Does the location of the salmon farms contribute to the reduction of rural poverty? An impact assessment of the Chilean case.

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Abstract

We test if the establishment of salmon farms in remote coastal areas had a significant impact on poverty reduction in the period 1992 -2002 for people from lower income strata in Los Lagos Region, Chile. We employ impact assessment techniques using as control group people residing in geographic areas where no salmon farms were established during the sample period. The poverty estimates are calculated using small-area models at the household level and a difference-in-differences approach is applied. Our results show that households residing in localities where salmon farms were installed reduced poverty more than those where these farms were not installed in the period. Additionally, we identify the geographical distances between localities and farms where this impact is significant. Our findings contribute to the debate on the socioeconomic effects of aquaculture for capital-intensive, international market-oriented industries.

Keywords: Poverty, salmon, aquaculture, small area estimation, impact assessment

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1. Introduction

Where, and under what circumstances, does aquaculture improve the living conditions of households? According to Beveridge et al. (2010), this question remains without a conclusive answer, even in literature that seeks to understand the impact of aquaculture activity on the welfare of associated communities. International evidence is mainly based on case studies, due to the different forms that this activity has adopted in the industries and places in which it has developed (see Béné et al. (2016) for an evaluation of this evidence). It is possible to find studies that show positive impacts (Belton et al., 2012; Toufique and Belton, 2014) or no impact at all (Nguyen et al., 2016).

There is a hypothesis in the literature which asserts that high technological and capital intensive aquaculture, which demands high skilled and specialized workers, might not have a large impact on rural poverty (Belton et al., 2012; Irz et al., 2007; Stevenson and Irz, 2009). The reason being that this type of aquaculture does not require low-skilled rural labor, and, therefore, would have little effect on the living conditions of the rural population. This could be the case of salmon farming, which is export oriented (Barton, 1998) and which carries out a significant part of its production process, the fattening of fish, in remote, coastal, rural areas (Barton, 1997).

Salmon farming in Chile is an interesting case to test this hypothesis that an intensive aquaculture industry does not benefit the rural poor. Chilean salmon aquaculture grew rapidly during the eighties and nineties to become the second largest exporter of salmon in the world (Bjørndal, 2002). In 1981, it produced 305 tons of salmon in total (Barton, 1998), while in 2002 it increased to 500,000 tons (Sernapesca, 2016). Moreover, the geographical concentration of its facilities in remote, coastal areas (Iizuka and Zanlungo, 2016, pp. 109–135) is instrumental to discovering the potential impact of this activity on the living conditions of the rural population living close to the farms. The magnitude of this spatially concentrated growth process makes it appropriate for identifying the impact that the development of the industry could have had on the living conditions of the rural population over a delimited span of time. Given these background facts, it seems reasonable to think that the development of this activity might have improved the living conditions and reduced the poverty rates of the populations living in the areas where this activity took place (Hosono et al., 2016, p. 79).

This research relies on the characteristics of the salmon growth process and the geographic concentration of activities to identify its potential effects on household incomes and poverty. We use impact assessment methodologies and the differences in differences (DID) approach to compare the temporal evolution of the poverty rate in remote coastal areas effected by salmon farms (the treated) with areas not impacted by the location of salmon farms (the controls). The sample period of 1992 to 2002 is chosen because of data availability, as will be discussed later. However, the period seems appropriate for the tested hypothesis since it covers the period of the most rapid growth in Chilean salmon aquaculture. We chose to perform this evaluation in Los Lagos region since this is the region where salmon farming was most highly concentrated during the period being considered.

Our article continues in the following section with some background information, including a brief description of the salmon farming sector and the definition and evolution of poverty in Chile. In section 3, we discuss methodological aspects of the study that include a review of the literature on the relationship between aquaculture and poverty, how to obtain geographically disaggregated estimates of poverty from small sample surveys, and the strategy used to assess the impact of salmon farming on poverty in remote coastal areas. In section 4, we present the results, and, in section 5, we summarize the conclusions.

2. Background: Salmon farming and poverty in Los Lagos region

The development of salmon production in Chile was the result of a partnership between the public sector and the Japan International Cooperation Agency in the 1970s (Fløysand et al., 2010). By 1994, Chile had become the second largest producer of salmon worldwide and was consolidated as an exporting industry. This success has been attributed to the excellent hydro-biological conditions for rearing, the international market advantage coming from its location in the Southern hemisphere with seasons opposite to the Northern hemisphere, and the low cost of labor and fish feed (Barton, 1997, 1998).

Salmon farming was initially concentrated in Los Lagos region in southern Chile (see Figure 1). Indeed, in the period of 1992-2002, 85% of rainbow trout, 80% of Pacific salmon and almost 100% of Atlantic salmon (the main species farmed) were produced in this region (Claude et al., 2000). The Chilean salmon industry is heavily concentrated in certain areas, with farms of great magnitude and high salmon density. Asche et al. (2013) show that Chile also follows the tendency towards fewer but larger companies. In fact, 80% of the harvest of Atlantic salmon is concentrated in ten companies. These figures are in line with the concentration of industry worldwide; for example, Norway, Scotland, and Canada concentrate 80% of their production in 25, 5, and 5 companies, respectively (Asche et al., 2013).

Different authors agree on the great impact that the industry has made in terms of labor absorption and job creation (Barrett et al., 2002; Fløysand et al., 2010). In 1994, the salmon industry directly employed 8,000 workers in Los Lagos region, plus around 3,000 to 4,000 workers in related industries, e.g., fish meal, net making and manteinance, land and sea transport of inputs and products, net pen lighting, infrastructure for fattening farms, cleaning and hygiene of net pens, etc. (Barton, 1997). In 2002, it was estimated that direct employment amounted to 38,400 workers (Iizuka et al., 2016, pp. 75–107). This means that 2% of the total labor force in 1992, and 7% in 2002, was employed in salmon aquaculture in Los Lagos region.However, most of these jobs were generated in urban areas. Barrett et al. (2002) pointed out that people perceived a rise in their purchasing power as a consequence of the salmon industry development, an aspect that might have influenced poverty reduction in the remote coastal areas.

In contrast, Fløysand et al. (2010) reported that people who live in these areas have a negative perception of the distribution of benefits generated by the salmon aquaculture sector. A source for this negative perception could be the impact that the industry has had on other activities and stakeholders, given the externalities and conflicts over the use of marine space. Externalities could come from pollution generated from feeding and salmon feces, which could reduce benthic biodiversity in areas with salmonid farms (Soto and Norambuena, 2004), and from the escape of salmon into the natural environment which, through the interaction with native fish, could produce significant damage on the ecosystem (Naylor et al., 2005). Regarding competitition for marine space, the main conflict is with the installation of salmon farms in the fishing grounds of artisanal fishermen. In the case of mussel aquaculture producers, they compete with salmon producers over the use of marine space for farm installation. At the same time, there is some evidence of potential environmental interactions on the productive level between the mussel and salmon producers (Whitmarsh et al., 2006).

Several authors have indicated that the salmon industry is characterized by low wage levels, poor or non-existent safety and health regulations, resistance to unionization, and low responsibility and respect for the community, the environment and the workers (Barrett et al., 2002; Barton, 1998; Ganga et al., 2010). In addition, during the period under review, a technological change that automated several of the productive processes was introduced, reducing labor intensity and generating a demand for more qualified labor (Barrett et al., 2002). These latter elements might have limited the impact of the industry on poverty reduction. However, no other work has addressed the impact of salmon farming on poverty in an empirically rigorous way.

When considering what potential impact the salmon industry might have on the living conditions of the remote coastal population, the greatest effects should come from the installation of salmon farms for fattening purposes in remote areas. Thus, the link to aquaculture activity in this case should come through the employment of remote coastal labor (this point is discussed in section 3.1). In this context, it is important to draw attention to the fact that Los Lagos region, and its minor administrative divisions, is one of the more isolated areas in Chile (Ministerio del Interior, 1999). Its fragmented geography probably gives rise to high costs of mobilization between different localities in terms of money and time. Therefore, farm location must take into consideration the difficulties of hiring workers living far from the salmon farms, both in terms of monetary costs and commutting time. In this sense, the potential effect of salmon farming on coastal household incomes should be geographically limited to the vicinity near where salmon farms are installed.

Figure 1: Los Lagos (X) Region and its Provinces

The official poverty estimates in Chile use the income method. This method employs income as an indicator of the ability of households or household members to meet their basic needs. The method identifies poor households by comparing their monthly per capita income with the value of a basket of basic goods and services ("basic basket"), which represents the poverty line or the minimum income established to meet the basic needs of one person. If the average income of the household is below the poverty line, the household is considered poor. The poverty line is lower in rural than in urban areas, considering that in rural areas, households can harvest or cultivate their own food (Ministerio de Desarrollo Social, n.d.a). In 1992, a person living in a rural area was considered poor if his monthly income was less than $17,362 Chilean pesos per month (about $1.53 US/day); by 2002, this figure rose to $29,473 (about $1.57 US/day), all in nominal terms.

Table 1 shows rural, urban, and total poverty rates at the national level for Los Lagos region in 1992 and 2003. Poverty incidence (PI) in the rural areas at the national level was reduced 11.9 percentage points during this period, while in Los Lagos region, the poverty rate fell only 5.3 percentage points. This contrasts with the trend of the poverty rate in the urban areas of Los Lagos region, which decreased by 20.6 percentage. This divergence in the evolution of the rural and urban poverty rate is not observed at the national level.

Table 1: Rural, urban, and total poverty incidence in Chile and Los Lagos Region, 1992 and 2003

	1992			2003		
	Rural	Urban	Total	Rural	Urban	Total
Chile	38.2	36.1	32.6	26.3	23.1	18.8
Los Lagos Region	34.7	50	34.2	29.4	28.6	21.6

Source: CASEN (1992,2003)

Several authors (Ganga et al., 2010; Ramírez and Ruben, 2015) point to the salmon industry as being responsible for the reduction in poverty rates in the Los Lagos region. However, Table 1 shows that this trend is also observed at the national level, where the influence of the salmon industry should be of lesser importance. Hence, there may be other inter-regional factors at stake, not necessarily related to the salmon industry, which could be behind the reduction of poverty in Los Lagos region in this period. On the other hand, there have been significant intraregional migratory flows from rural to urban areas, linked to new employment opportunities (Amtmann and Blanco W, 2001). Therefore, the process of poverty reduction does not necessarily occur at the same rate in the urban and rural areas. This is evident in the rural and urban poverty rates in Los Lagos region, as depicted in Table 1. Moreover, the impact that the salmon industry had on social conditions may be different in the rural and urban areas of this region.

3. Methods

We discuss three methodological issues: First, the linkages that exist between aquaculture and poverty in general, and, specifically, those that may exist in the present case – why and through which channels can aquaculture development affect poverty? Second, how geographically disaggregated estimates of poverty are obtained from small sample surveys in this study. Third, the strategy used to assess the impact of salmon farming on poverty in remote coastal areas.

3.1. Linkages between aquaculture and poverty

Aquaculture is considered an activity capable of contributing to poverty and food insecurity reduction. There are several conceptual pathways through which aquaculture growth can impact poverty (Edwards, 2000; Stevenson and Irz, 2009). Figure 2 summarizes some of these channels. Aquaculture could impact poverty through the household’s direct involment in the activity if the household increases its consumption of aquaculture products (Irz et al., 2007) or experiences a rise in income due to commercialization of surplus of production over consumption (Pant et al., 2014). Indirectly, it could increase the supply of fish in markets, reducing the price and making aquaculture products more affordable (Toufique and Belton, 2014). Moreover, it might impact indirectly by: 1) providing employment in the activity (Irz et al., 2007); 2) being a source of income and employment in firms that provide inputs and services to the industry (Asche, 2008); 3) being a source of income and employment in the processing industry; 4) impacting positively or negatively other activities through externalities (Primavera, 1997; Smith et al., 2010), and finally; 5) through ”consumption linkages” in the local communities and the multipliers of expenditure (Kassam and Dorward, 2017). According to Edwards (2000), the main benefits may come from improved food supply and/or increased income and employment. These latter benefits may arise in self-employed workers (e.g., income from the sale of a relatively high-value self-produced goods or services) or in dependent workers (e.g., employment in aquaculture value chains or in aquaculture farms).

Figure 2: The Impact pathways of aquaculture on poverty reduction. Source: Modified from Toufique and Belton (2014).

Direct	Indirect
Consumption	
• Greater consumption of salmon fish from own production	• Increased availability of salmon in the markets • Better accessibility to salmon due to reduced prices
Income	
• Higher income through participation in salmon industry • Higher returns for existing production	• Employment in salmon farms • Employment in firms that provide inputs and services to salmon farming • Employment in salmon industry higher value chains • ‘Consumer linkages’ in the rural non-farm economy and multipliers of expenditures • Positive/negative externalitities

There are several constraints, though, that could make it difficult for the poor to participate in the activity as independent producers; e.g., lack of assets or capital, restricted access to credit, lack of skills and technical knowledge, and high uninsurable risks. Thus, the potential benefits from aquaculture vary depending on the type of industry developed. Belton et al. (2012) classified different types of aquaculture, considering the scale of production and the characteristics of the production process, as peasant, quasi-capitalist, and capitalist. This scheme helps to identify different types of aquaculture, the relationship among these characteristics, and the heterogeneity of the impact that aquaculture has on poverty. In this typology, salmon cultivation could be seen as a capitalist mode of production, highly intensive in capital and in externally produced seed and feed, with permanent labor and professionalised management.

Irz et al. (2007) and Belton et al. (2012) have shown evidence of the potential of quasi-capitalist or capitalist aquaculture systems to generate high rural growth and reduce poverty. This is because these productive systems are connected with complex value chains, a large demand for unskilled labor, and abundant work opportunities. Stevenson and Irz (2009) concluded that the labor-intensity of new technologies is more important than increases in production. Thus, an intensive aquaculture system that is export-led with highly technical (capital intensive) processes, high-skilled and specialized workers, and capital accumulation targets, might not have a large effect on rural poverty. This is supported by the fact that this type of aquaculture does not demand low-skilled, rural labor, and, therefore, does not increase rural wages (Belton et al., 2012; Irz et al., 2007; Stevenson & Irz, 2009).

Given the capitalist-type system of salmon farming in Chile, it seems that the main potential channels through which poverty could be reduced as a result of the salmon sector are through direct employment in salmon farms or the related inputs or services, and the spending of this income on the consumption of goods and services provided locally and its multiplier effects (Kassam and Dorward, 2017). It is likely that poor people in rural areas do not benefit from direct consumption of salmon (as salmon is a high-value product and production is mainly for export) or from employment in the higher linkages of the value chain because processing centers are located in urban areas, far from where most of the fattening centers are located. Moreover, the geographical location of aquaculture farms is crucial for poor people to find a job, due to the transportation costs that they face if they have to travel long distances. The transportation cost will add to the households' reservation wage. Thus, poor people are likely to decline work in farms far from their homes (Laird, 2006). In other words, if the aquaculture farm is located far from a given locality, then it should not have a major impact on employment and income in that locality, and, hence, on its poverty indicators. In summary, it is expected that the main effect of salmon aquaculture farms in Chile in remote coastal areas should come through its direct employment effects and local income spending effects, and that these effects should have a limited geographic area of influence near the location of the salmon farms.

3.2. Poverty maps based on small area estimates

The main household survey in Chile is the Encuesta de Caracterización Socioeconómica Nacional, CASEN by its Spanish acronym. This survey allows estimating poverty rates with an acceptable accuracy up to the commune level, i.e., the third administrative level. However, in order to obtain more disaggregated estimates, which make measuring the economic influence of salmon farm establishment in small vicinities possible, it was necessary to estimate poverty incidence at the locality level. Poverty rate estimations based on the CASEN are not reliable at higher levels of disaggregation because they have very large standard errors. An alternative source of information that can be disaggregated, in principle, into very small geographical units is the Chilean Population and Housing Census (hereafter referred to as “the census”). The census, however, does not collect information on household income. Therefore, it is not possible to estimate poverty rates from this information. To overcome the problem of lack of information at low disaggregated level, we used the methodology proposed by Elbers et al. (2003, 2002) framed in the small-area estimation literature. We called this methodology ELL, after the initials of the authors’ names.

ELL uses unit-level models, where the units are households. This method makes it possible to create precise poverty maps at small geographic levels by combining the household survey data with a recent census. The ELL was applied in the following manner: First, we used CASEN to estimate a model that described, as accurately as possible, the association between the per capita household income and a set of households and/or household characteristic variables. This set of variables was restricted to those that could also be found in the census or in some set of tertiary data (e.g., geographic information systems (GIS)) which could be linked to both the census and CASEN. The model was used to predict the per capita income at the household level in the census. This was then compared to the poverty line to estimate poverty measures at the desired levels of aggregation. We assumed that the parameters of the estimated income model with household survey data were applicable to the census data.

The model that associates income (Y) to the household characteristics (X) is predictive and not explanatory. The criterion for choosing the predictive variables X is the quality of association between these and the predicted variable Y, the quality of the data, and the availability of the Xs at the time of the prediction. The method seeks to minimize the combination of bias and variance of the estimate, occasionally sacrificing theoretical precision in order to obtain greater empirical precision (Shmueli, 2010).

ELL has been used in many countries, including Chile at the comunal level (Agostini et al., 2008; Modrego et al., 2009), Cambodia, Morocco, Bulgaria, and Vietnam (Bedi et al., 2007), among others. The underlying theory of this methodology is shown in detail in a series of papers by Elbers et al. (2002, 2003).

In this paper, we use the ELL to estimate per capita household income, which is then compared to the official poverty line to obtain an estimate of the incidence of poverty at the local level. The application of this technique is one of the contributions of this article, since it allows us to obtain precise rural poverty measures at more dissagregated territorial levels than the ones allowed by the official estimates (Fujii, 2004).

3.3. Evaluation strategy

In order to isolate the effect of farm installation on the incidence of poverty from other factors that could be influencing poverty rate in these areas, we used the following evaluation strategy: we compare how poverty incidence evolved in remote coastal localities of Los Lagos region that before 1992 did not have concessions for farms in their surroundings, but after 1992 they did, with localities than did not show this change. We call the first ones "treated localities" (or “treated group”) and the second ones “control localities” (or “control group”). We used two types of control localities: the first corresponding to rural localities that did not have concessions of salmon in their surroundings in any year before 2002 (inclusive), which we called "Control 1". This strategy assumes that the localities without farms adequately reflect what would have happened to the localities with farms if these farms had not been installed there. The second corresponds to the localities that had salmon concessions before 1992, and also had salmon concessions after 1992. These localities we call "Control 2". This second control is established for the possibility that some localities of Control 1 are not good controls, because some of them may have characteristics which do not permit salmon farms installation. The comparison between the treatment group and Control 2 eliminates the possibility that the localities utilized are not suitable for the establishment of farms, since both groups have them. What differentiates them, then, is the year of establishment of farms (see Table 2). Control 2 captures the effect of the establishment of farms after 1992 on the poverty incidence in a locality . In the control localities, the trend of poverty should not change after 1992, but in treated localities we expect a break in the trend of poverty – a faster reduction of the poverty rate is expected if the installation of the farm has a positive effect on income.

To define which locality presents concessions of salmon in their surroundings, we define a circumference of radius *r* km drawn from the midpoint of the locality. The locality has a concession in its surroundings if the locality has at least one concession located inside that circumference, whereas the opposite indicates that there is no concession localized in the circumference, where $r \in \mathbb{N}[1,30]$[1]. Table 2 contains the definition of the control and treatment groups.

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[1] 30 Km it is not an arbitrary value. For any radius greater than 30 Km, almost all observations belong to the control group, therefore, its not possible to make proper comparison between groups.

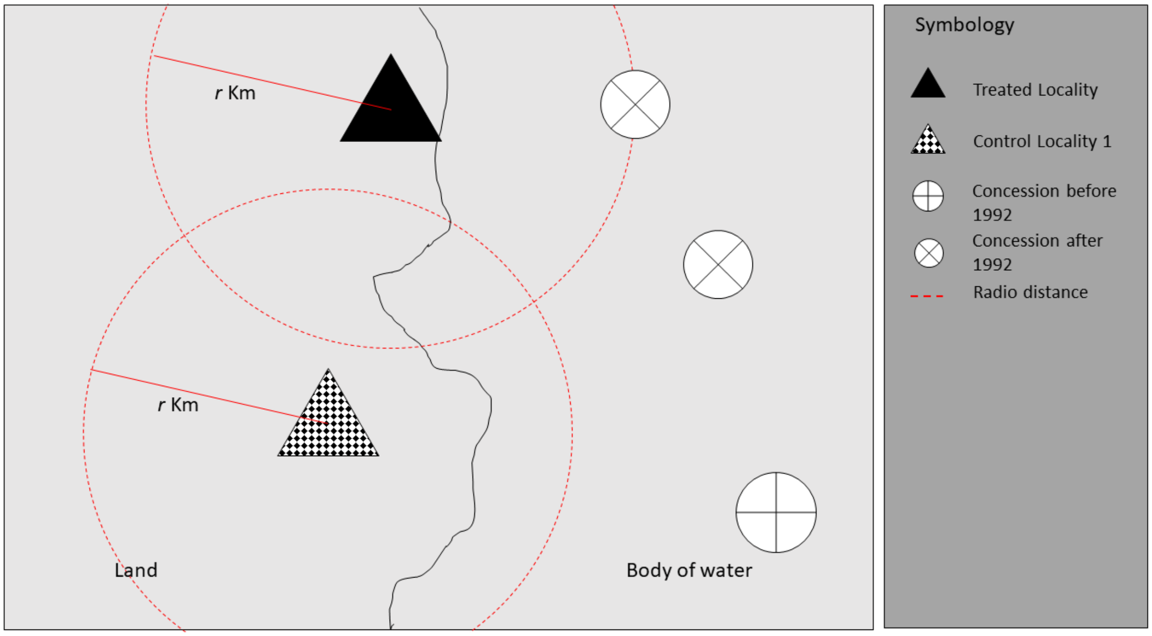
Table 2: Definition of control and treatment groups used for impact assessment.

Case	Control Group $(D = 0)$	Treatment Group $(D = 1)$
Control 1	Locations without salmon farms within a radius of *r* km, both in 1992 and 2002.	Locations without salmon farms in a radius of *r* km in 1992, but with at least one salmon farm within that radius after that year up to 2002.
Control 2	Locations with salmon farms within a radius of *r* km, both in 1992 and 2002.	

Source: own elaboration.

Figure 3 is used to illustrate the evaluation strategy using Control 1. It represents a fictituous geographical area. Land is situated to the left of the figure, and sea is on the right of the figure, separated by a demarcatory (non-linear) line that crosses the figure from north to south. Triangles represent localities and the circles represent farms. The treated localities are distinguished with a black triangle. The addition or multiplication signs on the farm circles distinguish farms established before 1992 or after 1992, respectively. The circumference around the locality defines the area of influence of the farm. In Figure 3, two localities and three farms are represented. The number of farms associated with a locality will depend on the distance that is defined as the influence area. In this case, the black-white locality is a control locality because it did not have a farm in 1992 or 2002, whereas the black locality is a treated locality because it has a farm established after 1992.

Figure 3: Illustration of treated and control localities using control 1



Source: own elaboration.

This strategy assumes that localities without farms adequately reflect what would have happened to them and to localities with farms (in terms of poverty incidence) if these had not been installed. In order to estimate the impact of the establishment of salmon farms in the localities, we need good estimates of the counterfactual – what would have happened to the poverty rate if the localities had not had a farm located at *r* Km of distance?

However, there may have been differences between the groups even before the advent of the farms. The pre-existing differences between the treated and controls could lead to an underestimation of the treatment effect in the event that the treated began in a worse condition than the controls, and an overestimation in the opposite case. This could introduce bias in the estimation of the effect. To eliminate this bias, we used the Differences in Differences (DID) method, assuming parallel trends (Heckman et al., 1999, pp. 1894–1896). In order to improve the efficiency of the estimation, and to control the characteristics that could be affecting the result variable (difference in IP), we made two types of regressions: one without additional regressors (WOAR) and one with additional regressors (WAR).

Natural regressors to include are those that maintain significant differences between the treated and controls and are not directly affected by the treatment (Bernal and Peña, 2011). In order to capture this effect, we included the educational gender equity index[2] (egei) and the travel time to the provincial capital (ttcap) as additional explanatory variables. We also interacted the latter with the indicator of treatment (control2) for the case of Control 2. Bernal & Peña (2011), indicated that starting in a less favorable condition could affect the evolution of the outcome variable (poverty in this case). "Egei" reflects the gender gap in educational issues, a key factor for development and overcoming poverty. Disadvantages in education may imply restricted access to the skills needed to participate in the labor market (United Nations, 2017). In addition, the degree of educational inequality among genders is an indicator of the degree of development of the local labor market. The higher this index, the more traditional and less developed is the market. Thus, the "egei" captures the differences in the levels of opportunities provided by local labor markets. "Ttcap" allows us to consider travel time, and, therefore, the costs that people face to reach the provincial capital. This is an indicator of the degree of connectivity that the inhabitants of the locality have with the larger urban centers. It does not only represent physical distances, but also the quality of the connections (infrastructure for mobilization, means of transport, etc.) that the locality has. The higher the level of connectivity, the lower the costs of connecting with other locations. Thus, both "egei" and "ttcap" can affect the evolution of poverty. We also tested the percentage of firms belonging to the primary sector ("primary") as an additional control variable. The idea was to control for the productive structure of the locality. The formal model is the following:

$$WOAR\colon \Delta\, y_L \ = \beta_0 \ + \beta_1 * D_L \ + \ v_L \qquad (1)$$

$$\text{WAR Control 1: } \Delta \mathrm{y_L} = \ \beta_{\{0\}} + \ \beta_1 * \mathrm{D_L} + \beta_2 * (\mathrm{primary_L}) + \beta_3 * \mathrm{ttcap_L} + \beta_4 * \mathrm{ttcap} * \mathrm{D_L} + \ \mathrm{v_L} \qquad (2)$$

$$\text{WAR Control 2: } \Delta \mathrm{y_L} = \ \beta_{\{0\}} + \ \beta_1 * \mathrm{D_L} + \beta_2 * (\mathrm{egei_L}) + \beta_3 * \mathrm{ttcap_L} + \beta_4 * \mathrm{ttcap} * \mathrm{D_L} + \ \mathrm{v_L} \qquad (3)$$

where $\Delta\, y_L$ is the difference in IP for the locality L, i.e., $IP_{2002} - IP_{1992}$. D_L is a variable that takes the value of 1 if the locality L is treated and zero otherwise. β_1 is

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[2] Educational gender equity index is calculated by (Ojeda et al., 2009)

the parameter that measures the impact of the establishment of salmon farms. $v_L = u_{2002L} - u_{1992L}$ is the error term of the model.

In order to check the robustness of the results, we incorporated the estimator of paired double differences (Bernal & Peña, 2011). This allows us to enhance comparability between the treated and controls. Thus, we take into account the potential bias arising from the possible non-random assignment of the treatment, assuming that the treatment is assigned only in observable traits and that non-observable traits follow a common trend (Bernal & Peña, 2011).

To construct the Propensity Score (PS), we used variables that could potentially affect the installation of the farms and the outcome variable at the same time (Bernal & Peña, 2011). These were: the distance time of travel (ttcap), assuming that greater distances imply higher transport costs and general operating costs for companies, and the isolation index (isol)[3], which seeks to reflect the cost for companies of installing in remote and isolated areas. In order to get a better covariable balance of PS, we tried different matching methods; namely, one nearest neighbor matching (PSM-NN1), two nearest neighbors matching (PSM-NN2) without replacement, five nearest neighbors matching (PSM-NN5) with replacement, and genetic matching (PSM-GEN) were tried.

4. Data and Results

4.1. Data

The unit of analysis of this study is the locality. Chile is divided administratively into 15 regions, and these into provinces. Each province is comprised of communes. Los Lagos region, until the year 2002, was made up of 4 provinces and 42 communes. The National Institute of Statistics (INE) divides the communes into census districts, classified as urban or rural. The rural census

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[3] This variable was built by the Undersecretary of Regional and Administrative Development (SUBDERE) and reveals the comparative disadvantages that some territories of the region face with respect to others. It takes into account the territorial situation considering geographical, economic, cultural-demographic and administrative aspects (Ministerio del Interior, 1999).

district is made up of one or more localities. Their locations are georeferenced and coded, which facilitates their identification. Using this geographical level of disaggregation provides us with enough observations and sufficient precise identification of the effect of salmon farming.

The demographic and socioeconomic characterization of the people belonging to each geographical unit is carried out using the CASEN and census. Both databases are required to be able to estimate poverty in small areas.

CASEN is a complex design survey, applied bi-annually or triennially by the Ministry of Social Development in order to acquire information about the demographic, educational, health, housing, labor, and income situation of households and the population. Its aim is to characterize the social conditions of the private dwelling households in the national territory. In addition, it considers the regions, and their urban and rural areas, as domains of study (Ministerio de Desarrollo Social, n.d.b). CASEN is representative of the urban and rural sectors at the national level, at the regional level, and for some self-represented communes (Ministerio de Desarrollo Social, n.d.b). The census is collected by INE every 10 years and includes demographic, labor and dwelling characteristics of the households. It does not include information on household incomes. The last available census in the country is for the year 2002, since the 2012 census failed and is not available.

The census data limits the possibility of applying the methodology employed in this study. We choose the period 1992 - 2002 because it is a period of rapid growth in the salmon aquaculture industry. In this study, we used CASEN from the years 2003 and 1992 to try to match the census data. For both years, the surveys were conducted between November and December. The censuses of 2002 and 1992 were held on April 24th and April 22nd of each year, respectively. In addition, we used the database of the Undersecretary of Fisheries and Aquaculture (Subpesca by its Spanish acronym), which contains geo-referenced information from aquaculture farms. In section 3.3 we defined the criterion used to associate farms with localities.

4.2. Results

We estimated the income models with the cluster (or communal) level variables that aim to decrease the variance of the common error component. Elbers et al. (2003) show that the greater the variance, the lower the accuracy of the method. The importance of the random effect is 13% and 14% for the 1992 and 2002 models, respectively. These values are in line with those reported by other applications of the method (Elbers et al., 2002), and allow small standard errors to be obtained in the estimates of the poverty measures (Elbers et al., 2002; Fujii, 2004). On the other hand, the R^2 for the heteroskedasticity model is approximately 0.08. Haslett et al. (2010) have found that, in general, with the application of ELL, it is unnecessary to model heteroscedasticity.

In order to have an idea of how adequate our results were, and given that there were no estimates of IP at the local level, we calculated the poverty incidence rates obtained with this method at the regional, urban, and rural levels and compared them with the official results. The last row of Table 3 reports the magnitude of the reduction in the poverty incidence between 1992 and 2002, whether we calculated it with ELL or used the estimates that come from the CASEN survey. Despite the differences in the proportions of individuals under the poverty line reported by both methods[4], absolute reductions in the urban and rural areas are practically the same, and differ only slightly more at the regional level. For the rural area, poverty falls by 46% in ELL and 37% in the official estimates. The urban area shows the same reduction between the ELL and the official estimates, which is 43%. The fall at the regional level is 41% and 37% for ELL and the official estimate, respectively. We can not test if these differences are

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[4] The main purpose of the ELL methodology is not to reproduce the absolute poverty rate, per se (because any poverty line is, in a way, arbitrary) (Ivaschenko, 2004), but to unveil which localities are the poorest and which are the richest, given a poverty line. It is usual in the literature to find differences in levels between estimated and actual poverty rates. Some authors, as Fujii (2004), in order to ensure correspondence with the official poverty rate in Bangladesh, adjust the estimated poverty line so that the actual poverty rate is reproduced. We also performed the assessment with an adjusted poverty line so that estimated poverty rates match the official ones. Our main findings did not change with this modification.

statistically significant because we do not know the standard deviations of the official estimates.

Table 3: Comparison between the incidence of poverty obtained through ELL and official estimates. Percentage values (%). The standard deviations of these estimates are given in parentheses.

	ELL			Official		
Year	Regional	Urban	Rural	Regional	Urban	Rural
1992	26.91 (1.51)	33.06 (1.77)	17.27 (1.11)	34.2	50	34.7
2002	15.9 (0.19)	18.93 (0.22)	9.35 (0.16)	21.6	28.6	21.8
Reduction	41	43	46	37	43	37

Source: Own calculations and Chilean Ministry of Social Development

4.3. Impact on poverty incidence

In Tables 4 and 5, we present the results for the single parameter that measures the differential impact on poverty incidence resulting from the establishment of farms compared with Control 1 and Control 2 respectively, i.e., the value of parameter β_1 in equations (1), (2) and (3). These results came from applying the DID method to the IP obtained from the ELL method at the locality level. Each column contains the results of the estimated models, i.e. WOAR, WAR, PSM-NN1, PSM-NN2, PSM-NN5, and PSM-GEN, using different distances of influence of the salmon farm to define the treatment group.[5]

The WOAR column for Control 1 (Table 4) shows that the average treatment effect in the locality, the local average treatment effect (LATE), is significant at 5% between 8 and 18 km with an average value of -4.9%. That is, the treated localities decreased the incidence of poverty more than they would have done without farms. In Figure 4, it is possible to see that its negative magnitude and significance

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[5] The results for the complete models corresponding to each specification are available on request from the authors.

increases with greater distances (black line), until it reaches a maximum at 13-14 km. Then, the significance and LATE begin to decrease. When controlling for additional regressors (WAR column in Table 5), LATE maintains its significance between 12 and 15 km. The red line in Figure 4 shows the behavior of LATE WAR. It is possible to visualize the difference with LATE WOAR. This result suggests that the preexisting differences influence the measured effect of farms' establishment with WOAR.

Table 4: Estimates of the average effect of treatment with Control 1, on the treated localities for the models with additional explanatory variables (WAR), without additional explanatory variables (WOAR), and different propensity score matching (PSM) variants.

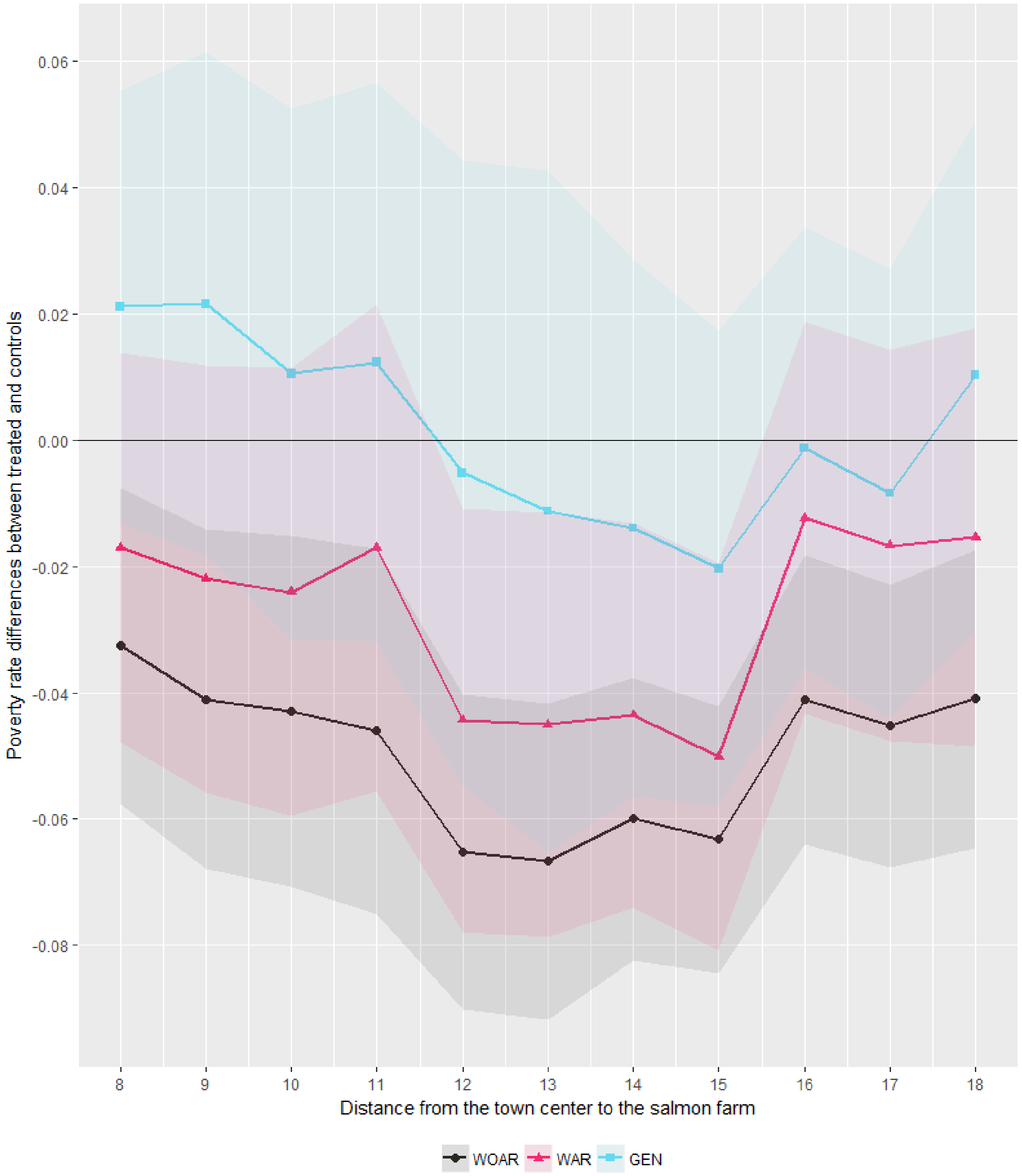
	Control 1					
Distance	WOAR	WAR	PSM-NN1	PSM-NN2	PSM-NN5	PSM-GEN
8 Km	-0.033(0.015)"	-0.017(0.019)	0.016(0.028)	0.008(0.025)	0.001(0.021)	0.021(0.021)
9 Km	-0.041(0.016)"	-0.022(0.02)	-0.026(0.023)	-0.026(0.019)	-0.009(0.021)	0.022(0.024)
10 Km	-0.043(0.017)"	-0.024(0.021)	-0.052(0.023)"	-0.054(0.027)'	-0.044(0.021)"	0.01(0.026)
11 Km	-0.046(0.017)*	-0.017(0.023)	-0.021(0.053)	-0.008(0.041)	0.016(0.035)	0.012(0.027)
12 Km	-0.065(0.015)**	-0.044(0.02)"	-0.023(0.052)	-0.017(0.033)	-0.016(0.026)	-0.005(0.03)
13 Km	-0.067(0.015)**	-0.045(0.02)"	0.004(0.053)	-0.041(0.036)	-0.019(0.03)	-0.011(0.033)
14 Km	-0.06(0.013)***	-0.044(0.018)"	-0.017(0.038)	-0.056(0.032)'	-0.03(0.026)	-0.014(0.026)
15 Km	-0.063(0.013)**	-0.05(0.018)*	-0.039(0.029)	-0.045(0.028)	-0.053(0.025)"	-0.02(0.023)
16 Km	-0.041(0.014)*	-0.012(0.019)	0.018(0.049)	0.004(0.043)	-0.005(0.037)	-0.001(0.021)
17 Km	-0.045(0.013)*	-0.017(0.018)	-0.025(0.052)	-0.007(0.046)	-0.014(0.045)	-0.008(0.022)
18 Km	-0.041(0.014)*	-0.015(0.02)	-0.033(0.053)	-0.001(0.038)	0.009(0.039)	0.01(0.025)

Significance codes: 0 *** 0.001 * 0.01 * 0.05 ’’ 0.1 ’

Standard errors between parentheses

Source: own estimations

Figure 4: Estimated average treatment on the treated at different distances for different models (WOAR, WAR, GEN). Control 1. The shaded areas represent the 95% confidence interval.



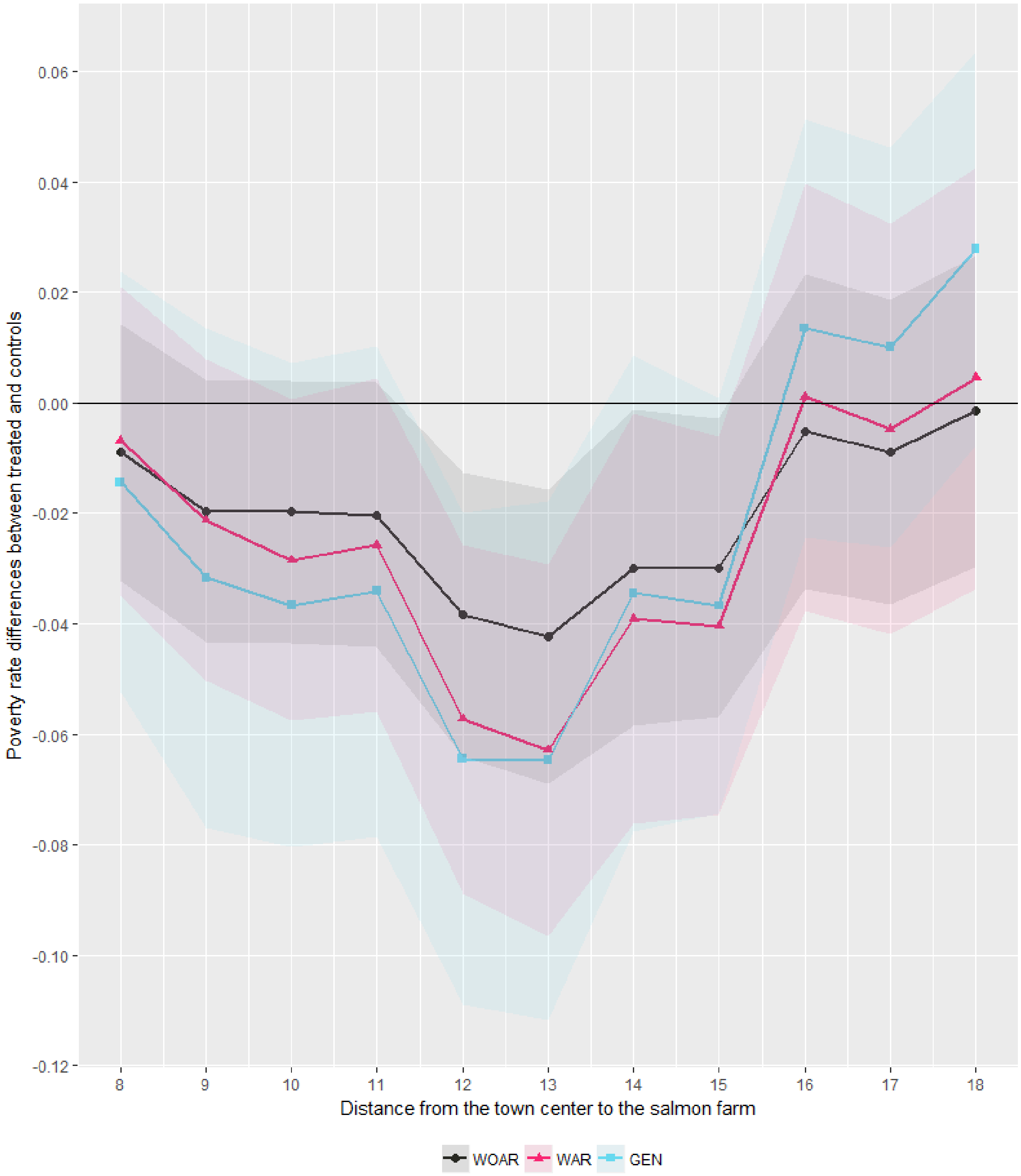
The WOAR column for Control 2 (Table 5) shows that LATE is significant at a distance of 12 and 15 km and averages -3.5%. When controlled with additional regressors, LATE maintains its significance in the same range of distances (column WAR, Table 5). Figure 5 allows us to visualize the behavior of the treatment effect for LATE WOAR and LATE WAR, and the difference between the two. As with Control 1, the results suggested the need to control for pre-existing differences.

Table 5: Estimates of the average effect of treatment with Control 2 on the treated localities for the models with additional explanatory variables (WAR), without additional explanatory variables (WOAR), and different propensity score matching (PSM) variants

	Control 2					
Distance	WOAR	WAR	PSM-NN1	PSM-NN2	PSM-NN5	PSM-GEN
8 Km	-0.009(0.014)	-0.007(0.017)	-0.015(0.023)	-0.013(0.023)	-0.025(0.023)	-0.014(0.023)
9 Km	-0.02(0.014)	-0.021(0.017)	-0.011(0.027)	-0.027(0.026)	-0.033(0.026)	-0.032(0.027)
10 Km	-0.02(0.014)	-0.028(0.017)	-0.065(0.026)''	-0.025(0.026)	-0.034(0.026)	-0.037(0.027)
11 Km	-0.02(0.014)	-0.026(0.018)	-0.023(0.028)	-0.024(0.026)	-0.029(0.027)	-0.034(0.027)
12 Km	-0.038(0.015)''	-0.057(0.019)*	-0.096(0.031)*	-0.072(0.025)*	-0.068(0.025)*	-0.064(0.027)''
13 Km	-0.042(0.016)*	-0.063(0.02)*	-0.094(0.034)*	-0.081(0.028)*	-0.078(0.027)*	-0.065(0.029)''
14 Km	-0.03(0.017)'	-0.039(0.022)'	-0.04(0.032)	-0.038(0.027)	-0.038(0.023)'	-0.034(0.026)
15 Km	-0.03(0.016)'	-0.04(0.021)'	-0.046(0.027)	-0.038(0.023)'	-0.054(0.024)''	-0.037(0.023)
16 Km	-0.005(0.017)	0.001(0.023)	-0.037(0.023)	-0.02(0.03)	-0.032(0.032)	0.014(0.023)
17 Km	-0.009(0.017)	-0.005(0.022)	0.001(0.037)	-0.029(0.029)	-0.01(0.033)	0.01(0.022)
18 Km	-0.002(0.017)	0.005(0.023)	-0.005(0.039)	-0.014(0.025)	-0.015(0.026)	0.028(0.022)

Significance codes: 0 *** 0.001 * 0.01 * 0.05 ’’ 0.1 ’
Standard errors between parentheses
Source: own estimations

Figure 5: Estimated average treatment effect on the treated at the different distances for different models (WOAR, WAR, GEN). Control 2. The shaded areas represent the 95% confidence interval.



Note that the effect between 0-11 Km is negative, but not significant, and the effect between 11-15 Km is negative, but significant. The methodology used rests on the comparison of a treatment group (households whose income was affected by the installation of salmon farms in their neighborhood in the sample period) with a control group (households whose income was not affected by the installation of a salmon farm in their neighborhood in the sample period). We discovered that the effect is significant within a certain vicinity of the farm. This is consistent with the idea that mobilization costs make it worthwhile for people living near the farm to work on it. We then tried with different treatment and control groups, which are defined by the distance from the locality where they live to the farm. As the definition of the treatment group becomes more restrictive (e.g. households that have a farm less than 11 km from its locality), we will include in the control group people that live more than 11 km from the farm (but, for example, less than 15 km) that are probably benefited from the farm installation (since they might work on the farm). They will, therefore, still be "similar", in income terms, to those that belong to the treatment group. Thus, the difference between the treatment and control groups will be blurred simply because we are including households that should belong to the treatment group in the control group, The differences between the groups will become statistically non-significant. The opposite will occur, in terms of including non-treated households in the treatment group, when the definition of treated household is extended to 16 – 30 km. Thus, actually what we obtain with this search grid over distances is the ability to identify the distance of the farms' influence (on average) on the income of rural households.

4.4. Robustness of the results

In Table 6, we report the balance[6] of the covariables of the PS measured by the absolute mean differences and variance ratio of these for methods PSM-NN1, PSM-NN5 and PSM-GEN at a distance of 12 and 15 km. It is possible to appreciate that matching methods remove the unbalance. However, Control 1 does

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[6] Rubin (2001) and Stuart et al. (2013) point out that covariable adjusted absolute mean differences close to zero, with threshold of 0.1 and variance ratios close to 2, may be acceptable.

not achieve good balance in all covariables, in any of the cases. On the other hand, Control 2 achieves good performance for all methods in the adjusted case. Note that all balance measures for Control 2 are closer to zero than Control 1. This result suggests that matching removes the potential bias on the estimate of a treatment effect for Control 2. Finally, the Genetic algorithm strikes a better balance.

When we estimated the treatment effect for Control 1 by GEN, LATE loses its significance at all distances (GEN column, Table 4) and the GEN estimators are significantly different than those of WOAR and WAR. This suggests the likely existence of relevant non-observable variables that affect treatment allocation, showing that Control 1 is not able to adequately reflect the effect of the treatment.

For Control 2, the LATE estimated by GEN maintains the significance between 12 and 13 km. However, LATE GEN does not maintain significant differences with LATE WAR in the 12 to 15 km range. This result suggests that, under the assumptions described, LATE is not biased by non-random allocation of the treatment. In short, Control 2 obtains a better balance in its covariables and does not present significant changes between the specifications, which gives us insights that this control is better than Control 1, when estimating LATE.

Table 6: Standarized difference in means and variance ratio between controls and treatment group for each control group, differents method and distances.

			Control 1				Control 2			
			Diff Un	Var. Ratio Un	Diff Adj	Var. Ratio Adj	Diff Un	Var. Ratio Un	Diff Adj	Var. Ratio Adj
NN1	12 Km	*isol*	0.43	3.18	0.27	5.43	0.1	1.39	0.03	1.02
		ttcap	1.06	16.12	-0.08	1.56	1.07	2.67	0.04	1.02
	15 Km	*isol*	0.44	2.78	0.33	4.73	0.24	1.18	0.08	1.04
		ttcap	0.96	13.04	-0.03	1.46	0.93	2.48	0.05	1.02

NN5	12 Km	*isol*	0.43	3.18	0.27	5.43	0.1	1.39	0.03	1.02
		ttcap	1.06	16.12	-0.08	1.56	1.07	2.67	0.04	1.02
	15 Km	*isol*	0.44	2.78	0.33	4.73	0.24	1.18	0.08	1.04
		ttcap	0.96	13.04	-0.03	1.46	0.93	2.48	0.05	1.02
GEN	12 Km	*isol*	0.43	3.18	0.27	5.43	0.1	1.39	0.03	1.02
		ttcap	1.06	16.12	-0.08	1.56	1.07	2.67	0.04	1.02
	15 Km	*isol*	0.96	13.04	0.44	2.58	0.93	2.48	0.04	1.02
		ttcap	0.44	2.78	-0.05	1.18	0.24	1.18	-0.04	1.05

Source: Author's calculations.

Note: Diff Un/Adj: Standarized Unadjusted/Adjusted difference in means between the two groups.

Var. Ratio Un/Adj: Unadjusted/Adjusted Variances ratio of the two groups.

Shaded cells show values that exceeds the threshold (0.1 for Diff and 2 for Var. Ratio).

The more robust results, given by the WOAR and GEN columns for Control 2 in Table 5, indicate that the LATE is significant at 5% between 12 and 13 km with an average value between -6.0% and - 6.4%.

5. Conclusions

We investigated whether the establishment of salmon fattening farms in remote coastal areas of Los Lagos region, Chile, impacted the area's poverty rate in the period of 1992-2002. For this purpose, we carried out an impact assessment using the differences in differences method, taking advantage of the variability generated by the gradual expansion of salmon farming into the different localities. At this level of geographical disaggregation, there are no official poverty measures. To construct them, we combined the 1992 and 2002 census data with respective CASEN household survey data (1992 and 2003), using ELL.

We found that the establishment of these farms had a positive impact on the IP. In fact, the localities reduced poverty, on average, around 6.0 percentage points more than they would have done without farms. Putting these results into context, the establishment and subsequent development of the fattening farms contributed, on average, to two-thirds of the reduction in rural poverty in the Los Lagos region during that period. This is a quantitatively important impact.

Several robustness tests confirm our findings. In particular, for the distance between 12 and 13 km, we find that there is no evidence of bias by non-random assignment and that the value of the parameter is not significantly different between different specifications of the controls, suggesting that there are no significant effects of unobservables.

The main forces driving poverty reduction in localities where salmon farms were established should have been the increased local labor demand and the effects of increased labor income. These mechanisms are not tested in the present study, but it seems the most likely way in which the results might be explained. However, the influence of salmon farms on poverty is limited geographically. The effect is discernible between 12 and 13 km distance. For greater distances, there seems to be no difference between having a farm or not. This phenomenon may be caused by the high costs of transportation faced by workers, product of the region's rugged geography, meaning that the salary paid by the farms does not compensate them for the greater cost of the trip.

The results obtained offer counter-evidence to the idea that only extensive or semi-intensive systems of aquaculture offer benefits to people of low resources. In the case of Chile, salmon farming is a highly intensive culturing system. The results suggest a significant impact on the living conditions of the rural population in the geographical areas where farms were set up.

ELL allows for investigating at low levels of geographic aggregation by combining the household surveys and the geographic information databases with censuses. ELL increases the accuracy of the variable of interest, allowing for the construction of indicators of poverty measures, nutrition, health, etc. This opens up a field for future small-area research. It also provides disaggregated information for decision makers to create more effective and focused public policy or to assess the effectiveness of state aid programs on a smaller scale.

It should be noted that one of the limitations of this study is the definition of poverty used. Looking at it in one dimension (that of income), leaves out the impact on other dimensions, i.e., health, education, etc. For this reason, future studies should address the impact on multidimensional poverty. Also, the methodology used in this study, although it allows for the accurate measurement of effects, does not serve to understand the channels by which the impact is transmitted. In addition, this study is focused exclusively on the fattening farms located in the rural areas of the Los Lagos region. Clearly, these limitations constitute avenues for future research to understand aquaculture in Chile and provide more evidence on how this food industry works.

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