Economic impact of the 2016 Red Tide over the exporting sector of Chile's Tenth Region

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Economic impact of the 2016 Red Tide over the exporting sector of Chile's Tenth Region*

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Abstract

This research aims to estimate the economic impact produced by the 2016 Red Tide phenomena on the ocean derived product export sector of the *Los Lagos* Region in southern Chile. For this purpose, a time series approach is employed using export data in terms of value and volume. Results suggest that the catastrophe had severe consequences over exported volume. Nevertheless, no significant results are found regarding exported net value.

JEL Codes: Q22, Q21, Q54, C22

Key words: Red Tide, Climate Change, Time-Series Analysis

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1 Introduction

What is commonly known as a Red Tide event is, rigorously speaking, a harmful algae bloom (HAB) in the ocean surface. A massive and abrubt development of this harmful algae population produces a significant alteration of many marine species and human health in terms of consumption. Biologists refer to this phenomena in different ways depending on several characteristics (Ochoa et al., 2003). However, in this paper, we will refer to it in generic terms as Red Tide.

Red Tides aren't new in Chile. In fact, the first official record of an event with these particularieties dates from 1972 (Guzman and Campodonico, 1975). Ever since, HAB's have become a frecuent phenomena in the southern part of the country. Most specifically, in between the *Los Lagos* region and the *Cabo de Hornos* within the national territory (Lembeye, 2008). However, throughout these four decades where records are available, the phenomena's impact has not been uniform. It has increased in terms of frecuency and intensity over the past years (Cabello and Godfrey, 2016).

In 2016 the *Los Lagos* region was affected by a HAB phenomena leaving multiple coastal towns in crisis. Especially due to the regions economic dependence on products derived from the sea. The 2016 HAB, unlike other times, lasted several months and covered an extensive geografical area as seen in Figure 1. It had unprecedented consequences. It started in February of that year, when the presence of harmful algae caused massive mortalities of farmed salmon along the coastal areas; specifically those located near Chiloé Island and within the Reloncaví Sound. Damage later extended to other species of bivalve molluscs, birds and other fish species. The bloom had its historical peak the last days of April of the same year (Buschmann et al., 2016).

On April 29th, facing the emergency, the Chilean government declares the coastal area of the *Los Lagos* region as a disaster-affected territory. By doing so, the intention was to facilitate resources and assistance for families dependent upon the fisheries sector for their livelihood (Ministerio de Hacienda, 2016a). In May, as a complementary reaction against the cathatstrophie, the Finance Ministry allocates tax benefits for afected families. Tax report and payment was postponed for taxpayers based in the affected territory (Ministerio de Hacienda, 2016b). Also in May, the Interior and Public Security Ministery granted direct monetary benefits in effort to reverse the downturn in income. (Intendencia Regional de Los Lagos, 2017).

There was a suspicion that the 2016 HAB developed after local companies had recently dumped salmon waste in the oscean. That idea, together with severe economic and environmental consequences of the catastrophe, trigered a significant social reaction. During the fall of 2016, a social movement erupted in Chiloé – an unprecedented event in the island's history. Multitudinous demonstrations were organized to demand more effective response from the national authorities and to accuse the local salmon industry for causing the disaster (due to irresponsible management of the residual waste from the salmon mortality) (Pedersen, 2017).

As a consequence of this HAB and other events over the past years, it is

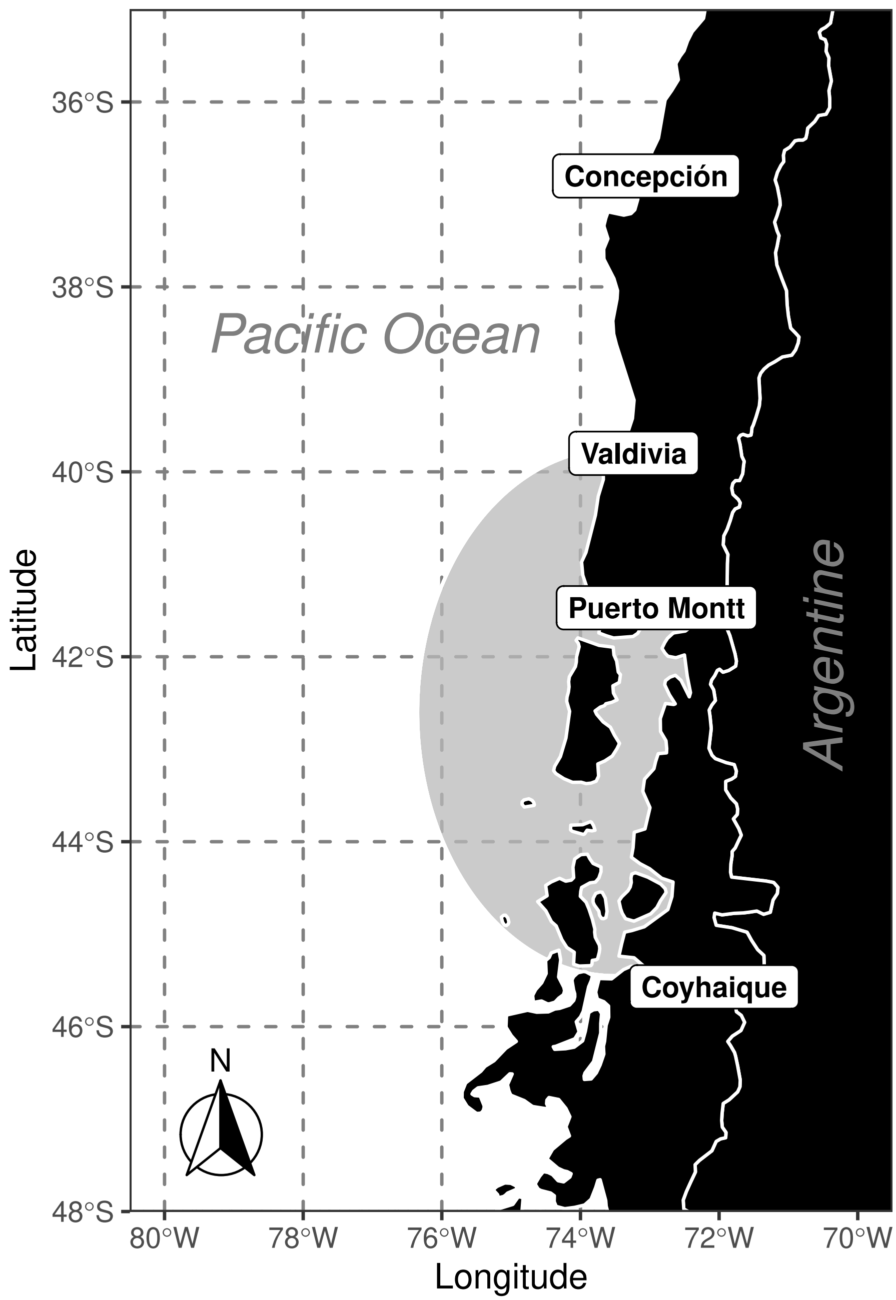

Figure 1: Map of the affected area

not surprising that there exists a lot of literature on the subject. These studies, mostly empirical, have focoused on the biological characteristics of HAB's and the 2016 bloom in particular. We can also find studies covering the nocive algues impact on human health and others regarding the socio-political reactions driven after the phenomenon (Mascareño et al., 2018; Pedersen, 2017). Nevertheless, in spite of the magnitude and coverage the natural catastrophe had in 2016, the economic impact has not been studied yet. In that sence, the main objective of this paper is to provide a first approach of the 2016's HAB economic consequences over the *Los Lagos* region. As explained in Section 3, the focous will be on the economic consequences over the exporting sector.

On the other hand, HAB's are a natural phenomena that, acording to existing evidence, will grow in terms of frequency and intensity as a result of climate change and human intervention in nature (Harvell et al., 1999). In that sense, the information presented in this paper will be relevant regarding future mitigation and prevention policy against HAB's. An effective response in terms of policy requires estimates of the potencial damage these natural catastrophes can produce.

The rest of the document is organized as follows: Section 2 delves into the economic relevance of fishing exports within the *Los Lagos* region. Section 3 analyzes both the investigative strategy adopted to identify the impact correctly and the data used for that purpose. In section 4 the main results are discussed and, finally, section 5 addresses the work's limitations and potenitial opportunities for futher research.

2 Background

To understand the scope of this phenomena, it's necessary to consider that within the *Los Lagos* region, the development of fishing and aquaculture activity has been significant over the past decades. As a matter of fact, today's regional economy depends relevantly on these economic activities and other productive sectors associated with fishing and aquaculture. Among the last, we can highlight the net washing industry, transport & commerce sector, canned seafood (especially mollusks), among others (CONICYT, 2010). All of this, without considering the diversified maritime tradition in the area (Lira, 2017).

The relative importance of fisheries and aquaculture activity is also observed in the export arena. Ocean derived products are, by far, the most relevant group of export within the region in terms of monetary value exported. As can be seen in Figure 2 of total exported value between 2010 and 2015 in the *Los Lagos* region, the main export groups are all different types of *Salmonids*.

For the strategy adopted in this paper, it is very relevant to state that the 2016 HAB was an exogenous phenomena. HAB's have become more severe over the past years given the consecuences of climate change and human intervention in the ocean. Basically, both these phenomena contribute to the generation of appropriate conditions for the blooms development, just as with the rise in ocean temperatures (Harvell et al., 1999). Although there have been discoveries

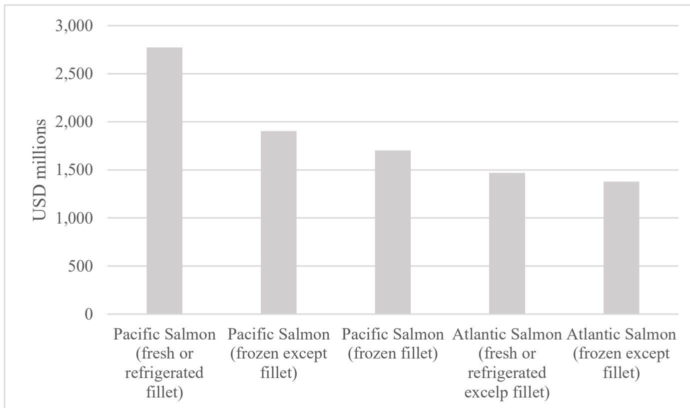

Figure 2: Total exported products in terms of US dollars between 2010 - 2015. *Los Lagos* region, Chile, 2015.

regarding HAB behavior, the technology or ability to predict their occurrence has not yet been achieved by scientists[1]. The above makes the phenomenon independent of decisions that individuals could potentially have taken to overcome the effects of the catastrophe. This fact will be critical for the adopted identification strategy.

3 Methods and data

In order to perfectly know the 2016 HAB impact over the ocean derived products export of the *Los Lagos* region, the optimal scenario would be to know the difference between the real value these exports had in 2016 after the catastrophe and the normal value they would have had in 2016 if the catastrophe didn't happen. Nontheless, we don't count with this second variable. Following MacKinlay (1997), we can only get an expected value of it and hence an expected difference between scenarios. To put it in algebraic terms, we can define y_t as the export value in a lapse of time t and $E(y_t|X_t)$ as the expected value of y_t given a vector of observable characteristics X_t; in this case, no HAB in year y_t. Having that stated, our interest is to know the value of the difference between y_t and $E(y_t|X_t)$, wich will be defined as Γ:

$$\Gamma = y_t - E(y_t|X_t) \tag{1}$$

The objective then is to have a good estimate of the real value of Γ. For that purpose, different methods have been proposed in the literature. Jin et al.

[1]Lee et al. (2013) for example, shows the difficulty of anticipating HAB's with models based on past monitoring.

(2008) employs a time series regression model over ocean derived product export data for *New England (USA)* between the years 1995 and 2005 to estimate the 2005 HAB's impact on exports in the affected area. Essentially, they follow an event study approach commonly used in financial analyzis; the interest variable is modeled as a combination of seasonal fluctuations, linear and non-linear trends and an event variable dummy (red tide pressence in this case). Our work presents a similar method. However, instead of using monthly dummies, we use a 12-month lag as a seasonal control. Then, the resulting equation to estimate is:

$$y_t = \beta_0 + \beta_1 L^{12} y_t + \beta_2 t + \beta_3 t^2 + \beta_4 D_t + \varepsilon \quad (2)$$

In this model, y_t represents the export value for month t of ocean derived products in the *Los Lagos* region. On the other hand, variables t and t^2 capture linear and nonlinear tendencies in the time series. The lag operator L represents a shift in the time series, where $L^k y_t = y_{t-k}$. D_t is a dummy variable that indicates the presence of a HABs phenomena that same month. In this case, D_t adopts a value of 1 for the months of April, May and June of the year 2016. ε_t represents an error term. Finally, in order to estimate the economic impact of 2016's HABs over the export of products derived from the ocean in the *Los Lagos* region, our interest will be on the value of the parameter β_4.

For the case of this study, we work with export data between the years 2010 and 2019 for the *Los Lagos* region. The data is obtained from Chilean Customs and provides information on the total ocean derived product export in the region such as fish, crustaceans, mollusks and other aquatic invertebrates. Based on this data we build a time series for monthly exports in terms of value (US dolars) and kilograms.

It's important to note that our attention is placed in both export value and weight in order to remark potential compensation between variables. In that sense, it's also relevant to outpoint that these variables of interest are taken in a normal and logarithmic scale with an intention to reduce data dispersion by the employment of the last.

Figure 3 shows the series behavior in a logarithmic scale. As one can observe, there is a clear seasonal tendency with considerable export growth between the months of November and February. This is a reasonable behavior considering the life cycle of one of the main export products within the region- *Coho Salmon*. Unlike other salmonid species, the coho salmon is harvested only during the summer. The tendency is also understandable according to the greater opening of fishing quotes from SERNAPESCA during those months for commercial fishing in sight of biomass reproduction. This demeanor is consistent for all of the sample years and for both cases: exported value and exported kilograms.

In a more revealing image, Figure 4 displays the monthly export volume mean for different time periods. As can be seen, the Figure considers the period before (2012 to 2015), during (2016) and after the catastrophe (2017 to 2019). According to what one can expect, there is a notorious drop of the exported mass between April and June in 2016 respect the other two considered time periods.

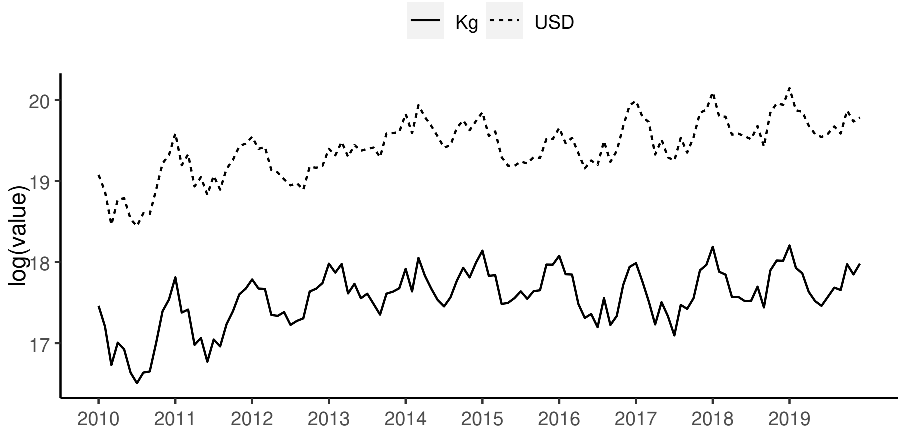

Figure 3: Time series in logarithmic scale

4 Results

This section presents the estimation results of the strategy previously discussed. Frame 1 contains the results for the two employed dependent variables: monetary export value and export volume (in kilograms) respectively. In the mentioned Frame, the first and second column show the results for export value using the normal and logarithmic scale respectively. Columns three and four do the same for the case of export volume.

As can be inferred from column (1) of Frame 1 for export value, there was no significant loss on the dependent variable in the time period of interest according to the model. Even though the estimated coefficient of interest has a negative sign, it is not statistically significant. The conclusions remain the same for the export value series in a logarithmic scale.

On the other hand, as noted previosly, Frame 1 also displays the regresions results for the case of exported volume in columns (3) and (4). In this case, results are statistically significant. According to our estimation, the loss in terms of export volume due to the 2016 HAB event was 10,76 thousand tons for the case of ocean derived products in each critical month. Now, if we consider this drop as the average lost during at least the four critical months of the catastrophe, we can state that an estimated total lost in terms of exported ocean derived products in the region was 43,04 thousand tons. On the other hand, in percentage terms (column (4)), the monthly downturn represents a 28% drop respect to the expected value for that time period in a hypothetical scenario with no HAB. All these results are statistically significant at a 95% level in the case of regular tons and 99% level in the case of the logarithmic scale.

Based on these results, it is not ruled out that, for example, the fall in export volume given the biomass contraction generated a price increase large enough to balance the exported value in the industry. It is also relevant to notice that in

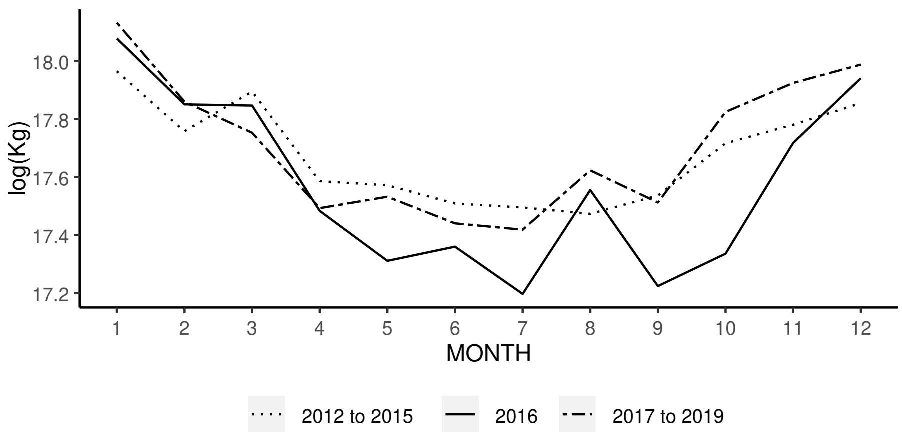

Figure 4: Monthly exported volume average for different time periods

the case of both time series, seasonality is significant. This dialogues correctly with the discussion presented in Section 3. The fact that the lag coefficient is positive for all cases suggests that both series follow seasonal trends. In other words, a month's export can be, in part, explained with the same month's export a year behind.

To corroborate the robustness of our estimation, the same methodology is reproduced in a placebo form for a year with no red tide. For that purpose, we use the year 2015 for the same region as a placebo. The results of this exercise are available in Table 2 of Appendix A. As can be seen, the results obtained in this sensitivity analysis are not significant but the seasonality trend remains, which reinforces the predictions discussed so far.

5 Discussion

Chile has seen, over the past decades, how the HAB phenomena has increased in terms of magnitude and frequency. This has brought relevant economic and envirinmental consecuences over the affected territory. In particular, 2016's HAB had devastating consequences for coastal economies of the *Los Lagos* region. However, as pointed at the beginning of this document, there are no studies that account for the economic impact caused by the HAB in the affected areas. In that sense, this paper aims to provide a first approach in this direction by analyzing the regions export evolution of ocean derived products.

Using the data provided by Chilean Customs we estimate this economic impact over the exporting sector. The results obtanied indicate that there was no real loss in terms of net exported value. Nevertheless, there was a 28% loss of ocean based exports, which was an unprecedented shock for the region. So these results open interesting debates. One could presumme that net exported

Table 1: Regression results

	(1) millp	(2) logvalp	(3) millkg	(4) logvalkg
d	-37.69	-0.174	-10.76*	-0.283**
	(-1.19)	(-1.60)	(-2.24)	(-2.67)
lag12	0.632***	0.472***	0.690***	0.593***
	(7.76)	(5.96)	(9.57)	(8.65)
date	-7.852	-0.0312	-1.333	-0.0285
	(-0.43)	(-0.54)	(-0.70)	(-0.70)
date2	0.00609	0.0000246	0.000995	0.0000213
	(0.44)	(0.57)	(0.70)	(0.70)
cons	2648.8	20.17	462.7	16.74
	(0.44)	(1.06)	(0.73)	(1.26)
N	108	108	108	108
R^2	0.466	0.969	0.552	0.944
DW	2.31	2.40	2.08	2.11

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

value was not affected due price compensations. The downturn in supply - due the HAB's presence - could have driven up prices of ocean based exports to compensate economic losses. However, this doesn't mean that the phenomena had no other economic impacts. The less production probably demanded less labor input in the exporting sector during the critical months. A hypothesis that dialogues correcty with the literature about social impact after the catastrophe.

Finally, considiring this last discussion, it is immportant to note that the analyzis developed here has multiple limitations. Most relevantly, it only considers the impact over exports and not over the entire ocean derived product sector or region as a whole. Given the relative importance of this sector within the region and, particularly, the coastal communities, it is conceivable that the shock could have had repercussions over other sectors within the local economy thru different mechanisms. First, impacting those productive enclaves linked to the exploitation, processing and commercialization of the different products and, secondly, through a reduction in demand in the area and a drop in future production, the income of the rest of the population within the affected territory. In that sense, it would be interesting to have a more complete impact study that would consider other variables of economic interest such as the general unemployment level, income consecuences, among others. The study of these variables and the respective mechanisms will remain as a subject for future research.

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A Robustness

To reinforce the conclusions obtained in Section 4, the robustness analysis results are here presented. These results are driven from the same identification strategy using 2015 as the year of impact.

As displayed in Figure 2, the results obtained are not statistically significant.

Table 2: Robustness results

	(1) millp	(2) logvalp	(3) millkg	(4) logvalkg
d	-41.33	-0.179	-2.723	-0.0756
	(-1.32)	(-1.67)	(-0.55)	(-0.69)
lag12	0.638***	0.489***	0.703***	0.604***
	(7.90)	(6.25)	(9.53)	(8.52)
date	-7.275	-0.0299	-1.824	-0.0414
	(-0.43)	(-0.56)	(-0.92)	(-0.96)
date2	0.00565	0.0000236	0.00136	0.0000308
	(0.44)	(0.58)	(0.92)	(0.96)
cons	2459.7	19.48	627.4	20.89
	(0.43)	(1.10)	(0.96)	(1.49)
N	108	108	108	108
R^2	0.472	0.969	0.529	0.943
DW	2.32	2.42	2.12	2.16

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$