Worldwide forestry incentives have pursued two main objectives: economic development (Enters and Durst, 2004; Goetzl, 2006) and the recovery of degraded or deforested land (Bennett, 2007; Chazdon et al., 2017; FAO, 2016; Gregersen et al., 2011). Forest plantations increased from 168 million to 278 million hectares from 1999 to 2015 (Keenan et al., 2015), which accounts for a considerable landscape modification and displacement of prior land uses, shaping new farm structures with socio-economic effects in local rural communities (Torres et al., 2015; Williams and Schirmer, 2012). According to Whiteman (2003) and Gregersen et al. (2011), the majority of the world's forest plantations have been established with direct (e.g., subsidies) or indirect economic incentives. In fact, many countries in Latin America, Oceania, and Asia have implemented subsidy programs that allow private forestry firms to finance up to 90% of the establishment and management costs of plantations (Brown, 2000; Bull et al., 2006).

The large impact of forestry subsidies on rural landscapes has motivated an ample body of research dedicated to analyzing the effects on ecology, biodiversity, economic performance, poverty, and livelihood diversification. However, few studies have addressed the impact of subsidies on economically relevant decisions related to the farm production system and household income structure in order to provide deeper insights into the mechanisms underlying reported macro land use changes and socioeconomic consequences. One of the few exceptions is Liu and Lan (2015), who analyzed the impact of a forestry subsidy that sought to convert sloped agricultural land to forest or grassland. They found that beneficiaries of the subsidy program presented higher livelihood diversification due to switching their efforts from farming to extensive crops and off-farm activities. However, Liu and Lan (2015) did not examine the effect of the subsidy on land use changes, nor did they evaluate these activities as direct drivers of income diversification.

Because small and medium landowners are recognized to have diversified production systems, including forestry and agricultural activities (Kahan, 2013), we argue that a forestry subsidy leads to the following two related decisions. First, an increase of the area under forest plantations displaces traditional land uses, such as annual crops, pastures, and native forest; and, second, since forestry plantations are less labor-intensive, we expect more time to be dedicated to off-farm activities, leading to an increase in off-farm income. According to Liu and Lan (2015), substituting arable land with less labor-demanding activities generates a surplus of household labor that is diverted to off-farm income activities.

For the purposes of our study, we use the case of the Chilean forestry subsidy implemented from 1974 to 2012 by the Decree Law 701 (DL701). The subsidy helped raise forestry exports from USD $127 million to more than $5,000 million FOB (INFOR, 2017a), placing Chile as the country with the highest rates of afforestation (i.e., creation of a new forest plantation) and reforestation in South America (Nahuelhual et al., 2012). That said, the objectives of this study are: 1) to analyze the effect of the DL701 on the farm economic structure of small forest landowners, and 2) to measure the effect of any structural change on the proportion of off-farm income reported by landowners. To fulfill these objectives, we purposely focused on the second phase (between 1998 and 2012) of the DL701, centered on small landowners, for two reasons. First, small landowners have captured the least amount of funds since the subsidy went into effect in the sector (in 1974), which makes them more relevant in terms of economic and social impact analysis. Second, small landowners are characterized as being more diversified and dependent on farm income. Hence, analyzing the impact on farm structure and on the relation between farm and off-farm income can provide more insights about substitution effects on productive activities in the countryside. In this study, farm structure was divided in four main activities: crops (annual crops and fruit production), pasture (grasslands and sown pastures), native forest, and commercial forest plantations.

This paper is organized as follows. Section 2 describes the forestry sector in Chile and the DL701; section 3 presents the theoretical framework and methodology for testing our hypotheses; sections 4 and 5 present results and discussion, respectively; finally, section 6 presents the main conclusions.

2.2. The case of Chile and its forestry sector

Chile has experienced rapid economic growth in the last two decades, resulting in an increase in the GDP per capita from USD $8,655 in 1997 to USD $24,635 by 2017, based on purchasing power parity (World Bank, 2018). Primary industries composed around 14% of the total GDP by 2016 (INE, 2017), with mining, fresh fruits, and forest products being the top three export activities. From these, the forestry sector is considered to play a key role in the recent economic growth of the country (Salas et al., 2016).

Chile has roughly 17 million ha of total forest cover, of which three million ha are exotic forest plantations for commercial purposes and 14 million ha are native forests (INFOR, 2017b). Seventy percent of the forest plantations are located in southern Chile, between the regions of Biobío and Los Lagos. The area under forest plantation is distributed among almost 23,000 owners, 97% of whom are small forest landowners growing less than 200 ha (INFOR, 2017b). Forest plantations in the country are reduced, basically, to two exotic genuses: Pinus (68%) and Eucalyptus (23%), intended mainly to become sawn wood (37%) and cellulose pulp (36%), respectively (CONAF, 2019).

As mentioned earlier, the Chilean forestry sector was strongly enhanced by the DL701, subsidy that covered 75 - 90% of the estimated establishment and management costs of afforestation, plus tax benefits. Forest landowners who benefited from the subsidy have the obligation of reforesting the area (i.e., re-establishing the forest after harvesting). Thus, the DL701 was conceived to stimulate the rapid expansion of forest plantations and consolidate the forest industry (Miranda et al., 2017; Van Dijk and Savenije, 2009). With a total government investment of around US$ 475 million over 34 years, from 1976 to 2010 (CORMA, 2018), the DL701 helped to establish 60% of the actual national area of forest plantations (FAO, 2016).

In 1998, 24 years after its inception, the DL701 was reformed to focus specifically on diverting funds to small forest landowners (CONAF, 2017a). Up to this year, three large companies were the primary beneficiaries of the subsidy, capturing more than 80% of the state funds (Beattie, 1995); hence, in 1998 the focus of the program changed to reverse this situation. Thus, the subsidy can be divided in two distinct phases: a first phase, from 1974 to 1998, that promoted the forest industry, and a second phase, from 1998 to 2012, that promoted forestry by small landowners. Besides focusing on small landowners, the second phase also aimed to direct resources to indigenous people and degraded land for conservation purposes, covering establishment costs of up to 90% for the first 15 planted hectares (Van Dijk and Savenije, 2009). In the second phase, the DL701 imposed four compulsory conditions on applicants (PUC, 2014): a) to work the land directly, b) to work an area with less than 12 HRB[1], c) possess assets not exceeding 3,500 UF (or US$ 150,000), and d) family income coming primarily from farm production. Also, beneficiaries must own soils appropriate for forestry: that is, those in the process of desertification, degraded soils, or soils with slopes greater than 100%.

As expected, during the period 1991-1998, only 12% of the total afforested area was established by smallholders, while during the second phase (1998-2014), this area reaches 37%. On the other hand, the total reforested area during the 10-year period before the 1998 reform reached 331,759 ha, but by the end of the following 10-year period it was 645,552 ha (CONAF, 2019), which could be explained by the requirement that recipients of the subsidy reforest the afforested area after harvesting. In the case of smallholders, the reforested area before the 1998 reform is almost nonexistent, reflecting the low participation of small landowners in the DL701. Although this group had a minimal impact on the national statistics, the reform of 1998 apparently achieved the desired effect of persuading small landowners to join the afforestation business.

2.3. Data and Methods

2.3.1. Data

The study was conducted in four regions of south-central Chile that make up 87% of the national planted land with forest plantations, namely: Maule, Biobío, La Araucanía, and Los Lagos. The period under analysis corresponds to the second phase of the DL701 (between 1998 and 2012), which targeted small forest landowners. The sample was divided into two groups: beneficiaries and non-beneficiaries of the subsidy, in which both groups comply with the eligibility criteria of being beneficiary of the program. That is, 1) to have soils with preferably forestry aptitude (i.e., degraded and sloped lands not suitable for agricultural production), evidenced in a management plan to establish forest plantations that must be presented in the Corporación Nacional Forestal

[1] In Chile, the Hectare Basic Equivalent (HRB) corresponds to an equivalence of physical hectares in terms of its productive capacity. The 1:1 equivalence was established using the irrigated lands of Central Chile (Maipo Valley) as a reference, due to its excellent agro-climatic and soil conditions.

(CONAF), and 2) that the applicant must be within the category of small scale landowner (i.e., having a maximum surface of 12 HRB). Accordingly, the sampling procedure was carried out in two steps. First, the group of beneficiaries was selected randomly and stratified by agro-ecological areas, namely interior dryland, central valley, and foothills, from a list of beneficiaries of the program. This selection list corresponded to the 2001-2003 cohort of beneficiaries of the National Forest Corporation Cadastral (PUC, 2014). As a second step, the control group was selected from two sources: rejected applicants listed in the Cadastral and small forest landowners personally contacted on site. In order to assure that this last group is eligible for the program, the selection was conditioned to filter questions before starting the survey using the two criteria explained above.

A survey was designed and administered to small forest landowners who already had forest plantations at the time of the survey, either subsidized or not. One additional requirement to respond to the survey was that the interviewee was living or in charge of the administration of the property in both 1998 and 2013; otherwise, the survey was not carried out. Thus, the survey was conducted in 2013 gathering socioeconomic information as well as land uses. In particular, small forest landowners self-reported the number of hectares dedicated to forest plantations, crops, pastures, and native forest in both 1998 and 2013, as well as the percentage of total income coming from within and outside the farm in 2013. The sample size was 602 valid observations, after removing outliers and missing values from the dataset.

2.3.2. Database treatment

Given the clear possibility of selection bias in the non-random assignment process of the DL701, beneficiaries and non-beneficiaries were paired in a matched sample using propensity score matching (PSM) (Mishra et al., 2015). We performed a logit regression as a participation model, using a set of traditional independent variables (Abebaw and Haile, 2013; PUC, 2014; Pufahl and Weiss, 2009), in particular, time invariant variables such as age, gender, education, indigenous, belonging to the 8th or 10th region; and baseline variables (i.e., in 1998), such as cultivated area, cattle production, water access at home, and having previous forestry experience. We keep these variables as they provide a good understanding of the local context in which the program is being introduced and good-quality information (Dehejia, 2005) (See Table A1 in the Appendices). The matching estimator used was one-to-one nearest neighbor without replacement (Rubin and Thomas, 1996), using a caliper of 0.025, considering that the standard deviation of the treatment variable was 0.1.

As an additional robustness check it was applied the Wilcoxon's signed rank test to the matched sample in order to compare between groups the outcome variable, surface of forest plantations established in 2013. Additionally, we checked the robustness of the estimated results with the sensitivity test proposed by Rosenbaum (2005). Essentially, the test aims at detecting potential hidden bias due to unobservable variables (Becker and Caliendo, 2007). The output of the participation model, the magnitude of imbalance reduction, and the sensitivity analysis after matching are presented in the Appendices (Tables A1, A2, and A3).

2.3.3. Empirical model

According to our objectives, the main hypotheses of the model are that the DL701 had a positive effect on the allocation of land dedicated to forest plantations, having as a consequence the substitution of prior economic activities of the farm, namely annual crops, native forests, and grassland. In addition, the new farm structure implies a reallocation of labor from on- to off-farm employment due to forest plantations being less labor-demanding than farming, resulting in a greater off-farm income.

To test these hypotheses, we propose a structural equation mediation model (SEM). As Fairchild et al. (2015) point out, mediation models allow for the identification of the mechanisms underlying the relationship between two or more variables, which in this case correspond to the effect of the DL701 on farm structure (i.e., land allocation) and, simultaneously, income structure (i.e., off-farm income). This process represents a causal chain of events where an independent variable is related to the dependent variable through a direct and indirect effect. Assuming that the variable P has an effect a on a mediating variable M that also affects the outcome variable Y with the magnitude b. P may still have a direct effect c on Y. Hence, the total effect of P on Y will be (a * b + c).

The specification of the SEM includes the subsidy (DL701), which affects land use changes in forest plantations (FOR), native forests (NAT), crops (CROP) and pastures (PAST) between 1998 and 2013, as well as the proportion of off-farm income within total income (OFF) in 2013. The variables of land use change were calculated as the simple difference in surface area (in hectares) between 1998 and 2013. In our model, FOR acts as mediator between the DL701 and the land use changes (i.e., NAT, CROP, and PAST), as well as between the DL701 and OFF. It is important to note that in spite of this logical chain of indirect relationships through the mediating variable FOR, the independent variable DL701 may also have a direct effect on the dependent variables PAST, CROP, NAT, and OFF. Thus, the resulting model considers two mediation processes simultaneously (Figure 1) and has five dependent variables that give rise to five equations, each with its own error terms. It is worth noting that in the case of PAST, CROP, and NAT, correlations were allowed because these are substitutable activities amongst themselves and with regard to FOR.

A set of control variables was also included in the model since household characteristics are relevant to the well-being status of small forest landowners (Mendola, 2007). Size of the farm, educational level, participation in community organizations or associations, gender, age, family size and ethnic origin were used in the FOR and OFF equations; region and agricultural specialization in 1998 (estimated as percentage of crops within total cultivated area) were included across all equations. The described model was estimated in STATA 15.1[2].

[2] StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC.

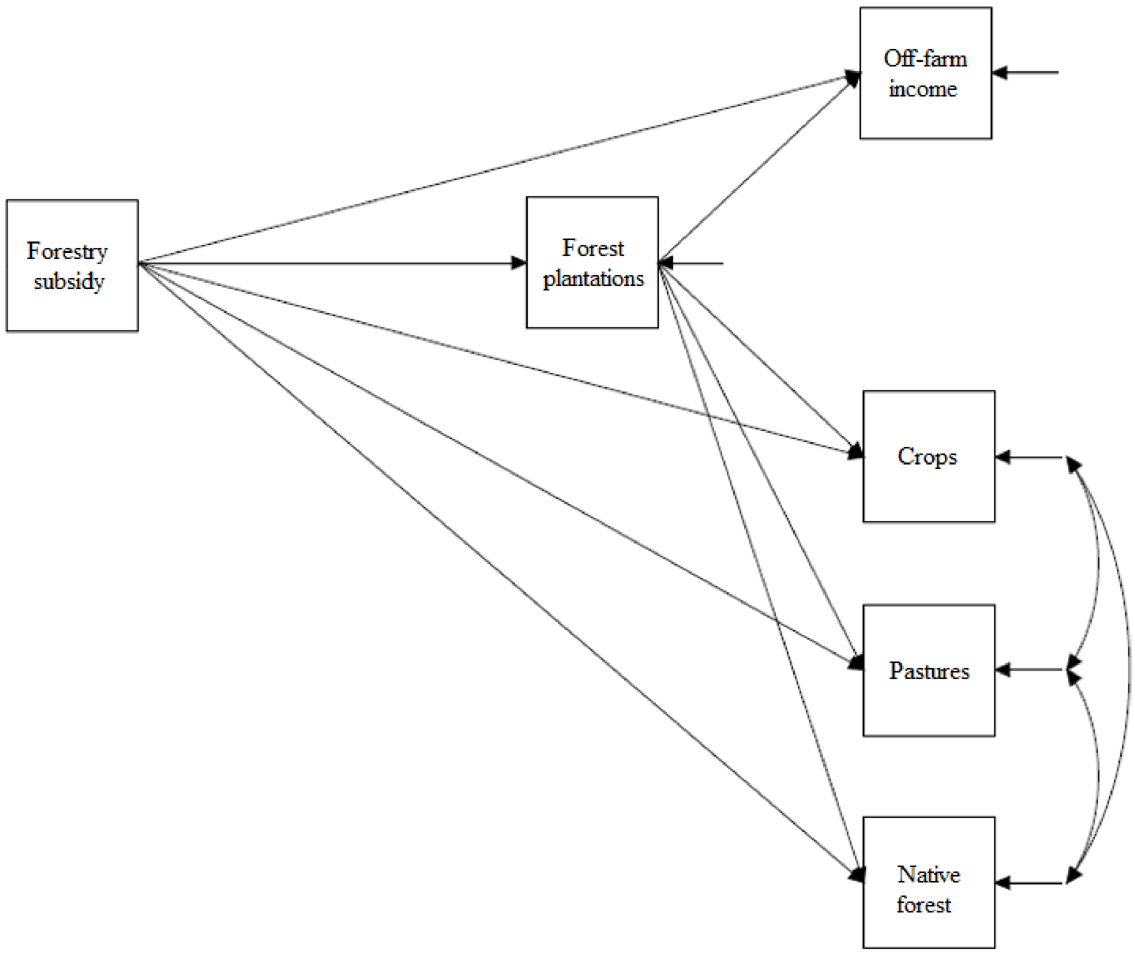

Figure 1. Structural equation mediation model of the impact of the forestry subsidy on land use changes (between 1998 and 2013) and off-farm income (2013)

2.4. Results

2.4.1. Descriptive statistics

The original sample consisted in 602 small scale owners complying with the eligibility criteria of the DL701 program, from which 314 received the subsidy and 288 did not. After one-to-one PSM, the sample was reduced from 602 to 472 observations to be used in the subsequent analysis (236 matched pairs of beneficiaries and non-beneficiaries). The overall imbalance correction was notable, reducing the mean bias from 11.3 in the unmatched sample to 1.9 in the matched sample. The results of the logit and imbalance reduction per variable are presented in the appendices

(Tables A1 and A2). Regarding the robustness of the matched sample, the Wilcoxon's signed rank test difference between treated and control small landowners in terms of the outcome variable used in the matching procedure, with $p < 0.0004$ (null hypothesis: no difference between groups). According to Rosenbaum (2005), this significance level is adequate for a randomized experiment, giving support to the quasi-experimental design used in this study.

Moreover, the Rosenbaum's sensitivity test revealed that even if with an unobserved heterogeneity of 30% (Gamma =1.3), inference about the treatment effect would be the same, with 95% confidence (Table A3 in the Appendices) [3]. Descriptive statistics of the variables involved in the mediation model performed after PSM are presented in Table 1.

Table 1. Descriptive statistics of the variables after matching (472 observations).

Code	Variable name	Beneficiaries (236 obs.)	Non-beneficiaries (236 obs.)	T-test [a]
FOR	Change in forest plantations between 1998 and 2013 (hectares)	6.4	3.7	***
CROP	Change in crops between 1998 and 2013 (hectares)	-1.4	-1.4	NS
PAST	Change in pastures between 1998 and 2013 (hectares)	-2.9	-0.4	***
NAT	Change in native forest between 1998 and 2013 (hectares)	-1.3	-0.4	**
OFF	Proportion of off-farm income in 2013 (percentage)	49.9	43.9	*
HA	Total surface in 2013 (hectares)	21.5	22.2	NS
EDU	Educational level in 2013 (1= more than primary education, 0= IOC[b]; percentage)	25.8	26.3	NS

[3] Stratified PSM was also performed confirming the robustness of the matching results.

ORG	Participation in any type of association in 2013 (1= yes, 0= no; percentage)	77.1	72.9	NS
IND	Being indigenous in 2013 (1= yes, 0= no; percentage)	23.7	23.3	NS
AGE	Age in 2013 (years)	60.1	60.2	NS
FAM	Size of the family in 2013 (number of members)	3.3	3.2	NS
GEN	Gender in 2013 (1= Female, 0= Male; percentage)	26.7	28.0	NS
ESPEC	Crop surface of total cultivated area in 1998 (percentage)	19.6	20.5	NS
REG7	Belonging to Maule region (percentage)	18.6	16.1	NS
REG8	Belonging to Biobío region (percentage)	36.0	36.9	NS
REG9	Belonging to Araucanía region (percentage)	30.5	31.4	NS
REG10	Belonging to the regions Los Lagos / Los Ríos (percentage)	14.8	15.7	NS

[a] Significance level ***:P < 0.01; **: P < 0.05; *: P < 0.1; NS = "not statistically significant". [b] IOC = "in other case".

Table 1 shows a pattern of land use change between 1998 and 2013 for both beneficiaries and non-beneficiaries of the subsidy, where the area of forest plantations increased while the area of crops, pastures, and native forest decreased. These changes in land uses, along with off-farm income in 2013, are the only variables that present statistically significant differences between the two groups in the sample. The biggest differences can be seen in forest plantations and pastures. It can also be observed that off-farm income, although marginally significant, is higher for the beneficiary group. This fact gives some insight into the hypothesis that forest plantations lead to an increase in off-farm activities.

As expected, no statistically significant differences between beneficiaries and non-beneficiaries were found in socio-economic variables after the matching procedure. Summarizing the descriptive statistics for the whole sample and without distinguishing between groups, the average age of participants was 60 years, and only 26% had more than primary school education. This is consistent with other studies that have found that in Chilean rural areas the population is old and possesses a low level of education (Engler et al., 2016; Jara-Rojas et al., 2013). The average size of farms is 22 ha, and of this, 20% was dedicated to agriculture in 1998. The family size is around three persons, women were the heads of the household in 27% of the sample, and 24% of small forest landowners considered themselves indigenous.

2.4.2. Effect of the forestry subsidy on land use change

The overall fit of the mediation model was good with a CFI/TLI and RMSEA of 0.993/0.977 and 0.022, respectively (Marsh et al., 2004). The correlation coefficient (r2) is significant at 0.001% confidence for each of the five equations ranged from 0.12 and 0.46, which is acceptable for SEM (Muthen, 2008). Results of the model, goodness of fit and the estimated coefficients are presented in Table 2.

It is worth noting that some of the control variables included in FOR were omitted in PAST, NAT, and CROP due to convergence problems, which is due to that these equations are allowed for correlation, as shown in Figure 1. In addition, as a preliminary validation of the SEM, the different equations included in it were verified separately in order to evaluate the proposed mediation relationships (Kenny, 2020). The parameters obtained from these separate estimations were similar in terms of significance and magnitude to those obtained through the SEM model. However, they did not shed light on the indirect effects found in the latter.

Results of the SEM indicate that the subsidy generated changes in land use at the farm level. The positive effect of the DL701 on FOR reveals that, between 1998 and 2013, beneficiaries of the program had on average 2.9 additional hectares of forest plantations. In addition, the DL701 had a direct negative effect on PAST, where beneficiaries of the subsidy reduced the area of pastures by an average of 1.6 hectares compared to non-beneficiaries. Additionally, the DL701 had a direct positive effect on CROP (with 90% confidence level) and no significant impact on NAT. However, we can observe a significant indirect effect of the DL701 on these two land uses, which is operating through the increase in FOR. In fact, the increase in forest plantations affected all the prior and traditional land uses, since FOR had a negative effect on PAST, NAT, and CROP, with reductions of 0.30, 0.15 and 0.27 hectares, respectively (Figure 1).

To estimate the indirect impact of the subsidy (i.e., through the increase in forest plantations), it is necessary to multiply the effect of the DL701 on FOR by the effect of FOR on each CROP, NAT, and PAST (see regression coefficients in Table 2). By doing so, the indirect effect of the DL701 was -0.78 for crops, -0.42 for native forest, and -0.88 for pastures, which represent the average reduction in hectares of traditional land uses as a result of an increase in one hectare of forest plantations. In the case of PAST, the total effect of the DL701 was estimated by adding the direct and indirect effects, which resulted in an aggregated loss of 2.5 hectares. This means that, just by being beneficiaries of the subsidy, small forest landowners reduced the area of pastures by about 2.5 hectares. As for CROP, the indirect effect of -0.78 must be added to the direct effect of 0.63 hectares, resulting in a negative total effect of 0.15 hectares. Although the direct effect was unexpected and counterintuitive, it is barely significant. It is relevant to notice that in the final analysis of results the total effect is mainly explained by the indirect effect.

To give context to these results, the average cultivated area per small landowner in 1998 was 17.1 hectares, including forest plantations, crops, pastures, and native forest. Hence, the average increase of 2.9 hectares in forest plantations due to the DL701 represents a 17% positive change during the period. From another perspective, the average surface of forest plantations established by beneficiaries in our sample increased by 6.4 hectares in the study period (from 2.7 ha in 1998 to 9.1 ha in 2013), of which the 2.9 additional hectares attributed to the DL701 represents 45%. This simple impact quantification makes explicit the impact of the DL701 on the extent of forest plantations established by beneficiaries of the subsidy. In practice, small forest landowners almost doubled the area dedicated to forest plantations as result of being recipients of the subsidy. Finally, considering that in 2013 the average area under production was very similar to that of 1998 (18.3 vs. 17.1 ha, not statistically different and minimal when looking at each case separately), on the basis of estimated net changes associated with each use, we can argue that during this period there were substitutions among subsidized forest plantations, crops, pastures, and native forest.

With regard to the control variables, we observed that REGION[4] was significant in equations of CROP and NAT at a 95% confidence level, but not for PAST and FOR. For CROP, the positive coefficients in the southern regions (Biobío, La Araucanía, and Los Lagos) compared to the Maule Region show that the reduction in hectares of crops was lower, which is a good reflection of what was actually observed in the country. According to our data, the Maule region registered an average reduction in cropping area of 55% per farm, while the Biobío, La Araucanía, and Los Lagos regions registered average reductions of 32%, 34% and 38%, respectively. In the NAT equation, the variable REGION was also significant and positive, which is reasonable considering that southern regions naturally concentrate a higher percentage of native forest and, therefore, present better conditions for regeneration (INFOR, 2015). Finally, in the case of FOR and PAST, there was no significant effect of REGION, indicating that the geographic location was irrelevant in explaining changes in pastures and forest plantations. This implies that, in general, the impact of the DL701 was similar across all regions.

Crop specialization in 1998 (ESPEC), measured as the proportion of crops within the total cultivated area (in hectares), was negatively related to CROP and positively related to FOR and PAST. These results suggest a larger replacement of crop area in more specialized and intensive farms, which should be more likely to diversify their portfolios. On the other hand, the null effect of ESPEC on NAT indicates that in crop-intensive farming systems there is no displacement of native forest. This is probably because in most of these cases the land allocated to native forest was rather low (the correlation coefficient between NAT and CROP by 1998 is 5.7%).

Finally, farm size, education, and belonging to organizations or associations that we used in the FOR equation were statistically significant. Forest plantations increased by 0.13 hectares per each hectare of farm size, and by 2.3 hectares if the small forest landowner had completed primary school. On the contrary, belonging to community organizations was associated with a reduction in forest plantations by 1.7 hectares. Sociodemographic variables included in FOR such as age, gender, being indigenous, and number of family members were not statistically significant.

[4] The reference corresponds to Maule (the northernmost region, coded as REG7).

2.4.3. Effect of the forestry subsidy on off-farm income

We found evidence that the subsidy was positively related to OFF, with a 90% confidence level, where beneficiaries showed a 5.4% increase in off-farm income within total income compared to non-beneficiaries. However, this effect was not related to the increase in subsidized forest plantations reported in section 4.2. FOR did not affect the small landowners' off-farm income, implying that it did not result in a significant release of labor to be allocated to off-farm activities. On the other hand, REGION was a determinant in the equation of OFF, showing that southern regions presented progressively lower off-farm income. Regarding human and physical capital, when small forest landowners had completed primary school, the proportion of off-farm income increased around 11%, in contrast to farm size, which was associated with a decrease in off-farm income by 0.42% per additional hectare. Because larger forest landowners can generate higher income with farming activities, they have less need to engage in off-farm activities. The effect of belonging to any community organization was negative and significant, being associated with 12% less off-farm income. This variable captures the landowners' participation in neighborhood committees, attending church, or football clubs.

Personal characteristics of small forest landowners were also evaluated in the OFF equation as a determinant of the decision to engage in off-farm activities. As expected, being indigenous is highly significant and negatively related to the percentage of off-farm income (19% reduction). Age was marginally significant and positive ($p < 0.1$), which could be explained by the percentage of retirement pensions. Finally, gender and number of family members were also positive and significant in the model of OFF, indicating that women have 6% more off-farm income than men, and that for each additional family member the proportion of off-farm income increases by 3%.

Table 2. Estimation results of the mediation model of land use changes between 1998 and 2013, and off-farm income by 2013. N= 471 obs.

Variables	FOR	CROP	NAT	PAST	OFF
DL701	2.88 ***	0.63 *	-0.46	-1.61 ***	5.39 *
FOR	-	-0.27 ***	-0.15 ***	-0.30 ***	0.19
HA	0.13 ***	-	-	-	-0.42 ***
EDU	2.34 ***	-	-	-	10.60 ***
ORG	-1.75 **	-	-	-	-11.79 ***
IND	-1.56	-	-	-	-18.89 ***
AGE	0.01	-	-	-	0.21 *
FAM	0.32	-	-	-	3.26 ***
GEN	0,76	-	-	-	6.20 *
ESPEC	3.11 **	-9.07 ***	0.90	4.34 ***	-8.32
REG8	-0.45	1.74 ***	1.70 ***	-1.37 *	-7.54 *
REG9	-0.03	0.91 **	1.60 ***	0.12	-18.73 ***
REG10	-0.76	1.19	1.09	0.39	-23.06 **
Significance level ***:P < 0.01; **: P < 0.05; *: P < 0.1					
R-square	0.19 ***	0.46 ***	0.21 ***	0.12 ***	0.22 ***
RMSEA	0.022 (90% CI: 0.00 - 0.045)				
CFI / TLI	0.993 / 0.977				

2.5. Discussion

Our main aim was to estimate the impact, at the individual level, of the farm productive and income structure of the forest subsidy. Our results show that engaging in subsidized forest plantations implies a rearrangement of farming activities and, eventually, the diversion into off-farm activities. The Chilean forestry subsidy DL701 modified farm structure directly and indirectly by changing the share of various productive activities in the small forest landowners' portfolio and by increasing the extent of forest plantations and decreasing hectares dedicated to crops, native forests, and pastures. Additionally, we found a positive correlation between the DL701 and off-farm income.

The change of farm structure evidenced in this study is consistent with the findings of Capitanio et al. (2014), who stated that farm incentives lead forest landowners to alter their cropping system and practices, affecting not only the promoted activity but also the coexisting activities. Indeed, Kristensen et al., (2016) have found that afforestation is one of the main reasons for land use extensification in European rural landscapes. However, the change in farm structure implies a change not only in income sources but also in the cash flow of the productive systems. Unlike annual crops or fruit production, most income from forest plantations comes only at the end of the cycle, with a long time period between the investment and harvest (FAO, 2003). These results are not trivial, since small forest landowners used to be the main inhabitants of rural communities surrounded by forest plantations, and they are typically considered more vulnerable than larger producers because they lack physical, human, and social capital. These results open questions regarding the impact of the changing farm and income structures over time on the poverty and vulnerability status of small forest landowners as a result of the DL701, which are beyond the scope of this research.

However, this paper found some interesting results regarding the relationship between physical, human, and social capital and forest plantations and off-farm income. For instance, the negative relationship of belonging to community organizations with forest plantations and off-farm income can be related to what is explained by the literature as dark social capital, that links cohesive or closed groups with a low rate of innovation (King et al., 2019). On the other hand, our results showed that educational level had a positive effect on both forest plantations and off-farm income due to higher human capital leading to better managerial skills for taking advantage of economic opportunities or new businesses (Handschuch et al., 2013; Wouterse, 2016). Finally, the negative relationship between physical capital and off farm income was expected since small landowners with higher level of resources and larger in scale can generate higher on-farm earnings requiring to spend more hours in the farm.

In addition, we can provide some insights about particular changes that the subsidy triggered for previous land uses as result of the increase in forest plantations. We found negative direct and indirect effects of the DL701 on PAST that can be explained by the legal requirements of the subsidy. The law established that forest plantations should be planted in soils with preferably forestry aptitude (i.e., degraded and sloped lands) (CONAF, 2017b), areas that tend to be occupied by natural pastures. In fact, a large part of the area under study is drylands, where the predominant grassland (called espinales) is a natural ecosystem of low productivity with increasing soil degradation (Martín-Forés et al., 2014; Martinez et al., 2010).

In the case of CROP and NAT, the DL701 presents a negative total effect, implying a displacement of land through the increase of FOR. As for CROP, there is a positive direct effect that is off-set by a strong and highly significant indirect effect. A possible explanation for the negative effect is that forest plantations are replacing crop cultivation established on degraded soils with a more suitable and profitable activity. It is relevant to notice that small forest landowners were not allowed to replace arable land even when they wanted to. The requirements to apply for the subsidy established by law do not include flat lands since they have higher levels of soil fertility, where crop production tends to be located (i.e., they do not qualify as soils with preferably forestry aptitude). This fact has been also noted by Martín-Forés et al. (2014), who observed that many owners have turned their traditional farming activities to forest plantation. Similarly, the lack of direct impact of the DL701 on NAT could be explained by the Native Forest Law (N° 20,283 of 2008) that prevents replacement and intense exploitation of native forests (CONAF, 2017c). Bowers (2005) also mentioned that the DL701 favors those with the lowest opportunity costs of compliance with the policy (e.g., those with the highest valued standing timber or with the cheapest land for further planting).

The results of our study do not allow us to identify impacts on farm income fluctuations throughout the years, since this will depend on the gross margins generated by each productive activity in the field throughout their entire production cycle, such as crops, pastures, native forests, and forest plantations. However, we can give possible explanations for why small landowners are replacing productive activities that generate income in the short run with forest plantations that give long term returns. First, if forest plantations are established in marginal areas with low rates of profitability, we would expect short-run income flow not to be affected. Therefore, the decision to afforest can be seen as an investment in retirement income, an argument that has been mentioned in situ by small forest landowners. In addition, forestry is an extensive activity requiring minimal attention, with lower production risks and management requirements; hence, a productive activity that implies less effort can compensate for lower short-run income.

Regarding the second hypothesis, that the DL701 has fostered a change in the relationship between farm and off-farm income as result of the increase in forest plantations, the results show, albeit marginally, that the subsidy had a positive impact on off-farm income. However, and contrary to our hypothesis, the effect of FOR on OFF was not significant. Combining these effects, the low direct impact and null indirect impact of the DL701 on OFF prevents us from concluding that subsidized forest plantations clearly affected off-farm income. We cannot give a satisfactory explanation for this result other than the limited possibilities of finding jobs where small forest landowners are usually located: rural areas with low connectivity. In addition, landowners who lack training and professional skills have fewer chances to get access to off-farm opportunities and earn money outside the farm (Liu et al., 2018). The lack of training is likely associated with the low rate of educational level presented in the descriptive statistics of section 4.1: only a quarter of the total sample has finished primary school. In fact, a study of the welfare effects of the DL701 found that counties with higher rates of subsidized forest plantations presented higher rates of poverty, underscoring that forest plantations create less employment than alternative productive systems, such as agriculture and livestock (Anríquez et al., 2018).

An analysis of sociodemographic factors can give us deeper insights into what explains the differences in off-farm income structure between beneficiaries and non-beneficiaries of the subsidy. As expected, we found that indigenous small landowners exhibit a lower rate of off-farm income, which is consistent with studies that conclude that ethnicity has a negative effect on off-farm jobs (Loaiza et al., 2015). The positive effect of gender, in which woman have higher off-farm income was unexpected; however, the literature also present mixed results regarding this relation. On one side, it has been shown a lower off-farm employment in the case of woman due to less job opportunities and lower payment (Doblhammer and Gumà, 2018); and on the other side it has also been argued that when agricultural activities do not generate enough income to sustain the family, women assume the responsibility of providing additional income, which has been called the breadwinner role (Kelly and Shortall, 2002). We also noticed that northern regions tended to have a higher proportion of OFF compared to southern regions. This hypothesis is supported by employment statistics in the forest and agricultural sector by region (ODEPA, 2019).

For comparison, the Maule region in 2017 captured 16.8% of the national agricultural employment and represented 27.6% of the total regional employment. For its part, the Biobío region captured

13.3% of the total agricultural workforce and 11.5% of the regional employment. Similarly, the participation of La Araucanía region was 11.9% and 21.9%, respectively. As can be seen, since most of the intensive labor agricultural activities are concentrated in the Maule region, we would expect small forest landowners to have more job opportunities and possibilities to diversify incomes. According to ODEPA (2018), waged employment in agriculture, which represents the closest opportunity for a small landowner, is higher in Maule (90,574 people) compared to southern regions, such as Biobío (70,183 people), La Araucanía (58,125), and Los Lagos (34,139).

Overall, our results at the farm level confirm the substitution effect seen at a larger scale level as result of the DL701. The subsidy has provoked a change in small forest landowners' activities, not only in those of the large companies that have contributed to the reported macro-impacts. Recognizing the latter raises questions related to the impact of subsidy programs in general, for example, how portfolio rearrangement affects the vulnerability of natural and productive systems to climatic shocks, and how this change affects the income flow of small landowners. Policy makers need to consider social, economic, and environmental implications of forestry subsidies not only at the aggregate level but also at the individual level due to the high diversity that exists among farmers.

However, our study presents some limitations that must be recognized. The fact that the control group included small forest landowners contacted *in situ*, in addition to those from administrative records, implies heterogeneity in the control group. Despite that the eligibility criteria to apply for the DL701 was verified in the field work and that the sample was subject to PSM to reduce bias selection, it still may represent an issue for the causal estimation. Another aspect that affects the causality of our inferences in evaluating farm structure changes is the possibility that small forest landowners had buy, sell or rent land during the analysis period. However, it is also relevant to point out that there were no significant differences between the total cultivated area between 1998 and 2013, on average, and scarce when comparing case-by-case. On other hand, we recognize as limitation that our study is based on retrospective information with respect to 15 years ago, which is subject to a higher level of error than variables consulted in present time.

As recommendation for future work, it would be interesting to deepen the effect of forestry subsidies by considering the heterogeneity of small forest landowners, such as the region of location and their personal characteristics. In our study these variables were used as controls, however, they open opportunities to explore differentiated impacts.

2.6. Conclusions

Subsidies for afforestation have proven to be effective in increasing forest plantations, but policy analysis should also consider social, economic, and environmental externalities. Our study modeled land use decisions and off-farm income of small forest landowners derived from a forestry subsidy that covered a large part of the establishment costs of forest plantations in Chile. Using an approach of structural equations with two-occasion data, the results show the importance of subsidies on the decision-making processes of small forest landowners. Beneficiaries rearranged their portfolios, prioritizing the subsidized activity over traditional existing land uses, namely crops, pastures, and native forest. We found an increase in forest plantations and decreasing pasturage hectares, but also a decrease in crops and native forest.

Despite the possibility that less labor-demanding activities (e.g., forest plantations) might lead farmers to seek additional income sources outside the farm, we did not find evidence that forest plantations by themselves have any influence on the percentage of off-farm income. This finding has implications for policy makers in terms of the activities that are being replaced as result of subsidies. Considering that shifting farm structures not only have an impact on land use change and off-farm income, and also on the livelihoods of rural people, more research is needed into the deeper socioeconomic externalities of agricultural subsidies, such as rural migration. This would allow stakeholders to better understand and forecast potential consequences of public policy and, thus, design effective programs to promote more sustainable development.

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2.8. Appendices

Table A1. Logit model's output to estimate the propensity to participate in the forestry program. N= 602 obs.

Variables	Coefficient	Standard error	P-value [a]
Age (years)	0.056	0.033	*
Age squared	-0.001	0.000	NS
Gender (female)	0.143	0.193	NS
Education (over primary school)	-0.193	0.216	NS
Indigenous	-0.141	0.230	NS
Individual owners	0.530	0.259	**
Cultivated area in 1998 (ha)	0.008	0.004	**
Having cattle in 1998	-0.464	0.205	**
Belonging to 8th region	1.052	0.268	***
Belonging to 9th region	0.931	0.297	***
Belonging to 10th region	0.718	0.327	**
Having water network at home in 1998	0.529	0.278	*
Distance to paved to road (km)	0.015	0.008	*
Having forestry experience in 1998	0.596	0.186	***
Constant	-2.679	0.831	***

[a] Significance level ***: P < 0.01; **: P < 0.05; *: P < 0.1; NS means "not statistically significant".

Output statistics: Prob > chi^2 = 0.0000; Log likelihood = -393.245; Pseudo R^2 = 0.056

Table A2. Imbalance reduction after propensity score matching (from 602 unmatched obs. to 472 matched obs.).

Variable	Sample	Mean		Bias reduction	T-test[a]
		Beneficiary	Non-benef.	(%)	
Age (years)	Unmatched	45.5	43.9		NS
	Matched	45.1	45.2	94.6	NS
Age squared	Unmatched	2243.5	2134.1		NS
	Matched	2225.1	2220.6	96.0	NS
Gender (female)	Unmatched	0.30	0.28		NS
	Matched	0.27	0.28	30.9	NS
Education (over primary school)	Unmatched	0.27	0.27		NS
	Matched	0.26	0.26	-27.7	NS
Indigenous	Unmatched	0.21	0.25		NS
	Matched	0.24	0.23	89.4	NS
Individual owners	Unmatched	0.89	0.83		**
	Matched	0.86	0.87	69.3	NS
Cultivated area in 1998 (ha)	Unmatched	19.1	16.6		NS
	Matched	17.1	17.1	98.0	NS
Having cattle in 1998	Unmatched	0.67	0.75		**
	Matched	0.75	0.72	68.6	NS
Belonging to 8th region	Unmatched	0.42	0.33		**
	Matched	0.36	0.37	91.0	NS
Belonging to 9th region	Unmatched	0.29	0.31		NS
	Matched	0.31	0.31	55.2	NS
Belonging to 10th region	Unmatched	0.14	0.16		NS
	Matched	0.15	0.16	48.4	NS
Having water network in 1998	Unmatched	0.18	0.13		*
	Matched	0.14	0.14	92.1	NS

Distance to paved to road (km)	Unmatched	14.1	9.6		**
	Matched	10.6	10.0	85.8	NS
Having forestry experience in 1998	Unmatched	0.43	0.33		**
	Matched	0.35	0.35	95.6	NS

Sample	Ps R2	p > chi2	Mean bias	Median bias	% Var
Unmatched	0.056	0.000	11.3	10.8	50
Matched	0.004	0.999	1.9	1.5	50

[a] Significance level ***: P < 0.01; **: P < 0.05; *: P < 0.1; NS means “not statistically significant”.

Table A3. Rosenbaum’s sensitivity bound analysis after running the propensity score matching.

Gamma*	Range of significance levels	
1.0	0.0001749	0.0001749
1.1	0.0000126	0.0016118
1.2	0.0000008	0.0087378
1.3	< 0.0000000	0.0316496
1.4	< 0.0000000	0.0839771
1.5	< 0.0000000	0.1748283

* Corresponds to different levels of hidden bias

3. Second chapter

The role of farmers' intrinsic motivation in the effectiveness of policy incentives to promote sustainable agricultural practices

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Abstract

This paper examines the effectiveness of intrinsic and extrinsic motivations on the adoption intensity of sustainable agricultural practices (SAPs) among annual crop farmers in Chile. We use the farmers' attitude towards SAPs as a proxy of intrinsic motivation, while extrinsic motivation is represented by an economic incentive to promote the use of SAPs. The policy program we studied is administered by the Chilean Ministry of Agriculture under the name System of Incentives for the Agro-Environmental Sustainability of Degraded Soils (SIRSD-S). Sustainable behaviour was defined as the adoption of (1) minimum tillage, (2) improved fallow, (3) stubble incorporation, (4) use of manure, and (5) use of compost. A count model was estimated that showed that both sources of motivation, and the interaction between them, significantly predicted the adoption of SAPs. Farmers with low levels of intrinsic motivation depended largely on the SIRSD-S to adopt SAPs, while the incentive was ineffective for intrinsically motivated farmers who adopted more SAPs regardless the presence of extrinsic motivation. Finally, the perception of risk of soil erosion and perceived behavioural control of this risk were found to play a positive role in the adoption of SAPs.

Keywords:

Agricultural practices, Count model, Economic incentive, Farmer's motivation, Sustainable behaviour, Technology adoption.

3.1. Introduction

Worldwide contemporary agriculture is characterized by the intensive use of inputs and soil tillage, which, in addition to conventional practices of removal and burning of stubble, have generated nutritional degradation, physical erosion, and loss of organic matter. To cope with this unsustainable trend, many countries have launched various programs to foster the adoption of sustainable agriculture (SA) by farmers, ranging from economic incentives to long-term technological packages. But changing from conventional to SA represents a radical transformation for farmers (Ward, Bell, Droppelmann, & Benton, 2018) – a decision that involves not only economic but also sociological and psychological drivers (Baumgart-Getz, Prokopy, & Floress, 2012; Burton, 2014; Kollmuss & Agyeman, 2002).

Numerous attempts to explain the adoption of SA or environmental actions have been made in the last decades. However, there is no consensus on the strategy, nor on the common drivers to be used to explain such behaviour (Knowler & Bradshaw, 2007; Kollmuss & Agyeman, 2002; Wauters & Mathijs, 2014). The classical model approach is based on the expected utility concept (Fernandez, 2017; Mugonola et al., 2013; Pedzisa, Rugube, Winter-Nelson, Baylis, & Mazvimavi, 2015). This approach accounts for structural variables of the individual and the environment, such as socioeconomic characteristics, soil/weather conditions, and extension variables, but falls short of considering social psychological factors (Greiner, Patterson, & Miller, 2009; Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2015). More recently, research on the adoption of SA has started incorporating social psychological approaches, which allows for a more comprehensive explanation of technology uptake (Meijer et al., 2015). Moreover, these novel approaches offer additional entry points for strengthening current policy programs and proposing new ones.

In spite of the mosaic of drivers that are recognized to affect adoption, economic incentives to guide `sustainable agricultural behaviour` (hereafter sustainable behaviour) are still the preferred tool among policy makers, though they exhibit variable degrees of success (Dayer, Lutter, Sesser, Hickey, & Gardali, 2018; Rode, Gómez-Baggethun, & Krause, 2014). In addition, it has been observed that the use of payments can change intrinsic motivations of behaviour, usually negatively, by making actions financially-conditioned (Deci, 1971; Frey & Jegen, 2001; Ryan & Deci, 2000b). Hence, economic and motivational factors not only have a relevant influence on behaviour, but also might be conditioning each other, so we expect an interplay between both variables affecting SA adoption. The interaction between intrinsic and extrinsic motivation in conservation settings has been studied in a number of ways (Rode et al., 2014), but little is known about the interacting contributions of each source of motivation on the explanation of observed behaviours.

In this paper we seek to answer the question: Are economic incentives equally effective at different levels of intrinsic motivation? With this aim, we explore the adoption intensity of SA, measured as the number of sustainable agricultural practices (SAPs) adopted by farmers, considering the interacting roles of extrinsic and intrinsic motivations. In particular, we evaluate the effect of the program `Incentive for the Agro-Environmental Sustainability of Degraded Soils` (SIRSD-S) as an extrinsic motivator for adopting SA, along with attitudes towards SAPs as a proxy for intrinsic motivation, and the interaction between the two. Our hypothesis is that extrinsic motivation will change behaviour towards adopting SA only when intrinsic motivation is low, as highly motivated farmers will not need monetary incentives to increase SA.

To test this hypothesis, we propose a model approach for sustainable agricultural behaviour that, in addition to motivations, considers risk perception of soil erosion and perceived behavioural control to face this risk. According to Rogers (1975), both appraisals are key drivers of protective behaviour, representing the extent to which individuals recognize the existence of a threat and their personal ability to cope with it. Either separately or jointly, these drivers have been used extensively in studies analyzing the conditions to adopt SA (see Gebrehiwot & van der Veen, 2015; Greiner et al., 2009; Pilarova, Bavorova, & Kandakov, 2018; Truelove, Carrico, & Thabrew, 2015; Wilson, Howard, & Burnett, 2014). Hence, our model uses risk-related measures that correspond to perceptions about soil erosion, which operate in parallel to the intrinsic and extrinsic motivations to adopt SAPs.

Although the interplay between motivations has received considerable attention in more fundamental psychological literature, to the best of our knowledge there are no studies in farming contexts that assess empirically how the interaction between intrinsic motivation and monetary incentives explains actual sustainable behaviours. Previous studies have usually discussed the interaction between motivations through exploratory analysis or experiments based on small samples, without quantifying the effects of such interaction. One exception is Polomé (2016), who assessed the interacting contribution of intrinsic and extrinsic motivations using a sample of 600 forest owners; however, this study focused on explaining participation in biodiversity-related protection programs rather than the adoption of sustainable agriculture. Addressing this gap in the literature has policy implications since farmers throughout the world are often operating within agricultural regimes that use agricultural subsidies or incentives as policy instruments aimed at enhancing sustainable behaviours. Nevertheless, the effectiveness of monetary incentives has been questioned, and unintended counterproductive effects from their delivery might arise (Dayer et al., 2018; Polomé, 2016; Rode et al., 2014), as explained previously.

In the next two sections we will discuss these concepts more deeply and examine their role in the explanation of environmental behaviours.

3.2. Incentives for sustainable agriculture: SIRSD-S program

We will test our hypothesis in the context of an incentive scheme for SA in Chile, named System of Incentives for the Agro-Environmental Sustainability of Degraded Soils (SIRSD-S). This incentive is a nationwide policy program, implemented by the Ministry of Agriculture in 2010 and continuing to the present, consisting of a co-payment of the operational and investment costs of a predefined list of SAPs (BCN, 2012). The main goal of the SIRSD-S is the recovery and maintenance of the productive potential of degraded soils through five specific activities: incorporation of phosphorus fertilizers, correction of essential chemical elements, vegetation cover in unprotected soils, sustainable management practices, and rehabilitation of soils with physical impediments (ODEPA, 2018a). The program has supported an array of practices that are not exclusively referred to as environmental goals but also as activities of productive conditioning (BCN, 2010). In terms of public investment, SIRSD-S has been one of the largest development initiatives in Chile (BCN, 2010). Based on a performance report[5], between 2011 and 2015 the program has annually affected 150,000-188,000 hectares, allocating in average US$ 45,200[6] per

[5] Universidad de Talca. 2017. Study of performance and impact evaluation of the system of incentives for the agro-environmental sustainability of agricultural soils (SIRSD-S). Final report. 157 p.

[6] Observed dollar by July 9, 2018: $657 Chilean pesos per U.S. dollar. Central Bank of Chile

year. In 2015, 19,171 farmers benefited from the program, concentrated mainly in the southern regions of the country[1].

The SIRSD-S program targets farmers by means of two public institutions: the Agricultural and Livestock Service (SAG), which handle medium-large scale farmers, and the Institute of Agricultural Development (INDAP), which focuses on small-scale farmers. Both institutions are oriented to commercially viable farms that are requested to issue invoices associated with their productive activities. Hence, the incentive targets a population that generates farm incomes and seek profits as a goal. INDAP comprises 82-86% of beneficiaries of the program, and the remaining percentage corresponds to SAG users1. Farmers have to submit an application prepared by an accredited operator belonging to the corresponding entity, either SAG or INDAP (ODEPA, 2018a). The amount of financial support from the program varies depending on the farmers' scale, covering up to 90% of reference costs of the granted activities in the case of small producers, 70% for medium ones, and 50% for large-scale producers (BCN, 2012). Payment to beneficiaries of the SIRSD-S is released once the committed practices have been carried out (management plan), which will be subject to control by the SAG or INDAP, according to the farmer classification. Farmers can receive the SIRSD-S incentive multiple times, depending on the number of management plans awarded.

3.3. Literature review

The literature on adoption of sustainable and conservation agriculture has used a variety of approaches to study farmers' behaviour (Honig, Petersen, Shearing, Pintér, & Kotze, 2015; Meijer et al., 2015). In the field of psychology, the theory of planned behaviour, protection motivation theory, and value beliefs and norms theory have been popular approaches to tackle a complex decision, such as engaging in SA. We propose a theoretical approach that examines intrinsic and extrinsic motivations and their interaction, considering perceptual measures of intrinsic motivations, risk of soil erosion, and behavioural control to cope with this threat.

(http://www.bcentral.cl/).

3.3.1. Motivational drivers of sustainable behaviour

An individual's personal motivation to engage in particular actions involves feeling inspired to do something based on their own individual reasons (Ryan and Deci, 2000), which might arise from emotional, ethical, financial, or even biological needs or goals, among others. The psychological literature distinguishes between intrinsic and extrinsic motivations. According to Deci (1971), intrinsically motivated individuals are those who act without apparent reward other than the activity itself. Intrinsic motivation comes from the inner life of the individual, being represented by feelings of personal enjoyment, as opposed to extrinsic motivation, which is related to satisfaction coming from tangible external benefits, such as profits and market/policy incentives (Rode et al., 2014; Ryan & Deci, 2000a).

Extrinsic motivation is instrumental in nature because it is primarily driven by a search for some external reward, such as a financial incentive, or to avoid external punishment, such as a fine (Ryan & Deci, 2000a). Economic incentives can steer farmers' behaviour to foster SA without going into the trouble of changing a farmer's individual beliefs or perceptions. As such, monetary incentives may be regarded an efficient solution for implementing a particular agricultural policy.

Importantly, this kind of external intervention might be over-justified in some cases (i.e., for farmers already implementing SA) and could even lead to the unintended effect of reducing intrinsic motivation. This effect would occur in self-motivated individuals as a result of cognitive re-evaluations of the incentivized behaviour, which are related to feelings of external control, self-regulation or competence (Ryan & Deci, 2000a). This is particularly disturbing because it would imply that once a financial incentive is cancelled (e.g., because of lack of funding, changing policy priorities, etc.), farmers might cease those practices.

Given the efforts of governments and international institutions to provide economic incentives to promote SA, the questions that arise are how effective they are and at what level of intrinsic motivation. In answering these questions, we could understand under what conditions of intrinsic motivation incentives are (not) necessary to reach higher rates of adoption, as well as determine the actual role of intrinsic motivation in this decision.

The hypotheses that follow from this review are:

H1a: Extrinsic motivation and intrinsic motivation have a positive relationship with the intensity of SA adoption.

H1b: There is a negative interaction between both motivators, making the effectiveness of the extrinsic incentive contingent upon intrinsic motivation being low.

3.3.2. Risk perception and perceived behavioral control of soil erosion, and attitudes towards remedial actions.

When hazards are present, Rogers' (1975) protection motivation theory predicts that threat and coping appraisals are crucial factors driving the intention to engage in self-protective behaviour. As soil erosion jeopardizes farmers' productivity in the long-term, the perception of threat promotes taking actions to repair or prevent further damage to the environment (Prokopy, Floress, Klotthor-Weinkauf, & Baumgart-Getz, 2008; Traoré, Landry, & Amara, 1998). Risk perception of a threat is associated with a primary impulse to take action, which has the potential to override other motives such as intrinsic values or beliefs (Kollmuss & Agyeman, 2002). For instance, the climate change literature has acknowledged that adaptation strategies will be rarely adopted if individuals do not experience the effects of climate change on their livelihoods (Alam, Sasaki, & Datta, 2017), but the assessment or recognition of a threat alone does not ensure taking remedial actions (Prokopy et al., 2008). Along with this, individuals who have low perceived ability or coping appraisals could deny the need to tackle the threat (Wilson et al., 2014). Therefore, awareness of environmental issues needs to be complemented with knowing and feeling self-confident about how to perform the self-protective behaviour (Kaiser, Wölfing, & Fuhrer, 1999).

If individuals are not confident of their ability to achieve a desired effect, then they will lack motivation to undertake actions (Bandura, 2000). Thus, the willingness to take remedial actions to protect themselves depends both on the realization of a threat and coping appraisals (Rogers, 1975). Subsequently, cognitive appraisals of environmental issues are crucial for the development of more affective assessments, such as attitudes towards remedial actions (Kaiser et al., 1999; Prokopy et al., 2008). For example, in a study of farmers' attitudes towards practices to avoid nutrient loss, Wilson et al. (2014) found that risk and coping perceptions positively affected the formation of attitudes. Attitudes correspond to individuals' dispositions based on negative or positive evaluations towards general or particular behaviours (Ajzen, 1991), which are decisive in determining pro-environmental behaviours (Kaiser et al., 1999; Kollmuss & Agyeman, 2002). In fact, positive beliefs or values towards conservation practices in terms of economic and soil quality outcomes have been found to influence the adoption decision (Ramírez-López, Désirée Beuchelt, & Velasco-Misael, 2013)

According to the above analysis of the role of risk perceptions and behavioral control in decisions, we propose the following hypothesis:

H2: Farmers will more strongly adopt SAPs when they perceive a higher risk to soil erosion, and when they have a stronger perceived behavioural control to cope with soil erosion.

3.4. Conceptual framework, data and methods

3.4.1. Conceptual framework

To test the hypotheses presented in sections 3.1 and 3.2, we built a structural model composed of three main groups of variables (Figure 1): (a) motivation, which is composed of intrinsic motivation represented by farmers' attitudes towards SAPs, and extrinsic motivation represented by the SIRDS-S incentive to adopt SAPs; (b) risk perception towards soil erosion; and (c) perceived behavioural control to cope with soil erosion. Control variables were also included because they are known to influence the adoption of new technologies (Mugonola et al., 2013), accounting for structural aspects, demographics, and environmental conditions. With respect to this last set of variables, two geographical variables were considered to isolate soil and weather conditions: the administrative region to which the farmers belong and belonging to the longitudinal central valley of the country.

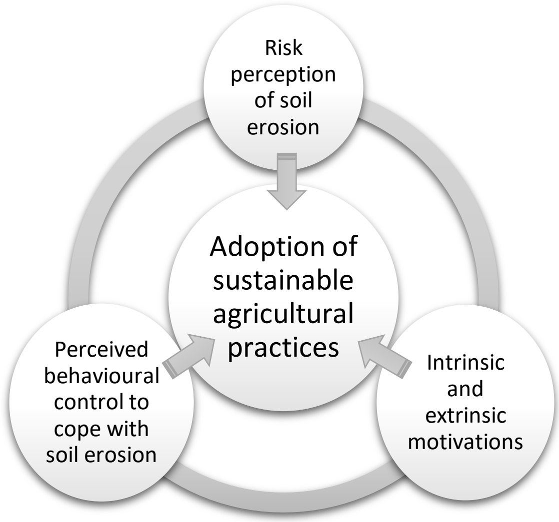

Figure 1. Conceptual framework to explain the adoption of sustainable agricultural practices (SAPs).

3.4.2. Study area, data collection, and survey

The study area is located in two regions of southern Chile, Biobío and Los Lagos (36º00' to 44º14' South), where annual cropping (cereals, pulses, tubers, and industrials) is one of the main productive activities, accounting for 73% of the total in the country (ODEPA, 2018b). In addition, the two regions in our study are the most relevant in terms of the intervention area and number of beneficiaries for INDAP and SAG, with 24% and 29% of the total beneficiaries, respectively[7].

The sampling procedure consisted of a random selection of annual crop farmers that included beneficiaries of the SIRSD-S program as well as non-beneficiaries, who served as a control group. Based on yearly cadasters of the program, the group of beneficiaries was defined as farmers who received the SIRSD-S incentive at least once between 2012 and 2015. Non-beneficiaries were farmers who applied to the program but were rejected during the same period. This information

[7] Universidad de Talca. 2017. Study of performance and impact evaluation of the system of incentives for the agro-environmental sustainability of agricultural soils (SIRSD-S). Final report. 157 p.

came from the two public services responsible for the assignment of the incentive (INDAP and SAG)[8].

The survey was applied face-to-face to farmers in their own fields during 2016 and was divided into nine sections. Sections 1-3 gathered socio-economic characteristics of the farmer and farm production system, and sections 4-7 collected information about the number of sustainable practices implemented in the field. We asked farmers whether they carried out a list of sustainable measures on their plots in the last productive season, from which we defined the SAPs for the purposes of this study. Section 8 incorporated questions about risk perceptions, attitudes and beliefs regarding SAPs, all aspects relevant to this study. The ninth section dealt with infrastructure, inventories, and cost structures. The database in question consisted of 425 observations.

3.4.3. Model estimation

Adoption of sustainable behaviour is commonly understood as a dichotomous decision, but the study of the intensity of adoption as the quantity of pro-environmental practices adopted can enrich the measurement (Feder et al., 1985; Pedzisa et al., 2015). In this sense, incremental adoption allows for identification of the factors that explain why farmers adopt more or fewer practices. For the purposes of this study (i.e., modeling behavior), an adoption intensity measure was constructed based on a count of practices, which represents the number of times a producer adopts SAPs instead of the coverage or effectiveness of these actions. In other words, the interpretation is that the greater the number of SAPs adopted, the greater the sustainable behavior.

The practices considered in this study were selected on the basis of FAO's definition of sustainable agricultural practices[9] that aim to enhance soil fertility without neglecting profitability, and the

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[8] Both entities have different users depending on the size of the farm. The farmer belongs to INDAP if he/she had 12 Basic Irrigation Hectares (HRB) or less; otherwise, he/she belongs to SAG. HRB represents an equivalence of area according to the capacity of use or production potential (the reference of top quality is one irrigated hectare in the Maipo River Valley of Chile).

[9] http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/soil-biodiversity/agriculture-and-soil-biodiversity/sustainable-agricultural-practices/en/

practices considered in SIRDS-S[10]. Hence, we built a variable of intensity of SA considering the following five practices related to the betterment of soil structure, with respect to alternative prevailing practices.: 1) minimum tillage, 2) improved fallow, 3) stubble incorporation, 4) use of manure, and 5) use of compost. The dependent variable takes discrete values from 0 (when adopting none) to 5. In particular, minimum tillage is associated with a lower frequency and intensity of tillage and vertical movement of the surface, which reduces soil and water loss (of the farmers in the sample, 10% adopted this practice); improved fallow is a shifting cultivation method consisting in the establishment of legumes on the field to make more nitrogen and phosphorus available for the next crop (9% of adoption); stubble incorporation to avoid burning by using machinery to chop and incorporate crop residues to the ground (24% of adoption); use of manure involves the incorporation of livestock/poultry by-products into the soil, including animal excrement and processed bed material (23% of adoption); and use of compost, i.e., the incorporation into the soil of fine stabilized organic matter resulting from composting processes (6% of adoption). It is relevant to say that stubble incorporation implies turning the surface layer of the soil in order to bury the residues from the previous crop, which might seem as opposite to the practice of minimum tillage (also evaluated in this study). However, at the field level, farmers make their own combination of practices and can choose between conventional plowing or minimum tillage regardless they had incorporated the stubble (e.g. in the case of zero tillage stubble incorporation would be excludable).

Although some degree of complementarity and substitutability between the practices considered in this study is adverted, all of them should be implementable by any farmer in the sample of annual crop producers. Thus, we use a count dependent variable measuring the number of SAPs adopted by farmers, following a Poisson distribution that can be written as:

$$Prob\,[Y_i = y_i | x_i] = \frac{e^{-\lambda_i}\ \lambda_i^{y_i}}{y_i} \quad , \qquad y_i = 0, 1, 2, 3, 4, 5$$

[10] http://www.indap.gob.cl/docs/default-source/default-document-library/decreto-4-del-2017-establece-tabla-de-costos-sirsd-s.pdf?sfvrsn=0

in which the number of sustainable practices adopted by the i th farm (from 0 up to 5) depends on a vector of explanatory variables x, representing social psychological and structural characteristics of farmers. According to Greene (2003), the parameter λ is commonly formulated as a log-linear model:

$$ln\ \lambda_i = x_i{}'\beta$$

that is expressed as the expected number of occurrences or counts in the sample (of sustainable agricultural practices in this study), resulting in:

$$E\ [y_i|x_i] = \ \lambda_i = e^{x_i'\beta}$$

Therefore, the effect of the explanatory variables (partial effects) on the intensity of SA adoption corresponds to

$$\frac{\partial E\ [y_i|x_i]}{\partial x_i} = \ \lambda_i\beta$$

The Poisson model relies on the assumption that the distribution of the variance and mean is the same; if this assumption is violated (i.e., over-dispersion), the Negative Binomial distribution is most appropriate (Greene, 2003).

For the purposes of this study, the empirical model is as follows:

$$P_i = \alpha R_i + \beta C_i + \gamma M_i + \delta S_i + \theta S_i * M_i + \rho Z_i + \epsilon_i \quad , \quad i = 1, 2, 3, \ldots, N$$

in which the dependent variable P_i is the number of SAPs implemented by farmers. R_i corresponds to the risk perception of soil erosion, C_i is the perceived behavioural control of soil erosion, M_i represent the intrinsic motivation to carry out SAPs (using attitudes towards them as a proxy), and

S_i is the SIRSD-S participation variable that takes value 1 if the farmer is beneficiary and 0 otherwise. The interaction term $S_i * M_i$ consists of the interaction of the SIRSD-S variable and attitudes towards SAPs. A vector of farm and farmer characteristics Z_i was also included to account for structural variables that may affect the adoption of practices. Finally, ϵ_i represents the random error associated with the adoption of SAPs.

The variables risk perception, perceived behavioral control, and attitude were measured using a 7-point Likert scale that ranged from strongly disagree to strongly agree with a specific statement. In particular, *risk perception* to soil erosion was measured by the statement: *'Indicate your perception regarding the level of risk associated with soil erosion*. *Perceived behavioural control* used the item: *'Indicate your perception regarding your capacity to deal with the effects that this risk (meaning risk associated with soil erosion) has on your business and production system*'. *Attitude* towards SAPs (intrinsic motivation) was measured using the average value of the following two sentences, *'Sustainable agricultural practices allow for the improvement of soil productivity',* and *'Sustainable agricultural practices allow for the improvement of economic benefits´*. Note that for simplicity in variable interpretation we use the same measurement strategy in all three perceptual variables.

The described model was estimated in STATA 15.1.

3.5. Results

3.5.1. Descriptive statistics

Table 1 shows descriptive statistics, grouping the sample by financing entity: INDAP (small farmers) and SAG users (medium to large farmers), in order to reduce size dispersion. Among the sample, 78% of farmers belong to INDAP and 22% to SAG. As described earlier, the criteria to be an INDAP user is to have a maximum of 12 basic irrigation hectares (an equivalence based on productive potential). Within each group of farmers, beneficiaries and non-beneficiaries of the SIRDS-S program were compared. The beneficiary group in INDAP and SAG accounts for 57% and 46%, respectively, providing a relatively balanced sample for estimation purposes. The adoption of SAPs in each differs. The average number of adopted practices among the whole sample is 0.72 (from a possible range of 0-5). Analysing the INDAP and SAG groups separately, the differences in the average adoption between beneficiaries and non-beneficiaries reaches 0.67 vs. 0.53 in the case of INDAP and 1.45 vs. 0.86 in the case of SAG. This difference provides preliminary insights regarding the expected effect of the SIRSD-S incentive (i.e. extrinsic motivation) on the adoption of SA.

Table 1. Mean comparison t-tests between beneficiaries and non-beneficiaries of the SIRSD-S incentive, grouping by financing entity (425 observations).

Variable	Description	INDAP (n=333)			SAG (n=92)		
		Non-B. (n=144)	Benef. (n=189)	Diff.[a]	Non-B. (n=50)	Benef. (n=42)	Diff.[a]
Intensity of adoption[b]	Sustainable agricultural practices adopted (0-5)	0.53	0.67	ns	0.86	1.45	**
Risk perception[b]	Risk perception of soil erosion (1-7)	4.46	4.28	ns	4.00a	4.40a	ns
Perceived behavioural control	Capability perception to face soil erosion (1-7)	3.43	3.83	***	4.14	4.69	*
Attitudes[b]	Attitudes towards SAPs (1-7)	5.49	5.82	***	5.78	6.27	***
Size	Total surface of the farm (hectares)	23.01	46.78	ns	137.72	213.63	ns
Organization	Belonging to community associations (%)	0.51	0.66	***	0.36	0.48	ns
Education[b]	Educational level (years)	7.56	8.30	ns	9.68	14.74	***
Experience	Experience (years)	39.19	40.19	ns	36.90	31.90	ns
Family enterprise[b]	Being family enterprise rather a company (%)	0.76	0.85	*	0.54	0.48	ns

Investment[b]	Total investment on the farm (thousand $US[11])	1.91	2.37	ns	6.27	9.18	ns
Valley	Belonging to the central valley of Chile (%)	0.58	0.49	*	0.46	0.57	ns

[a] = Means statistical difference at 99% (***), 95% (**), and 90% (*) confidence level; n.s. means 'not statistically significant'.

[b] = Indicates that Welch's t-test for comparison of means was used because Bartlett's test of equality of variances was rejected ($p < 0.05$).

Regarding socioeconomic characteristics, INDAP and SAG beneficiaries have a higher educational level compared to non-beneficiaries, but only in the case of SAG users was this difference statistically different (9.68 vs. 14.74 years). We found statistical differences in the case of INDAP users only between beneficiaries and non-beneficiaries in the variables 'belonging to community associations' (66 vs. 51%) and 'being a family enterprise' (85 vs. 76%). Interestingly, experience and degree of investments in the farm were not statistically different for SAG and INDAP users. A possible explanation for this result is that the practices included in the study are neither costly nor complex to implement.

The average farm size in the whole sample is 66 ha and the median is 17.50 ha. The size ranges from 1.3 to 250 physical ha, considering the 90% interval of the sample. By group, the mean and median size for INDAP users is 36.50 and 13.80 ha, respectively, while for SAG users it is 172.38 and 68.5 ha. Regarding the mean size comparison, there are no discernable statistical differences between beneficiaries and non-beneficiaries either among INDAP and SAG users. In the model presented in section 5.2, farm size was evaluated as a discrete variable by dividing the sample into three groups of an equal number of farmers. Grouping farm size in terciles allowed us to define small, medium, and large-scale farms (within the sample), providing a useful interpretation of the operation size impact, as we can appreciate potential non-linear effects on the adoption of SAPs (Engler et al., 2016).

[11] Observed dollar by July 9, 2018: $657 Chilean pesos per U.S. dollar. Central Bank of Chile (http://www.bcentral.cl/).

Turning to the perception variables, beneficiaries of the SIRSD-S, among both INDAP and SAG users, showed higher levels of intrinsic motivation associated with positive attitudes towards SAPs and higher perceived capability to cope with soil erosion. However, there were no significant differences in terms of risk perception of soil erosion between the groups. Finally, beneficiaries of the program tended to be located outside the central valley of Chile, which is the most fertile region of the country, being statistically different only in the case of INDAP users.

3.5.2. Model estimation results

The potential over-dispersion (e.g. high variability around the mean) of the count-dependent variable needs to be tested in order to choose the most appropriate specification within count data model (Cameron & Trivedi, 1990). We tested and discarded the Negative Binomial regression since it did not show evidence of over-dispersion (alpha test: p value = 0.327) (Greene, 2003) and, therefore, used the Poisson model. Because of the high rate of zeros in the dependent variable, we tested whether a zero-inflated Poisson regression provided a better fit to the data, but this was not the case (Vuong test; p value = 0.149), and finally, we opted for the standard Poisson model.

Estimation results in Table 2 show that the model was significant as a whole, with a Wald test showing a probability of rejection below 0.0001. The model had a pseudo R^2 of 0.12, showing seven out of 15 significant coefficients (95% confidence level). In addition, goodness-of-fit chi-square tests were not significant, which means that the model fit reasonably well (Table 2). Since the parameters estimated by the model are not directly interpretable, average marginal effects were reported to explain the percentage impact on the dependent variable when covariates increased by one unit, holding all other variables constant.

Table 2. Estimation results of the number of sustainable agricultural practices adopted by farmers (N=425 observations).

Variable	Coefficient[a]		Average Marginal Effects
Risk perception	0.12	***	0.08
Perceived behavioural control	0.11	**	0.08
Attitudes	0.45	***	0.19
SIRSD-S	2.16	**	0.18
SIRSD-S*attitudes	-0.31	**	-
Medium-farm	-0.15	n.s.	-0.11
Large-farm	-0.18	n.s.	-0.13
Investment	0.04	***	0.03
Education	-0.00	n.s	-0.00
Organization	-0.02	n.s	-0.01
Experience	-0.01	**	-0.01
Entity	0.15	n.s.	0.11
Family enterprise	-0.20	n.s.	-0.15
Valley	-0.29	n.s.	-0.21
Region	0.07	n.s.	0.05
Constant	-3.65	***	-
Wald $chi^2(15) = 174.80$; $Prob>chi^2 = 0.0000$			
Pseudo R^2= 0.12			
Deviance goodness-of-fit= 448.44; Prob > chi^2 (409) = 0.09			
Pearson goodness-of-fit= 435.82; Prob > chi^2 (409) = 0.17			

[a] = Means statistical difference at 99% (***), 95% (**), and 90% (*) confidence level; n.s. means 'not statistically significant'.

The results show a high correlation between psychological variables and sustainable behaviour. Among those, attitudes (intrinsic motivation) show the highest marginal effect, with a 0.19 incidence, meaning that one additional point in attitudes (higher level of agreement that SAPs are beneficial for production; scale 1 to 7) is associated with the adoption of 0.19 additional practices. The SIRSD-S incentive (extrinsic motivation) is also significant, with a marginal effect of 0.18, almost the same as attitudes (H1a). Along with this, turning to the core of this study, the interaction term of the model has a significant negative sign. Regarding the specific nature of the interaction, its negative sign means that the impact of one of the components on SA (either intrinsic or extrinsic motivation) diminishes at higher values of the other component[12]. Hence, in line with H1b, the effects of attitudes and the SIRSD-S are not independent in the explanation of SAPs adoption. Consequently, we cannot account for the impact of intrinsic and extrinsic motivations without considering the interplay between them.

To make this interaction easier to interpret, we have depicted the two-way interaction between the SIRSD-S incentive and attitudes towards SAPs. It plots the expected number of adopted practices against an increasing attitude score, comparing beneficiaries and non-beneficiaries of SIRDS-S. From right to left, when attitude is higher there are no significant differences between beneficiaries and non-beneficiaries, but as the attitude level decreases the extrinsic motivator does create a positive difference in the number of SAPs used. Furthermore, at the highest levels of attitudes, the displayed lines are crossed, showing a slightly negative effect of extrinsic motivation on adoption (Figure 1). Nevertheless, there is no statistical difference when we compare predicted adoption of SAPs between beneficiaries and non-beneficiaries (T-test: p-value > 0.1). On other side, it is worth informing that 98% of the sample has an attitude above 3.5 points, so it is not very practical to observe the effect of the incentive on the estimated adoption below this threshold. In fact, the median value of attitude is 6 points, which should be used to distinguish producers with higher and lower attitude within the sample.

[12] Reported (positive) average marginal effects of intrinsic and extrinsic motivations already consider the counterproductive (negative) effect of the interaction term.

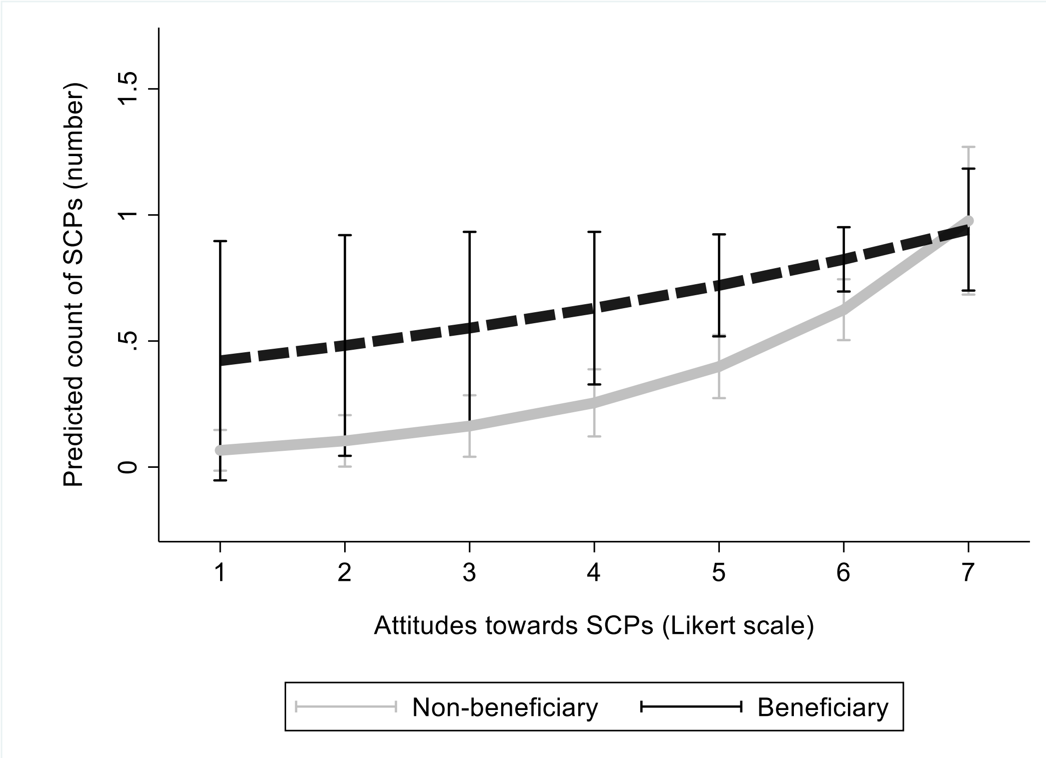

Figure 1. Two-way interaction between the SIRSD-S incentive (extrinsic motivation) and attitudes (intrinsic motivation) towards sustainable agricultural practices.

As shown in Table 2, risk perception of soil erosion and perceived behavioural control to cope with it are positively associated with SA. The marginal effect in both cases is 0.8, meaning that in an agreement scale from 1 to 7, an extra point is associated with an increase in 0.8 SAPs (H2). Finally, almost all structural variables included in the model were non-significant, with the exception of farmer experience and total investments in the farm, though with negligible coefficients (close to zero). This result supports the relevance of psychological variables in farmers' decisions, which can offset the impact of traditional socio-economic variables. Of the covariates, experience reduces the adoption by 0.01 SAPs per each additional year. This result was expected due to experienced farmers being more resistant to change and new systems because they have managed their crops in a certain way for a long time (Engler et al., 2016). Investments increase the adoption by 0.03 SAPs per additional thousand US dollars. The status of family enterprise and belonging to specific entities (i.e., INDAP or SAG), along with size, education, and belonging to any organization, did not present discernable impacts either increasing or reducing the adoption of SAPs. Similarly, geographic variables accounting for soil and weather conditions were not statistically significant.

3.6. Discussion

The aim of this study was to understand how a monetary incentive to promote farmers' sustainable behaviour operates, given the psychological context of their decision making. By including psychological drivers, we expanded the classical approach of technology adoption based on structural variables. We found that farmers' perceptions and beliefs played a key role in explaining the intensity of adoption of SAPs, largely overriding the statistical contribution demonstrated by structural variables. This finding highlights the relevance of including social psychological variables to complement adoption models based only on economic/structural factors.

Results show that risk perception and perceived behavioural control of soil erosion were significant and positively related to sustainable behaviour. This finding accords with several studies evaluating the uptake of SA, which show the positive correlation of behaviour with risk perception or awareness of the problem (Gould et al., 1989; Greiner et al., 2009; Knowler & Bradshaw, 2007; Pilarova et al., 2018) and perceived behavioural control or ability (Gebrehiwot & van der Veen, 2015; Truelove et al., 2015). Seminal studies on the matter also support our findings, in which risk perception represents the environmental necessity to behave in a sustainable way (Gould et al., 1989) and perceived behavioural control to cope with an identified threat regulates motivation (Bandura, 2000). Hence, not taking into consideration these two components might bias predictions of actual behaviour (Wilson et al., 2014).

In addition, it has been pointed out that after appraisals of threat and perceived behavioural control, more affective evaluations of behaviour such as attitudes come into play (Prokopy et al., 2008). Attitudes are behavioural dispositions based on an individual's beliefs, which come from favourable or unfavourable evaluations of the behaviour (Ajzen, 1991). In this study, we used attitudes related to expected productivity and benefits as a proxy for intrinsic motivation and found a positive correlation with SA adoption. Moreover, farmers' attitude towards SAPs were the strongest driver of sustainable behavior in terms of magnitude, in line with Wauters and Mathijs (2006).

The aforementioned results have direct implications for developing better policies that take into account individuals' perceptions and attitudes. Although generating changes at this level can be difficult and expensive, these persuasive interventions might have a more lasting and robust effect on behaviour. For instance, Truelove et al. (2015) suggest that training farmers in new cultivation methods allows them to have higher levels of self-efficacy regarding climate change adaptation. Educating farmers about the seriousness of environmental erosion that results from implementing conventional practices could also avoid relying exclusively on extrinsic motivations (economic incentives) to guide sustainable behaviours, as it would make farmers more aware of risks. However, the trend in environmental policy continues to be the use of monetary incentives to guide behaviour because it is the easiest way to induce farmers to behave sustainably.

Rather than demonstrating the effect of extrinsic and intrinsic motivation by themselves, our goal was to analyze the interplay between these two sources of motivation. We found the existence of an inversely proportional relationship among attitudes and the SIRSD-S, and specifically that the effect of one motivation on the response variable is reduced as the level of the other motivation increases (Figure 1). The interaction shows that farmers with lower attitudes depend largely on the SIRSD-S incentive to act more sustainably. This finding was also pointed out by Greiner et al. (2009), who analyzed motivations and risk perceptions surrounding the adoption of conservation practices in Australia. Conversely, individuals with high intrinsic motivation implement SA regardless the existence of economic compensation, which has practical implications for agricultural policies since not all farmers respond equally to incentives, implying that an efficient distribution of resources should target farmers with weaker attitudes toward SA.

Taking into account that we measure the adoption rate in 2016, after beneficiaries received the subsidy, this result shows the persistence of the effect of the subsidy on farmers' sustainable behavior. More specifically, in this case the farmers with lower attitude are impacted the most. As an analogy to the existing literature on motivational crowding-out, we found a different kind of undermining effect of intrinsic motivation on sustainable behaviour as result of the presence of a monetary incentive, based on the reduction of the impact rather than overstepping it when a monetary incentive is offered in the past. This adds to the motivation crowding literature because previous studies have been most concentrated on the undermining effect of monetary incentives on the magnitude of intrinsic motivation, overshadowing the practical behavioural impacts that arise from the interplay.

Our results provide policy implications, particularly for current soils recovery and sustainable programs. The effectiveness of policy incentives could be enhanced if the farmers' intrinsic motivations are taken into account, since monetary incentives in our study were apparently only effective on farmers with lower attitudes towards adoption. That is to say, farmers with high attitude levels do not need an incentive to behave sustainable, while farmers with low attitude levels do need an incentive. Diverse farmers' motivations should be considered to accommodate and focus agricultural policies (Honig et al., 2015; Howley, 2013). From the above, we believe that environmental policy should consider programs to increase farmers' intrinsic motivation rather than relying exclusively on providing economic incentives, as these do not generate the same response across farmers. Also, refining the eligibility criteria of incentive-based programs to identify intrinsically motivated farmers could increase rates of adoption without the risk of crowding-out prior self-motivations, as well as saving public funds and increasing efficiency.

Despite the contributions of our study, it still faces limitations that merit further research. First, more empirical studies to validate the crowding-out effect of extrinsic on intrinsic motivation are suggested, using longitudinal data to ensure causality wherever possible. Second, acknowledging that sustainable practices do not have the same effect on soil recovery and conservation, it would be interesting to have a measure to quantify such impacts and to identify their effect on attitudes. Furthermore, it is possible that intrinsic and extrinsic motivation are correlated and eventually explained by each other, which has implications in terms of causality. On the other side, attitudes as well as risk perceptions evolve over time, changing farmers' motivations to adopt SA. As the identification of such longer-term effects could be possible with longitudinal data, future studies might consider panel data sets to measure changes over time.

3.7. Conclusions

This article analyzes the intensity of adoption of SA among annual crop farmers in Chile, as predicted by their intrinsic and extrinsic motivations. Our findings indicate that social psychological variables override the contribution of structural variables, such that farmers' attitudes towards SAPs (intrinsic motivation), the SIRSD-S conservation subsidy (extrinsic motivation), the perception of risk of soil erosion, and perceived behavioural control to deal with it all had a positive effect. However, the most interesting finding is the significant and negative interaction between intrinsic and extrinsic motivation, showing that the SIRSD-S subsidy was ineffective for farmers with a high level of intrinsic motivation.

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4. Third chapter

Collective actions and leadership attributes: A cluster analysis of Water User Associations in Chile.

Under review in:

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Abstract

It is known that good leaders can greatly influence the effective governance of water resources. However, how their attributes relate to group-cooperation in Water User Associations (WUAs) remains an open question. This study addresses this gap by proving evidence of the relationship between a leader's characteristics and cooperative behavior. Using the case of Chile, we explore the factors of three non-cooperative behaviors in WUAs by peforming a two-stage cluster analysis. The analysis produced four clusters based on cooperation rates, where top performing WUAs are characterized by having presidents who: dedicate more time to managing the WUA, are more active in applying for governmental subsidies, are embedded in social organizations, have high levels of bridging social capital, and have a positive attitude toward the presidency. Policy makers aiming to improve the status and sustainability of hydric resources should consider interventions targeting WUAs' leaders, which are easily modifiable compared to structural variables of WUAs.

Keywords

Agricultural organization, Collective action, Common pool, Community presidents, Group cooperation, Irrigation user, Leader, Water governance, Water User Association.

4.1. Introduction

Poor governance in the water community or weak definition of responsibilities and obligations among water users may lead to a collective failure and the ruination of the irrigation allocative mechanism (Boelens and Hoogendam 2002). In response, incentives to increase collective action help to reach an equitable and efficient allocation of limited water resources (Divakar et al., 2011; Sethi & Somanathan, 2006). Indeed, Ostrom's governance principles for self-enduring Water Users Associations (WUAs) revolve around boundaries, rules, and enforcement, where graduated sanctions are suggested to help to deter uncooperative behavior (Ostrom, 1993). Empirical findings reinforce that sanctions and enforcement mechanisms are useful to avoid free-riding and to meet various users' demands (Greiner et al., 2016; Madani, 2010; Ray & Williams, 2002; Sethi & Somanathan, 2006)

However, enforcing rules usually implies personal costs for the users responsible for the WUA's management, while providing benefits to all participants within the community, which discourages involvement in such operations (Ostrom, 1990; Sethi & Somanathan, 2006). In this light, a leader's character becomes relevant not only in terms of the presence of that person in the organization but also in terms of personal capacity (i.e., leadership) to ensure collective agreements are met (Ho et al., 2016). Also, good leaders can greatly influence effective governance for the sustainable management of water resources (Chaudhry, 2018; Glowacki et al., 2015; Gutiérrez et al., 2011; Thapa et al., 2016; Villamayor-Tomas, 2014). Leaders are usually present in collective action settings, playing an important role in the establishment of goals, coordination of activities, monitoring cooperation, dispute resolution, or reward and punishment mechanisms (Glowacki et al., 2015; Wang & Wu, 2018).

Aside from the everyday functioning, leaders can play an important role during emergencies or natural disasters by maintaining cohesiveness, seeking external and internal funding, and mediating multiple risks to sustain the overall governance (Thapa et al., 2016). However, studies considering the role of leaders in collective action settings are rare (Glowacki et al., 2015), and even more so in the context of irrigation allocative mechanisms. According to Meinzen-Dick (2007), there is a need for careful research on the role leaders' characteristics and motivations play in affecting the performance of water distribution systems or institutions.

There are few empirical studies that consider leader characteristics when analyzing WUAs' collective action and, moreover, they tend to focus on specific and narrow aspects of leaders using coarse proxys of leadership (Chaudhry, 2018; Khwaja, 2009; Meinzen-dick, 2007; Nagrah et al., 2016; Villamayor-Tomas, 2014). To our knowledge, there are no studies exploring deeper attributes of WUAs' leaders and their association with collective action outcomes. Filling this gap in the literature could have policy implications because the administration of WUAs in many countries is communal in nature and relies on the coordination capacities of users who internally elect a leader or directive board. As presidents' characteristics vary from one WUA to another, this fact should be related to management performance and cooperation outcomes.

The above raises the following research questions: What is the relationship between leaders' leadership and group-cooperation? More specifically: Can highly-cooperative WUAs be distinguished by having good leaders? Using the case of Chile, our objective is to explore the factors that are related to cooperativeness in WUAs. According to Rivera et al. (2016), the most prevalent conflicts among Chilean WUAs are related to water distribution issues, including changes in diversion and overuse, and delayed payments. In our study, sixty-eight WUAs are compared focusing on three measures of cooperativeness, namely: the average rates of non-payment of fees, non-cleaning of channels, and water theft. Based on these non-cooperative behaviors, a cluster analysis was performed to identify relevant variables that potentially relate to the collective action of WUAs. We hypothesise that WUAs exhibiting high cooperation are characterized by having sanctions and leaders with better leadership.

In the next sub-sections, we present the case study used to address the hypothesis of this work, and the remainder of the paper is structured as follows: Section 2 describes the study area, data sources, and a definition of all variables used in the analysis; section 3 contains the methodology; section 4 presents results and discussion; and, finally, section 5 offers concluding remarks.

4.1.1. The case of Chile

Chile is 4,270 km long from north to south, with an almost regular width of 180 km from the Andes mountains east to the Pacific Ocean, offering different climates and numerous short and torrential rivers. Water resources are of great importance for the Chilean economy, which is mainly based on the export of primary products, and especially for the agricultural sector that is by far the top consumer of water (Herrera et al., 2019). The total cultivated land is about 2.1 million hectares, from which 1.3 million correspond to annual and permanent crops, while the remainder is distributed between sown pastures and fallow land (ODEPA, 2012a). The total irrigated area in the country is roughly 1.1 million hectares, which are mostly concentrated in the Maule Region that comprises 305,529 ha represented by more than 34,000 farms (ODEPA, 2012b).

Notwithstanding the Chilean Constitution's definition of water as "national property for public use", the role of the State in resolving water allocation problems is quite limited and rests on private negotiations (Donoso, 2015). The Water Code of 1981, still in force, grants water to users through private and transferable water rights separate from land ownership, where users can freely trade their rights of use as a reallocation mechanism (Bauer, 2015). Although the institutional setting in Chile confers low power to governmental institutions to oversee transactions, the General Water Directorate (Dirección General de Aguas, DGA) is mandated to protect and inventory water resources and granted water rights (Herrera et al., 2019).

As described by the Chilean National Irrigation Commission (CNR, 2018), the management of water resources for irrigation depends on three main decentralized private organizations composed by water users: (a) Surveillance Boards (Juntas de Vigilancia) that monitor the use of natural sources of water, such as reservoirs or rivers; (b) Channel Associations (Asociaciones de Canalistas) in charge of administering artificial watercourses, such as main irrigation channels and dams, and controlling water withdrawals among irrigators; and (c) Water Communities (Comunidades de Agua) responsible for managing secondary infrastructure distributing water at the farm level. These three private organizations are self-administered, however, in the case of the Surveillance Boards, the distribution of water flows to subordinated irrigation organizations might be defined in a context of public administration as it has permanent contact with the DGA (Valdés-Pineda et al., 2014).

According to national cadastres, there are 48 Surveillance Boards in Chile, 207 Channel Associations, and 3238 Water Communities legally constituted in the country (CNR, 2018). It is relevant to mention that although Channel Associations may act as intermediate irrigation organizations overseeing Water Communities, in some situations Channel Associations are tail-headed entities of the overall irrigation system and thus operate as Water Communities. Tail-headed irrigation organizations organize the water distribution among users, interact with the Surveillance Board, maintain water channels, and develop irrigation projects in order to improve water efficiency use.

In this study, we focus on tail-headed irrigation organizations in charge of delivering water to final users (i.e., Water Communities or Channel Associations), hereafter named Water User Associations (WUAs). It is relevant to note that WUAs can craft their statutes and do not need to be legally registered to operate (i.e., de facto entities); however, when formally constituted they must meet some minimum requirements from the Water Code. Notably, the Articles 239-240 of the Water Code require the definition of a directive board headed by an elected president, who has to ensure the compliance of the collective agreements (BCN, 2018). At this level, the president along with the directive board make decisions on how to manage the channels and distribute water. Hence, WUAs are where water users decide the final distribution and to take collective actions towards better outcomes, such as more security in water access, greater efficiency in the distribution, lower rate of conflicts among farmers, and better access to policy incentives.

4.2. Data and methods

4.2.1. Study area

The study area corresponds to the Maule region of Chile (34º41' - 36º33' S), located in the Central South part of the country that is characterized by a Mediterranean climate with excellent conditions for growing a diversified portfolio of crops, in which vegetables, fresh fruits and wine grapes are the main products. The Maule region contributes 14% of the national agricultural GDP and possesses 22% of the total number of farms in the country (ODEPA, 2019). Of the total agricultural area in this region, including sown and planted crops and pastures, 24% is irrigated land (ODEPA, 2019). The Maule region is fed by two watersheds, the Mataquito and Maule basins, covering 6,200 km2 and 20,300 km2, respectively, where the former is used for agricultural production while the latter is destined to produce either crops and hydroelectricity (BCN, 2019). Within agricultural lands in these areas, artificial watercourses are administered by numerous coexisting WUAs that deliver irrigation water to farmers. In the Maule region, 33 Channel Associations and

548 Water Communities are legally constituted (CNR, 2018). In the case of the latter, as mentioned earlier, they can operate as de facto entities, so the number of registered Water Communities may not accurately reflect the total number. In the case of Channel Associations, however, they cannot operate as the facto organizations as they necessarily need to be legally constituted. In this study we focus in Water Communities and tail-headed Channel Associations (of the overall irrigation system).

4.2.2. Data collection

We applied face-to-face questionnaires to elected presidents of 68 WUAs. The sampling procedure included a latitudinal stratification in order to cover the range of climatic conditions and type of agricultural systems of the region under study. The WUAs were identified using the snowball sample method (i.e., one president helps to get in touch with others). This non-probability technique was preferred since no public records were available that listed updated personal numbers or contact information of presidents. The requirements to be in the sample were: to be president for at least two years of a WUA with surface water rights of the 'permanent exercise' type and integrated by at least five users.

The questionnaire was administered between August and December 2019 and was divided into five sections. Sections one and two gathered general information about the president (e.g., socioeconomic attributes) and the WUA (e.g., structural conditions and distributional aspects), respectively. The third section addressed organizational issues of the community and activities as well as perceptions of water scarcity. In section four, presidents were asked to mark, in a five-point Likert scale, several statements about the WUA and their relationship with it, aiming to identify their beliefs and perceptions. Finally, the fifth section collected information regarding sanctioning systems and incidences of non-cooperation within the WUA. This latter aspect was conducted separately for the upper and lower sector of the distribution system to facilitate responses, and presidents responded about the number of non-cooperative users. The following activities were considered: non-attendance at meetings, delayed payment of fees, non-payment of fees, non-cleaning of channels, and water theft. The database in question consisted of 68 observations.

4.2.3. Data processing using factor analysis

In this study, leaders' attributes were measured using their own perceptions. Interviewed presidents rated an array of statements in a Likert scale from one to five, (where 1=strongly disagree; 2=disagree; 3=neutral; 4=agree; 5=strongly agree), to measure their attitude toward the presidency (i.e., perceptions about their position), leadership, and social capital, as well as the perceived WUA's social capital. To do so, each concept composed of several items were subject to Factor Analysis with Varimax Rotation to discriminate the most relevant items. The number of retained factors was defined based on the Kaiser criterion of eigenvalues above the value of one (Kaiser, 1960), and a threshold of 0.45 for factor loadings was used to select items for each construct. The complete sentences (i.e., items) rated by presidents and factor loadings are presented in Appendices.

4.2.4. Cluster analysis

To measure WUAs' performance, presidents were asked to report the number of non-cooperative users out the total participants for different duties. For the purposes of this study, three non-cooperative users' behaviors were considered as they result in the greatest detriment for the collective, namely: non-payment of fees, non-cleaning of channels, and water theft. These three non-cooperative behaviors were converted into non-cooperation rates per each WUA and used as grouping variables for a two-stage cluster analysis.

First, hierarchical clustering was performed to identify an adequate number of clusters composed of homogeneous observations, sufficiently dissimilar to other clusters using the Ward linkage method (Ward, 1963). Once the number of clusters were defined, a K-means clustering was implemented to classify each observation into each cluster (Govender & Sivakumar, 2020). After this procedure, analysis of variance and mean comparison tests were performed to compare the attributes of WUAs associated with different rates of cooperation.

4.3. Results

4.3.1. Descriptive statistics

In Table 1, descriptive statistics of the sample are presented to offer an overview of presidents' attributes, including perception-based variables, such as attitude toward the presidency, leadership, and social capital. This section is divided in two. First, structural and sociodemographic characteristics are described; second, a subsection is presented that is dedicated to explaining the constructs: a) attitude toward the presidency, b) leadership, c) presidents' social capital, and d) perceived WUAs' social capital along with a brief description of each.

Table 1. Descriptive statistics of WUAs' presidents (N=68).

Variable	N	Mean	Median	S.D.	Min.	Max.
Gender (1=man, 0= woman)	68	0.96	-	-	0	1
Age (years)	68	61.49	60	10.59	39	87
Experience in agriculture (years)	68	41.81	40	16.11	0	66
Education (years)	68	12.62	12	4.07	3	21
Participation in social organizations (from 0 to 5)	68	0.92	1	1.11	0	5
Participation in agricultural organizations (from 0 to 5)	68	0.60	1	0.60	0	2
Farm ownership (1=owner, 0= administrator)	68	0.90	-	-	0	1
Farm surface within the WUA (ha)	68	71.25	30	117.11	0.50	624
Water shares concentration (%)	63	0.10	0.03	0.13	0	0.58
Exposure to be affected by upper stream users (%)	68	0.49	0.46	0.35	0	1
On-farm income (%)	68	79.49	100	33	0	100
If lives within the WUA (1=yes, 0=no)	68	0.50	-	-	0	1
Time of travelling to get the WUA from home (minutes)	68	7.10	1.50	9.56	0	45
If dedicates more than half day a week to the WUAs duties (1=yes, 0=no)	68	0.37	-	-	0	1

If participated in courses or seminars in the last five years (1=yes, 0=no)	68	0.63	-	-	0	1
Time as president in the WUA (years)	68	10.43	10	7.40	2	39
If has experience in other directive positions in the WUA (1=yes, 0=no)	68	0.28	-	0.45	0	1
If has experience as president in other WUAs (1=yes, 0=no)	68	0.21	-	0.41	0	1
"Do you think that water availability has diminished in the last 10 years?" (1=yes, 0=no)	68	0.93	-	-	0	1
"To what extent do you think is the reduction over the last 10 years?" (%)	63	57.17	60	13.40	25	80
"Do you know the subsidies available for your WUA?" (1=yes, 0=no)	68	0.66	-	-	0	1
"How many project applications for subsidies have you made in the last 5 years?" (n)	67	4.73	2	7.41	0	35
"How many of them have you awarded?" (n)	45	5.11	3	6.44	0	31
Factor president's attitude toward the presidency (average of three items in 5-point Likert scale)	68	4.02	4.33	0.98	1	5
Factor president's leadership (average of three items in 5-point Likert scale)	68	4.18	4.33	0.84	1.33	5
Factor president's bridging social capital (average of five items in 5-point Likert scale)	68	3.45	3.40	0.98	1.40	5
Factor perceived WUA's social capital (average of three items in 5-point Likert scale)	68	3.82	4.00	0.94	1	5

4.3.1.1. Structural and sociodemographic characteristics of WUAs' presidents

Presidents are male in the vast majority of cases; only 6% of the interviewees were female. The median age and experience in agriculture were 60 and 40 years, respectively. The median educational level of presidents is 12 years, that corresponds to high school level. However, the range of educational level varies widely (3 to 21 years). Regarding participation in organizations, on average, presidents participated in one social organization out of four alternatives (neighborhood council; religious congregation, local club, other) and in one agricultural organization out of five options (cooperative; production association; technology transfer group; agricultural development institution [INDAP or SAG]; other).

As for land tenure, 90% of the presidents are owners of the farm while the remaining 10% are administrators. The farm surface area has a median and average of 30 and 71 ha, respectively, which reveal the skewed distribution of this variable, taking values from 0.5 to 624 ha. Another highly asymmetric characteristic is water shares concentration, measured as the number of water shares that the president owns over the total in his/her WUA. A low value in this parameter is indicative of a lower relative participation in the WUA's water endowment. The mean of this variable is 10% but the median is 3% in a range from a value close to 0% up to 58%. We also measured the position of the president along the canal from which they withdraw water to identify the degree of his/her exposure to be affected by upper stream users (but also as result of potential percolation). On average, the relative position of the presidents' farms tend to be located in the middle of the channel.

With regard to the presidents' income from agriculture, 66% of the presidents depend exclusively on on-farm income, although the range is from 33% to 100%. On the other hand, 50% of the presidents reside within the coverage area (i.e., irrigated land) of his/her WUA. The time of traveling to get the WUA from home, taking values equal to zero when the president lives within the community, has a median lesser than 2 minutes and a mean around 7 minutes, with a range from 0 to 45. Regarding dedication time to the WUAs duties, 37% of presidents devote more than half-day a week while the remaining 63% less than that. Regarding training and qualification programs, 63% of presidents participated in courses or seminars in the last five years, respectively, with a positive correlation of 73%.

In the sample, in most of the cases, presidents have been appointed in their positions for an average of 10 years, with a minimum of 2 and a maximum of 39. Additionally, presidents were consulted on whether they had experience in other directive positions (e.g., secretary, treasurer, director, etc.) in their own WUA and with regard to other WUAs. Regarding the WUA they are actually leading, 28% of the presidents have participated in other directive positions, while 21% of the cases have participated in other WUAs.

As for perceptions, 93% of presidents think that water availability has diminished over the last decade and that, on average, the magnitude of reduction within this period has been 57% in a range from 25 to 80%. Additionally, 66% of presidents responded that they are aware of the existence of governmental subsidies for WUAs. There are numerous public funding awards for the construction of civil works such as lining of channels, dams, construction of reservoirs and irrigation gates to improve management, and projects for water quality improvement, among others (CNR, 2020). The median applications for subsidies is two in the last five years, although the mean is around five in a range from 0 to 35 applications by WUA, which highlights the skewed distribution of this variable. In terms of the rate of approval (i.e., number of applications to subsidies awarded [n=45]), the mean is five, the median three, and the range from 0 to 31.

4.3.1.2. Perception constructs from factor analyses

The presidents' constructs of attitude toward the presidency, leadership, and social capital, as well as the perceived WUA's social capital (as perceived by the president), were built by selecting relevant items using factor analyses as described in section 2.3. In Table 1 we report the simple average of the selected items.

In the case of the president's attitude toward the presidency, three items were considered that aimed to capture their feelings about their present and future as presidents. The factor analysis retained only one factor and the three items included were selected for having loadings over 0.45 (Table A1), which together have a Cronbach alpha of 0.67 and average interitem covariance of 0.64.

Regarding the president's leadership, seven indicators previously validated in a related study were used to develop a measure for this construct (Yilmaz & Örmeci, 2018). We performed a factor analysis over 29 leadership-related perceptions of 46 presidents belonging to agricultural organizations, yielding seven factors or dimensions. The item with the highest loading for each of the seven dimensions was considered in the present paper, being adapted to the WUAs' context and then consulted in our questionnaire. Using these seven items measuring leadership, the factor analysis carried out retained three factors. However, based on the Kaiser criterion we decided to retain just the first factor. The loadings of each of the seven included items are reported in Table A2, from which three were selected. The Cronbach alpha for these three items is 0.72 and the average interitem covariance 0.51.

As for the president's social capital, eight items related to the president involvement with the users of the WUA, professionals or experts, and institutions were used. The factor analysis identified four factors but, based on the Kaiser criterion, we retained only the first factor. In Table A3 are shown the loadings of each item, where the first factor was composed by four items that relates to bridging networks (i.e., connection with professionals, surveillance boards, public institutions, and universities), with a Cronbach alpha of 0.72 and average interitem covariance of 0.88.

Concerning perceived WUA's social capital, three items extracted from Krishna (2004) were adapted and assessed by presidents to measure group social capital. The aim of these statements was related to the degree of solidarity and togetherness within the community. In this case, the factor analysis identified two factors but only the first factor was retained based on the Kaiser criterion. All the three items considered were selected as they were above 0.45 (Table A4). The Cronbach alpha of these three items was 0.68 with an average interitem covariance of 0.60.

The reported Cronbach alphas for the selected items in each construct are all close to 0.7, which has been typically suggested as an acceptance threshold (Cortina, 1993). The same author, however, advises a cautious interpretation of this statistic. Factors with higher number of items tend to have a better alpha but this does not guarantee item intercorrelation. In the present study, although the constructs' Cronbach alphas are near to the threshold, the average interitem correlation is satisfactory in all cases.

Turning to the descriptive statistics of the above explained perception-based variables, Table 1 shows that these constructs tend to be concentrated to the right of the distribution, with a mean around four (i.e., “agree” with the sentences) and a standard deviation close to one. It is worth noticing, however, that the construct bridging social capital is less biased to right (with a median of 3.4). Thus, most of the presidents have poor vertical connections with entities or water institutions.

4.3.2. Cluster analysis results

The hierarchical clustering allowed us to identify an adequate number of clusters for comparison purposes, that in this study is based on the rates of non-payment of fees, non-cleaning of channels, and water theft. Using the whole sample of 68 WUAs presidents, there was a group of four individuals that consistently appeared different from the remaining observations. Because of the small size of this group compared to the others, the four observations were treated as a separate group without including them when constructing the clusters. The new cluster analysis, now with 64 observations, indicated that three clusters with different cooperation levels could be distinguished. Table 2 shows the definition and mean values of relevant variables for the three clusters, plus the addition of the aforementioned fourth outlier cluster, which is only reported for illustrative purposes (i.e., was not considered in the analyses of variance nor in the mean comparison tests).

First and foremost, the grouping variables non-payment of fees, non-cleaning of channels, and water theft were all significantly different among the three clusters, which validate the segmentation of the sample and emphasize heterogeneity in cooperativeness among WUAs. In this regard, we named Cluster 1 as “high cooperators” since response rate was low on all non-cooperation items. In the other extreme, we find Cluster 4, hereafter named “low cooperators”, being notably far from the mean values of the three clusters. This cluster is characterized by a high rate of non-cooperation, especially in non-payment of fees and non-cleaning of channels. In between we can distinguish Clusters 2 and 3 that exhibit particular characteristics. Cluster 2 features the highest rates of non-cleaning of channels and especially water theft, which suppose great harm to the rest of the users that belong to the WUA and hereafter called as “rulebreakers”. Cluster 3 is highlighted basically for the highest rate of non-payment of fees, renamed as “poor payers”; although it does not represent direct damage to other users, it does limit the operation and general functioning of the WUA.

As an overview from Table 2, there were statistically significant distinguishing differences among clusters either in terms of WUA's attributes (2 out of 16) and presidents characteristics (8 out of 27). Among president’s variables, these differences were found especially in variables related to commitment and dedication. In the following, we discuss the results reported by cluster, emphasizing the president’s characteristics, as this is the focus of this paper.

Table 2. Mean comparisons for president's and WUA's characteristics between group-cooperation clusters (n=64).

	Variable	Cluster 1: High coop. (n= 30)		Cluster 2: Rulebreak. (n= 13)		Cluster 3: Poor pay. (n= 21)		Cluster 4: Low coop. (n= 4)
Grouping variables	Non-payment of fees (%) *	0.47	a	0.69	a	12.67	b	23.5
	Non-cleaning of channels (%)	0.00	a	8.92	b	5.38	b	59.5
	Water theft (%) *	0.47	a	18.38	b	1.81	a	2.0
President's characteristics	Gender (1=man, 0=woman)	0.90		1.00		1.00		1.00
	Age (years)	62.80		59.54		60.05		65.5
	Experience in agriculture (years)	42.50		36.00		41.81		55.50
	Education (years)	12.83		14.38		11.71		10.00
	Participation in social organizations (number of organizations)	1.30	a	0.69	ab	0.48	b	1.25
	Participation in agricultural organizations (number of organizations)	0.57		0.77		0.52		0.75
	Farm ownership (1=owner, 0= administrator)	0.93		0.77		0.90		1.00
	Farm surface within the WUA (ha)	77.79		67.19		73.13		25.50
	Water shares concentration (%)	7.14		11.62		11.19		14.96
	Exposure to be affected by upper stream users (%)	46.54		65.93		46.01		24.08
	On-farm income (%)	77.00		65.38		87.86		100.00
	If lives within the WUA (1=yes, 0=no)	0.60		0.23		0.52		0.50
	Time of travelling to get the WUA from home (minutes)	7.33		7.53		6.90		5.00
	If dedicates more than half day a week to the WUA (1=yes, 0=no)	0.67	a	0.08	b	0.19	b	0.00
	If participated in courses or seminars in the last five years (1=yes, 0=no)	0.70		0.62		0.57		0.50
	Time as president in the WUA (years)	10.03		9.85		11.33		10.5
	If has experience in other directive positions in the WUA (1=yes, 0=no)	0.30		0.23		0.29		0.25
	If has experience as president in other WUAs (1= yes, 0=no)	0.20		0.23		0.19		0.25
	"Do you think that water availability has diminished in the last 10 years?" (1= yes, 0= no)	0.90		0.85		1.00		1.00

	"To what extent do you think water availability has been reduced over the last 10 years?" (%)	58.19	52.82	59.52	50.00
	"Do you know the subsidies available for your WUA?" (1=yes, 0=no)	0.87 a	0.69 a	0.33 b	0.75
	"How many project applications to subsidies have you made in the last 5 years?" (n)	7.93 a	3.77 ab	1.62 b	1.00
	"How many of them have you awarded?" (n)	6.83 a	6.33 ab	1.92 b	1.50
	Factor president's attitude toward the presidency (average of three items in 5-point Likert scale)	4.33 a	3.44 b	4.02 ab	3.58
	Factor president's leadership (average of five items in 5-point Likert scale) *	4.61 a	3.92 b	3.87 b	3.33
	Factor president's bridging social capital (average of five items in 5-point Likert scale)	3.75 a	3.58 ab	3.09 b	2.70
WUA's characteristics	Latitude of location (parallel south)	35.68 a	35.08 b	35.39 c	35.28
	If has fruit crops among the three most important (1=yes, 0=no)	0.67	0.85	0.67	0.75
	If suffer non-authorized extraction of water by outsiders (1=yes, 0=no)	0.33 a	0.77 b	0.43 ab	0.25
	Users using flow dividers as withdrawal system (%)	0.21	0.38	0.07	0
	Total length of the distribution system (km)	33.00	11.77	15.85	5.75
	Irrigated land out the total (%)	88.79	83.23	78.14	64.25
	Canal lining with cement (%)	21.93	13.81	9.84	16.67
	Homogeneity in size (%)	19.35	17.16	20.53	17.78
	Total number of users (n)	225.7	81.08	122.24	98.75
	Average user size (ha)	18.43	20.31	13.19	5.38
	If implements shifts as allocation mechanism (1=yes, 0=no)	0.60	0.54	0.71	0.75
	If belongs to a Channel Association (1=yes, 0=no)	0.50	0.85	0.62	0.75
	If has sanctions for non-payment (1=yes, 0=no)	0.83	0.62	0.52	0.25
	If has sanctions for non-cleaning of channels (1=yes, 0=no)	0.47	0.31	0.38	0.00
	If has sanctions for water theft (1=yes, 0=no)	0.40	0.54	0.48	0.00
	Factor perceived WUA's social capital (average of three items in 5-point Likert scale)	4.12	3.54	3.62	3.58

Different letters in the same row indicate significant differences at $p<0.05$, using Kruskal-Wallis rank test and post-hoc Sidak method

4.3.2.1. Cluster “high cooperators” (44% of the sample)

This group of WUAs is characterized by presidents having a significantly higher participation in community organizations (mean of 1.3 organizations out of four options), which is sometimes used as a proxy of social capital. More interestingly, this result is quite similar to the mean comparison for the factor president’s bridging social capital, which is significantly higher for “high cooperators”. Another salient characteristic in this group is that presidents devote more time to their WUA duties. The percentage of presidents dedicating more than a half a day weekly in this group is 67%, compared to the scarce 8% of “rulebreakers”, 19% of “poor payers” and the 0% of “low cooperators” (not included in he statistical comparison). Related to the above, presidents of “high cooperators” are not only more informed about available subsidies for WUAs (87% are informed) but also have submitted and have been awarded more applications for government subsidies in the last five years with means of 7.9 and 6.8 projects, respectively.

Turning to perception-based variables, presidents of “high cooperators” present significantly higher scores of attitude toward the presidency (4.3), leadership (4.6), and bridging social capital (3.8). These ratings score around four, which means “agree” on the 5-point Likert scale used to measure these constructs. Regarding community attributes, WUAs belonging to “high cooperators” are distinguished for a low prevalence of non-authorized extraction of water by outsiders (33% of WUAs face this problem, being significantly lower than in the case of “rulebreakers” (77%) and lower than “poor payers” (43%). Another relevant variable of “high cooperators” is that, compared to the other clusters, they are located in southern latitudes (35.68 parallel south).

Although not statistically significant, we also found that the few female presidents in the sample (3 out of 30 WUAs) belong to “high cooperators”. In addition, presidents of this cluster have the lowest concentration of water rights (7.14%) compared to “rulebreakers” (11.62%), “poor payers” (11.19%) and “low cooperators” (14.96%). As for community attributes, WUAs within “high cooperators” are characterized by a higher proportion of irrigated land out the total (88.8%), are larger with a mean of 226 users compared to 81, 122, and 98 in the other groups, and have longer distribution systems (33 km) with more percentage of lined channels (21.9%).

“high cooperators”, on average, depend on channel associations to a lesser extent (50%), and rely more on sanctions in case of non-payment of fees and non-cleaning of channels (83% and 47%), respectively.

4.3.2.2. Cluster “rulebreakers” (19% of the sample)

The presidents of this cluster present a very poor dedication of time to their WUA duties, with only 8% devoting more than half a day a week. Moreover, the president’s attitude toward the presidency is significantly lower, with a score of 3.4 that is close to be neutral in the five-point Likert scale. In relation to WUAs’ attributes, this cluster has two discriminant characteristics compared to other clusters. On one hand, “rulebreakers” are significatively more affected by outsiders (77% compared to 33%, 43% and 25% in the other groups) and, on the other hand, are located in northern latitudes (35.08 parallel south).

Although not statistically significant, presidents of “rulebreakers” present the highest mean values of education (14.4 years compared to 12.6 of the total sample) and the greatest percentage of farm administrator presidents serving as presidents (33% compared to an average of 10% of the total sample). Also, in this group presidents present the lowest dependence on on-farm income (65% compared to sample average of 79%) and, as expected, have the lowest rate of living within the WUA (23%). Furthermore, presidents of this cluster have the highest exposure to be affected by upper stream users (66% of relative position throughout the withdrawal canal), as well as the highest perception of general water scarcity over the last ten years (85%).

Although not statistically significant, this cluster features for the lowest number of users (81 farmers) but the highest average user size (20.3 ha) and prevalence of fruit crops (85% compared to an average of 69% of the other three groups). In addition, “rulebreakers” are relatively more heterogenous in size. The percentage of users with flow dividers as withdrawal system (38%) is higher in this cluster while the implementation of shifts as allocation mechanism (54%) is lower. Finally, “rulebreakers” belong to Channel Associations (85%) and set out sanctions for water theft (54%) to a greater extent than other clusters.

4.3.2.3. Cluster "poor payers" (31% of the sample)

WUAs within this cluster are distinguished statistically by having presidents with the lowest participation in social organizations (0.5 organizations out of four options) and a very low score in bridging social capital (3.1 in five point Likert scale). In addition, presidents present as less dedicated to their duties (19% devote more than a half day a week), are not well informed about the availability of subsidies for WUAs and exhibit a modest number of performed and awarded project applications in the last five years (1.6 and 1.9, respectively).

In terms structural aspects of the WUA, this cluster is located in the middle part of the area under study (35.39 parallel south) and are the second most affected by non-authorized extraction of water by outsiders. It also worth mentioning that in this group, although not statistically significant, the percentage of WUAs that have sanctions for non-payment is 52%, being lower than "high cooperators" (82%) and "rulebreakers" (62%).

4.3.2.4. Cluster "low cooperators" (6% of the sample)

Since this cluster was isolated from the statistical analysis for being outlier observations, the following presents the mean values of the selected variables for comparison with the the other clusters.

Firstly, presidents of "low cooperators" are older (66 years) and have more experience in agriculture (56 years). Their presidents are all owners of the farm and rely exclusively on on-farm income. This group also presents, on average, the lowest productive surface, with 25.5 ha compared to the sample average of 71.25 ha. In addition, presidents of this cluster hold more water shares than those of other clusters (15% compared to the sample average of 10%) and are less exposed to be affected by water extractions of farmers located in the upper stream (24% of relative position throughout the withdrawal channel), which might be related to a lower perception of water scarcity over the last 10 years (50%). On the other hand, the presidents of this group have a poor participation in courses and seminars (50%), low educational level (10 years) and very few applications for public subsidies, with an average of one application in five years compared to the sample average of 4.7. In addition, presidents of "low cooperators" have the lowest scores of bridging social capital (2.7 in 5-point Likert scale) and leadership (3.3 in 5-point Likert scale).

Concerning distinctive WUAs attributes characterizing this group, compared to the remaining clusters, "Low cooperators" have the lowest average user size (5.4 ha), proportion of irrigated land out the total (64%), length of distribution system (5.8 km), and non-authorized extraction of water by outsiders (25%). These WUAs also do not use flow dividers as a withdrawal system. Finally, "low cooperators" show the lowest use of sanctions for water theft (0%), non-cleaning of channels (0%), and non-payment of fees (25%).

4.4. Discussion

It is well known that sharing a common pool resource imposes several collective organizational challenges and that leaders may represent a pivotal role in this regard by taking advantage of the resource in the present and sustaining its use in the long term. However, in the context of WUAs, little empirical evidence exists regarding which leaders' characteristics can be associated with better or poorer collective action outcomes. By including personal features of presidents of the communities in the characterization of WUAs (e.g., leadership, social capital, and their willingness and dedication), we expand on past works typically focused on structural and organizational variables to discuss the governance of the commons.

In this study we explored collective action outcomes of 68 WUAs in Chile that follow a centralized governance structure, finding significant individual patterns of presidents and structural conditions of communities grouped into four clusters based on cooperation outcomes. These results highlight the relevance of considering leader-related variables when studying collective action, at least in the context of water user associations, and the importance of being conscious of non-obvious relationships when cooperation encompasses different tasks. Indeed, we show that cooperation is not a straightforward measure since several combinations of high/low rates of compliance among users' obligations can be distinguished within the same cluster. For instance, we recognized a cluster of high non-payment of fees but low water theft that contrast with another elicited cluster demonstrating low non-payment but high water theft.

The only cluster of WUAs that presented positive transversal cooperation in all the users' obligations included in the analysis was named "high cooperators". The only cluster of WUAs that presented positive transversal cooperation in all the users' obligations included in the analysis was named "high cooperators". This group consistently exhibited the best cooperation performance and thus serves as a benchmark of high collective action in the sample, allowing us to respond to our fundamental question raised in section 1: whether highly cooperative WUAs are distinguished for having good leaders. On the opposite extreme, the cluster called "low cooperators" have the highest rates of non-payment of fees and non-cleaning of channels, though very low rates of water theft. In between, we identified a cluster named "rulebreakers" which is featured by a high rate of water theft and low rate of non-payment of fees, while the cluster "poor payers" is just the opposite description (i.e., low water theft but high non-payment).

Among other attributes, presidents of "high cooperators" stand out for being informed about available public subsidies to improve the WUAs' infrastructure and management as well as for more active participation in social organizations. In this light, membership in voluntary associations can be related to some extent to the stock of individuals' social capital (Glaeser et al., 2002; Putnam et al., 1993), as it has implications for the generation of informal ties with various groups and the possibility to gain access to information. According to Glowacki et al. (2015), leaders with strong social connections can reduce their costs and improve their leadership.

Additionally, presidents leading "high cooperators" endeavour to make a greater effort for their communities as they dedicate more time to their WUA's duties, which is accompanied by taking advantage of subsidies for the improvement of their channels. These results agree with Dutra et al. (2015), who stated that leaders' personal effort to the collective benefit allows the development of successful initiatives to improve the management of natural resources. To some extent, the effort invested might be associated with the higher attitude toward the presidency exhibited by the presidents of "high cooperators". As attitude represents the behavioral disposition to the object based on individual's beliefs (Ajzen, 1991), a president's attitude toward the presidency can be linked to their willingness to spend time and resources on the WUA's affairs.

Subsequently, personal assets such as bridging social capital and leadership are expected to come into play, where presidents use their ability to seek opportunities, set objectives, and carry out the WUAs' projects. As for bridging social capital —referring in this case to vertical connections with irrigation-related institutions, experts, or research centers— it was found that presidents of "high cooperators" have higher values compared to other clusters. Networks with bridging organizations allow for knowledge exchange, trust building, establishing common goals, and facilitating other linkages (Berkes, 2009). According to the same author, bridging networks and leadership in natural resources co-management settings exert a prominent role in reaching a successful governance. Indeed, group decisions and actions may fall into stagnation due to poor leaders' leadership (Dutra et al., 2015). Hence, WUAs' presidents' personal assets seem to play an important role in collective action because better attitude and leadership are associated with higher cooperation, in the context of centralized governance structures. Although causality is not established, the correlation between presidents' variables and higher cooperation in WUAs may resonate in policy implications. Performing persuasive interventions and providing training to presidents could improve their attitude toward the presidency and their leadership, respectively, to foster collective action in WUAs.

As expected, WUAs' structural and organizational characteristics are also relevant for cooperation. Our findings show that the cluster "high cooperators", compared to other clusters, tend to be located in southern latitudes. This is likely due to water availability conditions which become scarcer moving north in Central Chile, where in previous years the General Directorate of Water Resources (DGA, 2014) predicted more restricted water availability situations for the Rapel and Mataquito basins compared to the Maule basin (34.2, 35.0 and 35.4 parallel south, respectively [as reference]). To the higher scarcity moving north within the study area, and based on the interviewed WUAs responses, we can add that in higher latitudes annual crops (e.g., potatoes, corn, and wheat) are prevalent, while in lower latitudes more profitable crops are more common (e.g., cherries, apples, and kiwifruits), that may lead to a higher marginal value product of water and thus an increased demand for the resource. In another vein, "high cooperators" are distinguished by being less affected by non-authorized water use from outsiders (e.g., industries, farms, residences). This variable relates in some way with fair conditions, which translates into a sense of respect and belonging among community members that motivates individuals to cooperate and engage in group-oriented behavior (De Cremer, 2002).

Rather than challenge the characteristics of presidents and the community, the goal of this paper was to provide evidence of the relevance of considering leaders' attributes when evaluating group cooperation and proposing benchmarks. Our results add to the limited empirical knowledge about the relationship between leader characteristics and collective action and suggest potential interventions to foster cooperation in the use of common-pool resources. Numerous countries have relied on the administration of national water resources by private WUAs (Meinzen-Dick, 2007); however, internal capacity is not necessarily present and may lead to poor collective action performance. Since leaders play a relevant role in surpassing collective action problems (Dutra et al., 2015; Glowacki et al., 2015; Gutiérrez et al., 2011; Ho et al., 2016), outcome-related policy incentives and capacity building for presidents or managers could enhance collective action in WUAs, thereby safeguarding the status and sustainability of water resources.

Despite the contributions explained in this section, the present paper has some limitations that require further research. First, this study is based on self-reports from WUAs presidents who are partly responsible for the organization's performance, which suppose a bias in responses. Furthermore, although WUAs in Chile are of centralized-type, potential influence on the part of the directive board that accompanies the labor of the president may also affect its performance but also the performance of the WUA. Also, as collective action is a multidimensional issue involving several behaviors or duties, the selection of specific actions made in this study may not address the true complexity of the concept. Therefore, it is recommended that further research include other aspects of collective actions that may not be included here. Moreover, future studies might expand this work to analyze the causality of factors influencing a higher cooperation performance and also to explore possible interactions between WUA-related variables, such as leaders' personal attributes, structural conditions, and sanctions. Another interesting topic is to deepen in the role of women leaders, since in spite of their low participation in the presidency of WUAs, all the female presidents interviewed in this study belong to the top performing cluster.

4.5. Conclusion

This study compared presidential and community-level characteristics of 68 WUAs based on their collective action performance, using the Chilean context of centralized WUA governance. Four clusters of cooperation were identified, showing distinguishing attributes related to three different group behaviors, namely water theft, non-cleaning of channels, and non-payment of fees. In all the three group behaviors, higher levels of cooperation were significantly associated with few community characteristics, highlighting the importance of presidents' attributes over WUAs' structural conditions. Presidents leading highly cooperative WUAs were distinguished by higher participation in social organizations, greater dedication of time to their duties, being more aware of funding opportunities, applying for and being awarded a greater number of subsidies, having a good attitude toward the presidency, and high bridging social capital and leadership. Policymakers aiming to improve the status and sustainability of water resources should consider interventions targeting leaders of WUAs, especially in countries relying on private self-administered WUAs.

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4.7. Appendices: Items and factor loadings to build constructs

Table A1. Selected items of presidents' attitudes toward the presidency after factor analysis.

Item	F 1	Selected
I feel satisfaction to be the president of my WUA	0.67	Yes
I enthusiastically do my job as president	0.60	Yes
I'm interested in continuing to be president of this WUA in the future	0.55	Yes

Table A2. Selected items of presidents' leadership after factor analysis (forced to retain one factor)

Item	F 1	Selected
I carry out the tasks of the WUA with the cooperation of the users	0.34	No
I tend to try new ideas or solutions within the WUA	0.56	Yes
I do everything I can to support group or personal innovations	0.73	Yes
My dedication for the benefit of the WUA is acknowledged by all	0.31	No
I show my interest in the needs and feelings of the users	0.73	Yes
I benefit from the innovations of the WUA	0.25	No
I immediately notice the barriers and challenges limiting the success of the WUA	0.41	No

Table A3. Selected items of presidents' social capital after factor analysis (forced to retain one factor).

Item	F 1	Selected
I consider myself a friend of several farmers in this WUA	0.02	No
I regularly meet with professionals or experts in agriculture	0.67	Yes
I know people from the directive board of other WUAs	0.46	Yes

I keep in touch with the Surveillance Board to which my WUA belongs	0.51	Yes
I have contacts at the National Irrigation Commission, General Directorate of Water, or Directorate of Hydraulic Works.	0.63	Yes
I have had links with universities or research centers	0.61	Yes
I would say that most people in the WUA are trustworthy	-0.15	No
Although a WUA project does not directly benefit me, I still continue contributing to it	0.05	No

Table A4. Selected items of perceived WUAs' social capital after factor analysis (forced to retain one factor)

Item	F 1	Selected
The feeling of union or closeness is strong within the WUA	0.80	Yes
If something unfortunate happens to any user, it is likely that everyone joins to help her/him	0.63	Yes
In the face of a natural disaster in the WUA, users are likely to cooperate	0.47	Yes

4.8. Reception e-mail from the journal Water Resources Research

28-07-2020 Gmail - AGU journal submission 2020WR028498

Gmail carlos bopp <cboppm@gmail.com>

AGU journal submission 2020WR028498

wrr@agu.org <wrr@agu.org> 28 de julio de 2020, 17:03
Responder a: wrr@agu.org
Para: cboppm@gmail.com

Dear Dr. Bopp:

We would like to inform you that you have been listed as an author on manuscript 2020WR028498, Collective actions and leadership attributes: A cluster analysis of Water User Associations in Chile., which has been submitted for possible publication in Water Resources Research.

The corresponding author, Alejandra Engler, has indicated that the submission has been made with the consent of all authors. Please note, manuscript communications are sent to the corresponding author. All authors may check the status of the manuscript at any time using this link: https://wrr-submit.agu.org/cgi-bin/main.plex?el=A3FU2GPmG6A6HeRC6F6A9ftd2KhmB0CbRfILwjduc3oO9wZ

ORCIDS are required for all corresponding authors and strongly encouraged for coauthors.

AGU has officially joined with many other publishers in a commitment to include the ORCID (Open Researcher and Contributor ID) for authors of all papers published starting in 2016. Funding agencies are also asking for ORCIDs.

Including the ORCID as part of published author information in papers will better enable linking of content and accurate discovery across individuals, similar to the way DOIs have enabled reference linking across journals. Given a specific scientist's permission, AGU can also add published papers to his or her ORCID record. See our statement https://eos.org/agu-news/agu-opens-its-journals-to-author-identifiers. We can also provide credit to you through ORCID when you serve as a reviewer.

If you have not already created an ORCID or linked it to your GEMS profile, please do so as soon as possible. You can both create and link an ORCID from your user profile. From your homepage, under General Tasks, click Modify Profile/Password. Under the ORCID field, select "Click here" to register and/or link your ORCID.

We appreciate your contribution to Water Resources Research, and we will make every effort to efficiently and fairly handle your submission.

Sincerely,

Water Resources Research Editorial Office

5. Comprehensive conclusions of the thesis

The purpose of this thesis was to analyze the relationship between agricultural incentives and land producers' behavior. Using different databases for each of the three thesis chapters, the general objective was addressed under a variety of contexts (i.e., forest production, annual cropping, and common pool irrigation), types of incentives (direct subsidies and non-economic stimulus) and individuals' behaviors (investment decisions, adoption of sustainable agricultural practices, and collective actions). Likewise, the incentives considered were discussed in terms of their intended effects, but unintended effects were also examined in the case of chapters 1 and 2. In both cases, the incentives were effective in their objective but relevant externalities were also detected, highlighting the importance of considering this possibility when designing, implementing, and evaluating agricultural development policies because a stimulus usually produces chained or cascading effects that may lead to undesirable results. Therefore, the findings of this thesis have political implications and raise the need to address possible unintended effects, which will certainly depend on the intuition and experience of the researcher or policymaker.

In terms of methodological approaches, a series of statistical resources were studied and implemented to address the objectives of each thesis chapter. In the case of the first chapter, which analyzed a sample of forest producers, Propensity Score Matching and Latent Change Scores were used as inputs for the estimation of a Structural Equation Mediation Model that allowed for a reduction in selection biases and favored causality in estimating the effect of the subsidy DL701 on the growth of forest plantations, land use changes, and the proportion of off-farm income. Regarding the second chapter in the field of annual crop production, a conceptual framework was proposed that expands the classic approach of technology adoption, based on structural variables, by including psychological factors. The intensity of adoption of sustainable agricultural practices was explained through a count model with a Poisson distribution, including an interaction term that allowed for the plotting of the correlation between intrinsic and extrinsic motivations (i.e., the SIRSD-S incentive). Regarding the third chapter, the methodological approach was exploratory, applying a cluster analysis to analyze group behaviors in Water Communities. It allowed for the identification of those attributes of presidents and the organizations that are associated with variation in the performance of aggregate cooperation.

In summary, the results of the three chapters raise the possibility of refining analyses of incentives by discussing avenues for improvements and changes in their focus, where the extension of information, technology transfer, and creation of human and social capital are key factors for these purposes. The findings of this thesis also suggest the benefits of modeling the behavior of agricultural and forest producers, usually addressed by the discipline of agricultural economics, considering a broader scope of behavioral approaches. A more comprehensive analytical perspective built on classical models offers the possibility of discovering the existence of non-obvious relationships, as well as relevant dismissed factors. I believe that this inference is not limited to the specific cases analyzed throughout this thesis, but also applies to the general understanding of humanity and the phenomena that we witness.

6. Appendices: Complementary activities carried out during the PhD

6.1. Publications developed and in development

Bopp, C., Bravo-Ureta, B., Jara-Rojas, R., Engler, A. Irrigation water use, shadow values and productivity: Evidence from stochastic production frontiers for a sample of Chilean wine grape growers (In development).

Jara-Rojas, R., Fuentes, F., Bopp, C. Engler, A. Use of the Universal Soil Loss Equation (USLE) to analyze the targeting of the soil recovery program in Chile (In development)

Bopp, C., Engler, A., Jara-Rojas, R., Araya-Alman, M. Economic performance of Chilean winegrowers: the impact of production approaches and the adoption of technologies (In development).

Bopp, C., Araya-Alman, M., Engler, A., Jara-Rojas, R., Igor, Y. What are the factors explaining pesticide sprayings on grapevines? A comparison of 440 plots belonging to three wine valleys of Chile. Acta Horticulturae (Accepted, in press).

Engler, A., Jara-Rojas, R., & Bopp, C. (2016). Efficient use of water resources in vineyards: A recursive joint estimation for the adoption of irrigation technology and scheduling. Water Resources Management, 30(14), 5369-5383.

Engler, A., Jara-Rojas, R., y Bopp, C. (2016). Irrigation technologies in the Chilean wine production: technical, economic and social aspects. Technical bulletin. Talca, Chile. Univ. de Talca. 60 p.

6.2. Attendance at conferences

50° Congress of the Argentine Association of Agrarian Economy. Buenos Aires – Argentina. Nov., 2019. Work presentation "Use of the Universal Soil Loss Equation (USLE) to analyze the targeting of the soil recovery program in Chile".

1° International Congress of Precision Agriculture of the International Society of Horticultural Sciences (ISHS). Palermo – Italia. Oct., 2019. Work presentation: “What are the factors explaining pesticide sprayings on grapevines? A comparison of 440 plots belonging to three wine valleys of Chile”.

30° International Congress of the International Association of Agricultural Economics (IAAE). Vancouver - Canadá. Jul. 2018. Work presentation: “Soil conservation behavior among annual crop farmers: the moderating role of intrinsic on extrinsic motivations”.

Regional Congress of Agricultural Economics and Inter Conference of the International Association of Agricultural Economics (IAAE). Talca – Chile. Oct. 2017. Work presentation: “Forestry incentive: evaluation of land use changes and off-farm income at the farm level”.

11° Conference of the Association of Wine Economists. Padua - Italia. Jun. 2017. Work presentation: “Economic performance of Chilean winegrowers: the impact of production approaches and the adoption of technologies”.

21° Congress of the Chilean Association of Agricultural Economics. Iquique - Chile. Nov. 2016. Work presentation: “Effect of the forestry incentive DL701 on land use changes - preliminary results”.

3° Trinational Research Days. Talca - Chile. Ene. 2016. Work presentation: “Efficient use of water resources in vineyards: a recursive joint estimation for the adoption of irrigation technology”.

6.3. Internships and training

Research internship at the University of Connecticut (Storrs - United States). Jan.-Mar., 2020. Research stay of 2 months in the Department of Agriculture and Natural Resources, supervised by Dr. Boris Bravo-Ureta. During the internship I acquired knowledge of productivity analysis that resulted in a draft of the work “Irrigation water use, shadow values and productivity:

Evidence from stochastic production frontiers for a sample of Chilean wine grape growers” . In addition, I participated in the weekly seminars of the department.

Research internship at Wageningen University (Wageningen - Netherlands). Aug.-Nov., 2018. Research stay of 3 months in the Department of Strategic Agricultural Communication, supervised by Dr. Marijn Poortvliet. During the internship, the writing of the second thesis chapter was completed which was sent to the *Journal of Environmental Management*. In addition, I participated in the weekly seminars of the department.

Intensive course "The Essentials of Scientific Writing and Presenting" that offered techniques on writing effectively and presenting scientific information. Oct., 2018. Wageningen University (Wageningen - The Netherlands).

World Bank's "Survey Solutions" application. Autonomous online training which allow the design and implementation of computer-assisted interviews. May.- Jun., 2019.

6.4. Teaching, consulting and scientific collaboration

Course "Identification of variables, data collection and exploratory analysis" for extension service providers of the Training Program in Extension Methodologies. Nov. 2019. Teaching to at INIA Raihuen. San Javier, VII R.

Class "Theory of the producer (or the firm)" for third-year students of Agronomy. Sep. 2019. Teaching at Universidad de Talca. Talca, VII R.

Class "Baking: Fundamentals - industrial process" for students of the evening program in Agricultural Engineering (INGEA). Sep. 2019. Teaching at Universidad Católica del Maule. Curicó, VII R.

Survey design on the Survey Solutions platform (World Bank) and subsequent implementation in the field to collect data using tablets (CAPI: Computer Assisted Personal Interview). Jun.-

Dec., 2019. Survey development service for the Department of Agricultural Economics of the Universidad de Talca. Talca, VII R.

Informant professor of the student David Pesantes. Thesis of the Master in International Agribusiness. Dec. 2018. “Relationship between Farmers’ Vulnerability to Soil Erosion and Conservation Agriculture Behavior ”. Universidad de Talca. Talca, VII R.

PhD thesis student in the Fondecyt Regular project n° 1180556: "From individualism to collective actions for the conservation of water resources: impacts and implications". Mar. 2018- present. Department of Agricultural Economics, Universidad de Talca. Talca, VII R.

Research assistant Núcleo Milenio CESIEP (The Center for the Socioeconomic Impact of Environmental Policies). Mar. 2016- present. Pontificia Universidad Católica de Chile. Santiago, RM.

Research assistant in the Fondecyt Regular project n° 1140615: “Adoption of irrigation technologies among small and medium farmers in the Maule region: the role of social capital”. Mar. 2014- Mar. 2017. Department of Agricultural Economics, Universidad de Talca. Talca, VII R.