Market driven management of climate change impacts in the Spanish mussel sector

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Abstract

Mussel farming is the largest aquaculture activity in Spain both in volume and value, being a key pillar for the development of the coastal areas in Galicia (NW Spain), where this production is concentrated. The available scientific knowledge suggests that in the long term the primary productivity of the Galician estuaries will be reduced due to climate change. Consequently, adaptive management will be required to face this challenge. The impact of the likely production decrease will depend, among other factors, on the availability of substitutes, being their identification the main object of this research. So, it was analysed whether this markets are integrated or not through cointegration tests, finding that only the French and the Spanish markets are partially integrated. This implies that since very little substitutes are available for the Galician fresh mussels, decreases in production will not necessarily affect producer's income, as prices increases will compensate the (eventual) reduction in volume. In terms of policy, this study suggests that market intelligence may contribute to an adaptive, pragmatic and flexible framework to face climate change impacts, avoiding too anticipated or blind responses that may result in economic, environmental and social costs.

Keywords: Climate change, mussel farming; cointegration, market intelligence.

Highlights:

French, Italian and Spanish mussel markets cannot be regarded as an integrated market

Spanish and French mussels are imperfect substitutes

Reductions in production will be countervailed by increasing prices

Market intelligence is a key to guide responses to climate change

Strategies minimizing risks linked to climatic uncertainty should be designed

1. Introduction

Climate change is a major threat for human societies [1] and scientific evidence supports the conclusion that this process is already altering marine ecosystems [2], including changes in marine ecosystem productivity, fisheries, ocean CO_2 uptake, oceanic oxygen concentrations and terrestrial vegetation [1], as well as modifications in the intensity and timing of coastal upwelling with consequent impacts on fish migration patterns, recruitment, growth, distribution, abundance and predatory-prey relationships [3].

The implications of such a phenomenon for the fisheries and aquaculture sectors and coastal and riparian communities are difficult to ignore [4] but, at the same time, they are not deeply understood and, consequently, a risk of mismanagement exists. Particularly, how markets should react to changes in production is key to optimize producers and policy-makers efforts to achieve resilience [5].

In fact, climate change is considered an added factor of uncertainty that complicates the challenges to be addressed by fisheries and aquaculture to the extent that is expected to affect the volume and price of production, the operational costs [6] as well as revenues and profits of enterprises and households that depend on them [7,8].

Mussel farming in Galicia (Spain) is the figurehead of a system of industrial relations that contribute to the welfare of society both directly, by generating employment and income, and indirectly through ancillary and related activities. In 2011 the turnover was 157 million euros, and its technical coefficient was 0.23 [9], i.e., for every euro of production, 0.23 euros of intermediate inputs were demanded from upstream industries, contributing to sustain activity and employment in such activities. To those impacts should be added investment, with an additional demand of 37 euros for every 100 euros of turnover from sectors such as shipbuilding, construction of rafts, etc. [10]. It also generates 3436 full-time equivalent jobs plus 779 family workers[1].

This production system is linked to a very specific location: 98% of the Spanish mussel production comes from the Galician estuaries (NW Spain) [11], where a reduction in primary production is expected in the long term. Among the significant changes that are likely to occur in this area are the warming of the ocean surface [12], extreme events such us heat waves [13], the increasing of the renewal time of the estuaries and the weakening of upwelling [14].

The NW Iberian Peninsula is the northern limit of the Eastern boundary Large Marine Ecosystem that extends along the Atlantic coasts of Africa and Europe from 10^0N to 44^0N [15,16]. At these latitudes, coastal winds are favourable to the upwelling of the cold and nutrient-rich Eastern North Atlantic Central Water during the spring and

[1] Data obtained from the survey of the Input-output table of the Galician fishing sector 2011.

summer and favourable to the downwelling of surface coastal waters during the autumn and winter [15,17] contributing to the high productivity of this kind of areas [18]. This unique combination of wind patterns and coastal morphology makes the Galician estuaries exceptional sites for the extensive culture of mussels (Mytilus galloprovincialis) on hanging ropes [14] and explains world's highest rates of growth [19].

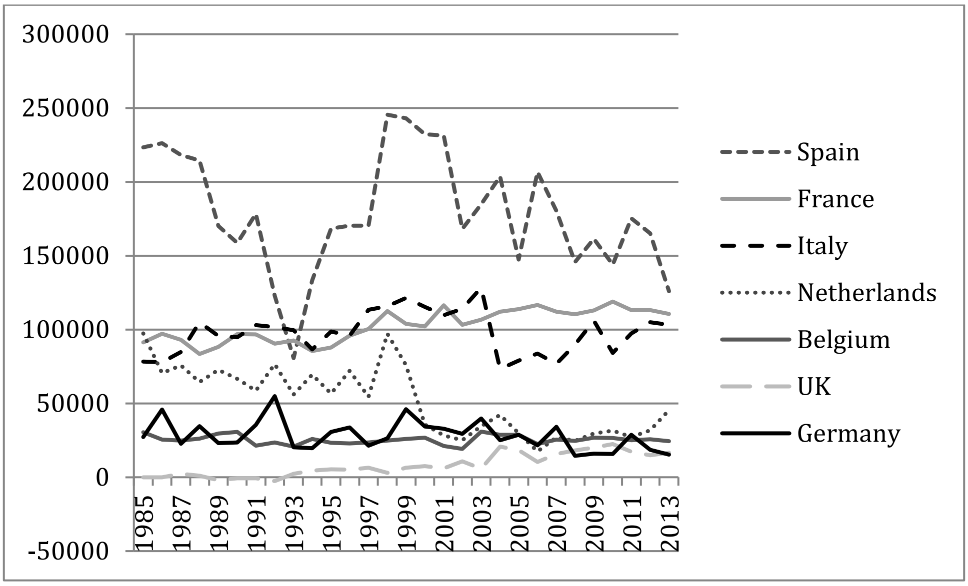
Hence, even though the available evidence is not conclusive, most of the research suggests a weakening in the upwelling intensity in the NW Iberian coast [14,20–24]. Therefore, given the dependency of the high growth rates on the coastal upwelling and the circulation of the *Rías* [25], climate change represents a serious threat for mussel farming in Galicia. However, this may not necessarily imply a reduction in producer's income, since it depends not only on total production but also on prices. If substitutes are available fishers income will decrease; if, on the contrary, no substitutes are available, a reduction in volume will lead to higher prices, increasing unitary revenues. This means that market management may represent a suitable way to address the socio-economic impacts of climate change and reduce uncertainty for sea-resources dependent population. Understanding market dynamics is key to optimise mitigation strategies and to adopt a resilient behaviour of productive activities. This paper examines long-run relationships (substitution) between major European mussel markets (Spain, France and Italy) using cointegration analysis, to assess the degree of integration among these markets. The results can help in the design of adequate policies aimed at mitigating the effects of climate change on farmer's income.

2. Background.

Spain, France and Italy are the three major producers [26] and consumers of mussels in Europe, being Spain the third world largest producer (after China and Chile) and accounting for almost a half of the European volume.

Going deeper into details, Spain represents the largest European market with an apparent consumption of 125,845t in 2013, even though since 1998 shows a decreasing trend that leads to a convergence with the French (110,665t) and the Italian (103,234t) markets. At a significantly lower level, below 50,000t, are countries like The Netherlands, Belgium, Germany or the UK. In this second group, the progressive reduction in the Dutch national consumption is striking, probably due to a drop in internal production. Specifically, the scarcity of seed and the fall in the growth rates led the Dutch production from 80,000t in the 90s to half of these figures in recent years [27]

Figure 1.
Mussel apparent consumption in the major European markets (t.)
Source: FAO, 2015.



Going further in the delineation of the national markets, the components of the apparent consumption in Spain, France and Italy are next analysed. Since, to obtain yearly consumption, exports are netted out from imports plus the internal production, the surface over the white bar (Fig. 2, 3 and 4) represents apparent consumption.

Figure 2.
Spanish apparent consumption of mussels (t).
Source: FAO, 2015.

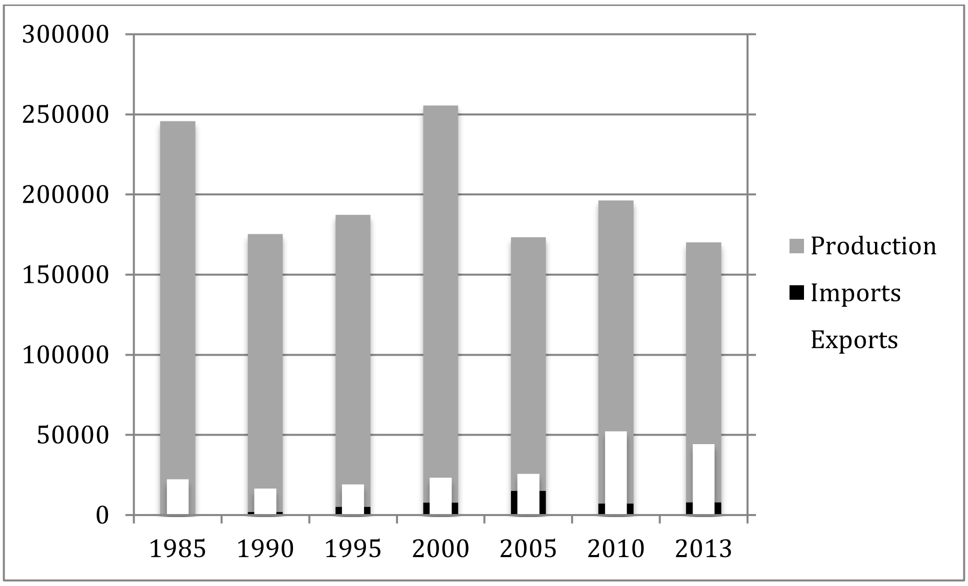


Figure 3.
French apparent consumption of mussels (t).
Source: FAO, 2015.

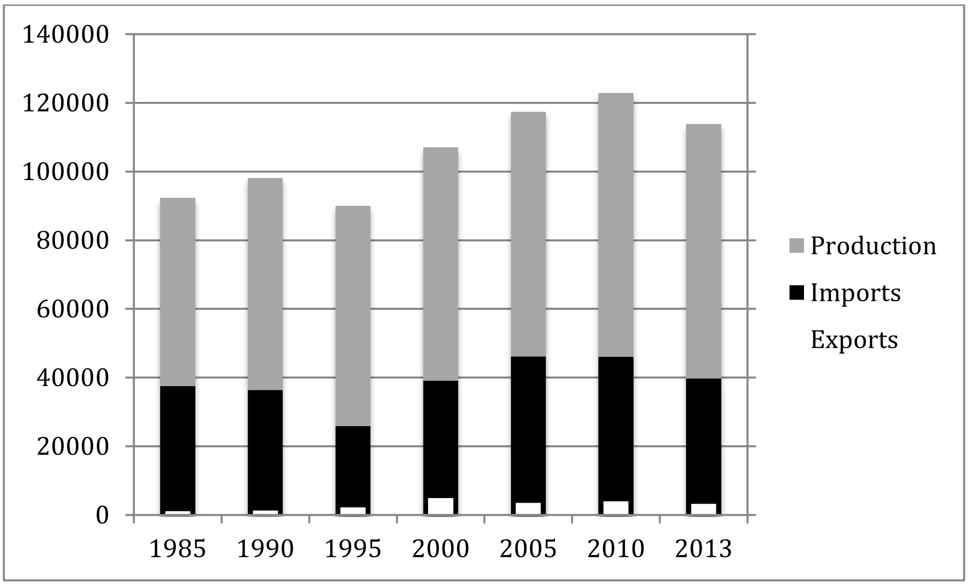
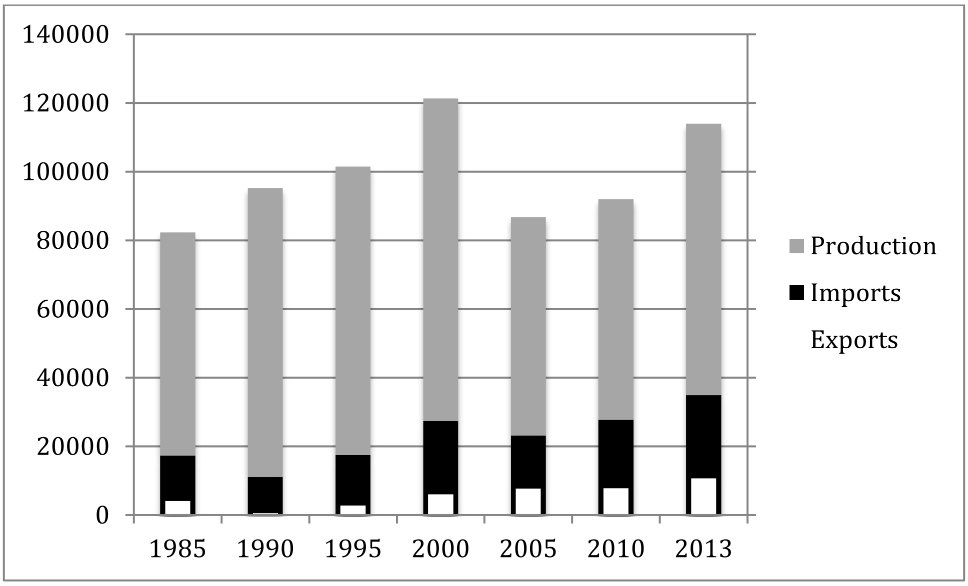


Figure 4.
Italian apparent consumption of mussels (t).
Source: FAO, 2015.



Spain constitutes a national-production dominated market, with a very low level of imports. As for France, during the last years, imports cover one third of total consumption, while exports are marginal. The insufficiency of the national supply is covered through imports from Spain during the whole year, Ireland and UK from January to April, the Netherlands in September and Italy from April to July [28]. Ultimately, Italy also shows a high identification between national production and consumption, with imports representing about one third of the internal demand.

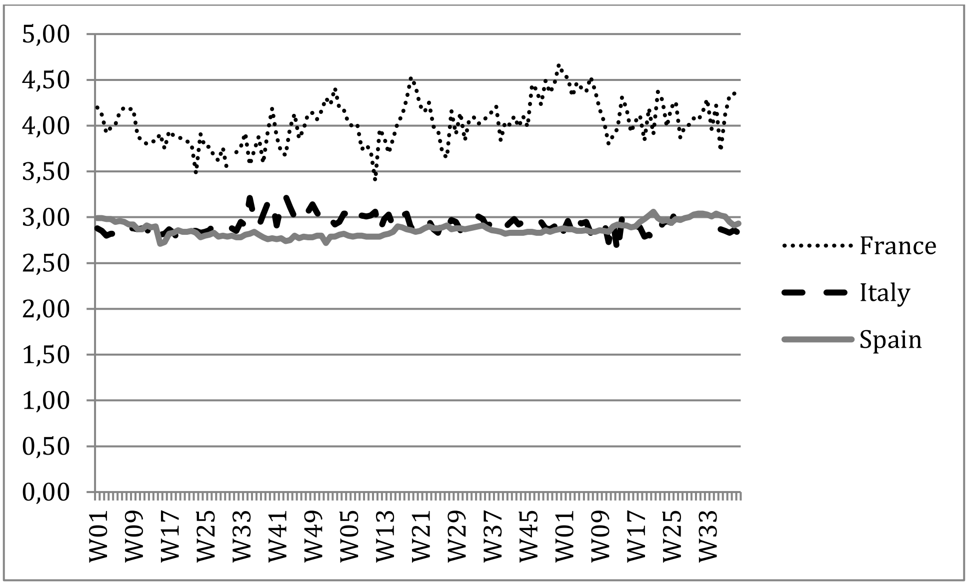
3. Material and methods.

The data used for the econometric analysis are weekly retail prices from EUMOFA (European Market Observatory for Fisheries and Aquaculture Products), which provides data at national level on fresh mussel prices from Spain, France, Italy, Netherlands, Sweden, UK and Belgium. An advantage of using retail data is that it is the price from the wholesaler that is measured, with tariffs, transportation costs and all other transaction costs included. Hence it provides a reliable image of the market, defined as "the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs" [29].

However, only series from the three first countries were consistent enough to feed the cointegration tests. In any case, Spain, France and Italy are the major mussel producers, accounting together for 75.5% of the total European production, and also the main consumers (Fig. 1).

Available data covers 92 weeks starting at the first week of January 2016. Unfortunately, in the Italian series there are 13 missing data, probably due the absence of transactions during those weeks. In fact, no transactions for these periods were identified through ISMEA (Istituto di Servizi per il Mercato Agricolo Alimentare). To maximize the number of observations (a condition required to obtain robust unit root and cointegration tests) missing values were linearly interpolated.

Figure 5.
Retail prices of fresh mussel in France, Italy and Spain
Source: Eumofa, 2016.



The mussel price in the three countries shows a similar path, even though in the French case, on the one hand, prices exhibit higher variability, probably due the seasonality of its production, concentrated in summer [28]. On the other hand prices in France are slightly higher than in the other two countries, with a gap that goes from about 0.5 euros to 1.5.

Given that the objective of this study is to identify the existence of complementarities/substitutabilities across different European mussel markets, the standard approach in the literature, based on the analysis of prices in these markets, has been followed. The definition of a market for a good or group of goods based on prices dates back to Stigler (1969), who shows that if the prices of two goods tend to uniformity (once that travel costs allowances are taken into account) they should belong to the same market. On the contrary, if prices of these goods do not tend to be equal through time then they should be ascribed to different markets. Given that these relationships should hold in the long run, the empirical literature has focused its attention into the identification of equilibrium long run relationships between different prices. In the econometric jargon, this implies testing for cointegration between market prices. Following the standard procedure, as for instance in [30], [31]or [32], evidence of price changes in one market generating changes in a different market reflects a long run relationship of the form

$$p_t^i - \beta_0 - \beta_1 p_t^j = \varepsilon_t \qquad (1)$$

where p_t^i and p_t^j represent the prices of the goods in markets i and j respectively at time t, β_0 is a constant term reflecting transportation or transaction costs and quality differences (or even different relative consumer preferences), and β_1 is the relationship between the prices. If $\beta_1 = 0$, there is no relationship between these two prices, and these goods markets should be regarded as non-integrated. However, a non-zero coefficient implies the existence of a long run relationship between these markets, and the closer the coefficient β_1 is to 1, the closer the law of one price, which suggests that the relative price between these goods is constant. The econometric procedure, therefore, consists in analysing whether the different mussel markets included in the analysis can be regarded as integrated or not by testing the existence of such long run relationships. Among the different econometric approaches available, following the standard procedure in the literature, the Johansen [33,34] cointegration methodology has been applied.

Let Y_t be a (mx1) vector of prices (in logs), where m refers to the number of markets included in the analysis, and assume that Y_t follows an unrestricted vector autoregression process (VAR) on the levels of the prices:

$$Y_t = \Pi_1 Y_{t-1} + \cdots + \Pi_k Y_{t-k} + \Gamma D_t + \mu + e_t \qquad (2)$$

where the Π's are (kxm) matrices of unknown parameters, μ is a constant term, D_t is the vector of deterministic terms (intercepts and/or time trends), and e_t is a (mx1) vector of identically and independently distributed error terms, with zero mean and a contemporaneous covariance matrix Ω. As is well known (see Lütkepohl and Krätzig, 2004, for instance), this VAR can be reparametrized to an error correction form of the type:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \cdots + \Gamma_{k-1} \Delta Y_{t-k+1} + \Pi Y_{t-k+} \psi D_t + \mu + e_t \quad (3)$$

where $\Gamma_i = -I + \Pi_1 + \cdots + \Pi_i, i = 1, \ldots, k-1$ and $\Pi = -I + \Pi_1 + \cdots + \Pi_k$. In other words, the matrix Π is the long run level solution to equation (2). If Y_t is a vector of non-stationary variables, the left hand-side and the first (k-1) variables in equation (3) are I(0), i.e., stationary, while the k-th element in (3) is a linear combination of I(1) variables. Given the assumptions for the error term, the k-th element in (2) must also be stationary, which in turn implies that either Y_t contains a number of long run relationships or that Π is a matrix of zeros. The rank of Π, denoted by r, will inform us about the number of linear combinations of Y_t that are stationary. If r=n, the variables in the levels equation are stationary. If r=0, and $\Pi = 0$, none of the linear combinations are stationary. Finally, if 0<r<n, there are r cointegrating vectors. This may be written as $\Pi = \alpha\beta'$, where α and β are nxr matrices. Also, β contains the cointegrating relationships and α embodies the adjustment parameters.

4. Results.

The first step in the modelling strategy is to check for the existence of unit roots in the individual price time series. Given the availability of data, and their relative time length, the analysis had to be restricted to the cases of France, Italy and Spain. The remaining countries do not provide price series long enough as to perform any reliable time series analysis. Therefore, the investigation will explore whether these three markets are integrated, either as a whole or pairwise. To check for unit roots, the standard Augmented Dickey Fuller test (ADF) was performed (Table 1)[2]. Given the plotted series, the test was run with an intercept and without a trend. Results do not allow to

[2] The existence of unit roots has also been explored with alternative tests, such as the KPSS or the Phillips-Perron. In all cases the results are similar to those reported in table 1. These results are not shown for brevity, but are available from the authors upon request,

reject the null of a unit root in the level of the series, but strongly reject the null of a unit root in the first difference. The associated *p*-value of the test is well above the 5% level for the three level series, while is zero for the first-difference. Therefore, the three price series should be regarded as non-stationary.

Table 1. Unit root tests

		ADF test	
		t-Statistic	p-value
France			
	Level	-1.86	0.35
	First Difference	6.28	0.00
Italy			
	Level	-2.12	0.21
	First Difference	-5.29	0.00
Spain			
	Level	-1.34	0.60
	First Difference	-10.86	0.00

The next step of the modelling procedure (testing for the existence of a stationary linear combination of these prices, i.e., whether some cointegrating relationship can be identified) followed the Johansen methodology, and used the maximum eigenvalue statistic for the test (Table2)[3].

Starting with a three-price VAR, it was checked whether the mussel markets in Spain, France and Italy are jointly integrated. Panel (a) in table 2 indicates that the hypothesis of no-cointegration cannot be rejected, given that the value of the test statistic (13.66) is

[3] Results with the trace statistic are similar to those reported in the text.

well below the 5% critical value (22.29, with a *p*-value of 0.49). Therefore, it is concluded that these three markets cannot be regarded as a single integrated market. Next, whether these markets taken in pairs are integrated or not was tested, starting with the Spanish and French markets (panel (b) of table 2). In this case, the null of no cointegration is rejected (test statistic of 19.18, above the 5% critical value of 14.26), while the null of a one cointegrating equation cannot be rejected (test statistic of 2.26 below the 5% critical value of 3.84). Thus, the Spanish and French mussel markets should be analysed as a single integrated market, the respective prices follow a long run co-movement. For the remaining combinations (Spain and Italy, and France and Italy), the null of no cointegration cannot be rejected. Therefore, the empirical results show that only the Spanish and French markets form an integrated market.

Table 2. Cointegration tests

		Maximum Eigenvalue Statistic	5% c.v.	p-value
(a)	**Spain, France and Italy**			
	No cointegration	13.66	22.29	0.49
	1 cointegrating vector	7.98	15.89	0.55
	2 cointegrating vectors	2.71	9.16	0.63
(b)	**Spain and France**			
	No cointegration	19.18	14.26	0.00
	1 cointegrating vector	2.26	3.84	0.13
(c)	**Spain and Italy**			
	No cointegration	11.80	14.26	0.11

1 cointegrating vector	5.12	3.84	0.02

(d) **France and Italy**

No cointegration	12.56	14.26	0.09
1 cointegrating vector	8.96	3.84	0.00

The final step in the procedure is to check whether the degree of integration is perfect or not. The hypothesis that the two series are imperfect substitutes or if, alternatively, the law of one prices holds and the relative price is constant can be tested by imposing the restriction $\beta' = (1, -1)'$. Moreover, for these cointegrated series it was also tested which market is the price leader, i.e., which price influences the other market in the long run. For this, a standard weak exogeneity test was run, which is tested for each of the prices on the α matrix by imposing the restriction that all of the coefficients on the corresponding row of the matrix are jointly zero. The first test indicates that the degree of substitutability is not perfect, since the restriction that the cointegrating equation has coefficients (1,-1) is strongly rejected. Imposing a -1 coefficient for the French market implies a coefficient of 1.13 for Spain, with a t-stat of 2.50. Therefore, these two markets, even though integrated, do not form a perfect uniform entity, which entails the possibility that prices in one market may influence prices in the other. The weak exogeneity test is summarised in table 3. Results indicate that the null of weak exogeneity is rejected for the French market at the 1%, but the null that the Spanish mussel prices are weakly exogenous cannot be rejected. This implies that in the long run the Spanish mussel prices determine the prices in the French market, indicating thus a dominant position in the European mussel market.

Table 3. Weak exogeneity test

Potentially exonegous variable	LR test statistic	p-value

Spanish mussel	0.01	0.97
French mussel	14.05	0.00

5. Discussion.

Climate change is expected to influence mussel production in the Galician estuaries through different ways: water warming, reducing water circulation or weakening the upwelling and, consequently, reducing primary production. But, as long as no perfect substitutes are available, it is expected that reductions in production will be countervailed by increasing prices with no apparent impacts on producer's income. Notice that, the weakening of the upwelling is under debate, with now general consensus in the scientific community, which clearly reflects the uncertainty linked to climate change. In this sense, if no relevant consequences for primary productivity take place, productive and governance system should remain stable. In both cases, markets stability allows focusing on strategies that minimize the importance of uncertain climate variability and changing scenarios, following Mantua and Francis [36] suggestion. Our results show that the French, Italian and the Spanish markets cannot be regarded as a single integrated market but that the first and the latter form a partially integrated market, being the Spanish mussel prices determinants of the French ones. Therefore, the impact of climate change on farmer's income is not clearly identified, given that expected future falls in production will be probably joined by rising national prices in Spain. Market management, thus, becomes crucial.

The literature on climate change impacts has pointed out that, on the one hand, environmental uncertainty generates governance uncertainty and difficulties to maintain management control [2], which may result in governance conflicts [37] and, on the other hand, that mitigation options are limited, as fisheries are often location-specific and are operating at levels of utilization that preclude substitution flexibility by fishers [38]. Nevertheless these papers, as well as others [5] suggest that impacts may be addressed not only though spatial or physical intervention, but also through soft interventions based on markets intelligence.

In the Spanish case, the risk of the internal demand being covered by foreign production is internally controllable. Firstly, because, as it has been shown, there are no substitutes, except the French mussel (being a partial one). Secondly, because French mussel industry shows a net deficit of production. The main reason is the lack of physical space for expansion. Current rearing areas are fully exploited and new development requires additional space [28]. Therefore, there are additional limits for an eventual substitution of the Spanish production by its main competitor. On the contrary, Spain contributes to balance demand and supply in France.

In the same vein, since markets are mainly "national", instruments that reinforce product differentiation, as the Protected Geographical Indication (PGI) *Mejillón de Galicia*, are key to protect such position. Moreover, as the national preferences of consumers have to do with aspects like size, colour, taste or farming method, stressing such factors may help to boost differentiation. For instance, while in France consumers show a strong preference for *bouchot* mussels [28], in Spain the rafts represent an idiosyncratic farming method, and in both cases the traditional methods are object of valorisation through the PGIs, in Galicia for the whole production areas and in France at local level (*AOP Moules de Bouchots de la baie Mont Saint-Michel*). In this sense, managing differentiation strategies implies reinforcing traceability, commercialization processes, etc. It should be noted that, in this case, what fosters competitiveness, also fosters social and economic resilience.

Additionally it should be kept in mind that, as the weak exogeneity test shows, prices of Spanish mussel influence the French ones, but not the other way round. Therefore a wider scope for marketing action is available for Spanish producers. A relevant linked issue is productivity. In this sense, while it is true that natural productivity is threatened, cooperative strategies, organizational improvements, technological innovation, closer collaboration with scientific institutions, etc., may countervail this trend, being market information key to avoid individualistic short-term strategies that would create more uncertainty and difficulties to effective governance.

The literature has also signalled that management strategies relying upon "accurate" predictions of climate changes are doomed to fail [36], since they deliver governance routes that being robust, also tend to be deterministic and ponderous rather than flexible, following a path of increasingly restrictive operating flexibility for fishers [2] and a skew towards engineering solutions and the lack of strategies focusing on minimizing the importance of uncertain climate variability and changing scenarios [36], rather than stimulating a producer's behaviour based on long-term production approaches that also support the non- consumptive values of ecosystems. Therefore, better knowledge inputs on markets behaviour may help avoiding or limiting i) too much anticipated and highly uncertain responses, rushing for mitigation with no clear enough ground, and ii) short-term reactions, tending to overexploitation of natural resources as a way to maintain producers income.

In the end, this kind of market driven management of climate change impact responds to those principles enounced to for successful adaptation to climate change [4], particularly by introducing flexibility to deal with complexity and change and by creating (or revealing) incentives that encourage conservation and reduce pressure on natural resources. Going further, what this case shows is that not only the expected environmental impacts are relevant but also how producers, policy makers, etc., manage them. Understanding the adaptive capacity, not only in ecological terms but also in social and economic terms, will facilitate strategic management planning, specially in cases of high uncertainty, as changes in upwelling due to climate change. Soft tools, particularly, the use of market intelligence may help to address complex issues like climate change by contributing to reduce uncertainty and by avoiding or, at least limiting, the unbalance of pre-existing governance systems. For sure, additional measures in order to achieve economic, social and environmental sustainability are going to be necessary but markets are also adjusted mechanisms that may contribute to address climate change impacts in flexible ways.

6. Conclusions.

Climate change is already occurring and is expected to have a deep impact in fisheries, aquaculture, coastal and riparian communities, etc., and, as a matter of fact, it has been elevated to a top priority for many institutions, policy makers, stakeholders, etc., with many voices urging for action. But, as uncertainty is a key characteristic of such phenomenon, a knowledge gap is yet to be fulfilled in order to avoid blind or weak action.

This study demonstrates that market intelligence is key to guide responses to climate change in fisheries and aquaculture management and promote a resilient and adaptive behaviour. Specifically, our results show that very little substitutes are available for the Spanish fresh mussels, which means that decreases in production due to up-welling weakening will not necessary affect producer's income, as prices increases will compensate the (eventual) reduction in volume.

Furthermore, the weakening in upwelling is still a phenomenon under scientific debate, and thus, the hypothesis of no changes in upwelling cannot be discarded. But under this hypothesis the productive system is expected to remain stable and, in any case, eventual mitigation action should focus on other impacts of climate change. This should not be interpreted as neglecting the fight against climate change at a global level, but rather, as a search for appropriate tools at a local level. Particularly, the focus should be placed both on monitoring (while gaining time for assessing environmental impacts), and on strategies that minimize the importance of uncertain climate variability and changing scenarios.

More generally, what this study suggests is that market intelligence may contribute to an adaptive, pragmatic and flexible framework to face climate change impacts, avoiding too anticipated responses that may result in economic, environmental and social costs. Obviously, this kind of soft mechanism will be not the most suitable alternative in every case but it should be part of the available toolbox when designing mitigation responses.

Ultimately, since effective responses should be contextualized, it is necessary to carry out additional research about the capacity and the limitations that market mechanisms have to mitigate this type of impacts without destabilizing productive and governance systems, as well as other soft mechanism (as institutional, educational, or others) that promote resilience and, in the end, sustainability.

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