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Consumers' preferences for testing algal bloom in seafood markets

A comparison study of mussel consumption in China, Vietnam, and Chile

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Abstract

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Keywords: mussel aquaculture, harmful algal bloom, choice experiment, consumers’ preferences

JEL Codes: Q22, Q51, Q53

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1. Introduction

Algal blooms are a common marine phenomenon worldwide. Severe outbreaks of toxin-producing algae, known as harmful algal blooms (HAB), have increased in frequency and severity. Contributing factors include climate change (O'Neil et al., 2012; Peperzak, 2003; Wells et al., 2020), coastal eutrophication (O'Neil et al., 2012; Onderka, 2007), and human activities such as the discharge of industrial, agricultural, and sewage effluents into coastal waters (Anderson, 2009; Davidson et al., 2014; García-Hernández et al., 2005). HABs pose dangers to marine life and incur substantial economic costs to society. These costs encompass increased public health risks and potential disruptions to livelihoods, particularly in sectors like aquaculture, coastal tourism, and real estate (Brown et al., 2020; Jardine et al., 2020; Lewitus et al., 2012; Theodorou et al., 2020). The adverse health effects on humans are a significant concern among these impacts. Humans can be affected through direct exposure, but the more common channels include inhalation of toxins released by the algae and particularly the consumption of contaminated shellfish (Sonak et al., 2018). Potential health effects range from gastroenteritis and abdominal pain to liver, kidney, and intestinal damage (Svirčev et al., 2017). This disease risk encompasses significant health costs to individuals (e.g., healthcare and medication expenses, loss of income due to illness, cost of pain and suffering, cost of premature death, etc.). For instance, by focusing on respiratory diseases, Kouakou and Poder (2019) estimate welfare losses ranging from about 0.16 - 0.771 quality-adjusted life years per child in response to illness caused by HAB.

To mitigate the impact of HAB, governments often adopt monitoring and early warning systems, which usually involve precautionary closures of fisheries and aquaculture areas to prevent human poisoning. Such preventive actions have had significant socioeconomic impacts (Brown et al., 2020; Chenouf et al., 2023), with relatively more significant negative consequences on more vulnerable fishing communities (Jardine et al., 2020; Moore et al., 2019). However, in many regions, particularly in countries where informal vendors play essential roles in the seafood market, the enforcement of regulations on the harvest and sale of seafood contaminated by HAB can be weak (Anderson, 2009; van den Bergh et al., 2002). This regulatory gap makes food poisoning from HAB a tangible risk for consumers. It highlights the importance of understanding how consumers react to these risks and how this risk affects seafood consumer behavior.

This paper examines consumers' preferences for reducing the risk of HAB contamination in mussel consumption through a uniform choice experiment conducted in Chile, China, and Vietnam. In addition to assessing consumer preferences, the study explores the welfare effects of HAB on mussel consumers and identifies heterogeneous preferences among different consumer groups. We chose mussels as the focal product because they are commonly consumed around the world and highly vulnerable to HAB contamination.

We find that overall, consumers in the studied countries have strong preferences for a test that would indicate HAB-contaminated mussels. The strong preferences for the test translate into large WTPs for the HAB test in the Chilean and Chinese samples. These results imply that the increasing occurrence of HAB globally might have sizable welfare losses for consumers in the form of concerns about health risks. Then, better market information could reduce exposure to products contaminated with HAB, ensure food safety, and significantly improve social welfare. There is nonetheless significant heterogeneity in their preferences among consumers. Perceptions towards HAB and mussels can help explain these heterogeneous preferences. However, the link between perceptions and preferences varies across countries, possibly due to country-specific contexts.

This study contributes to several lines of research. First, our study expands the evidence on the welfare impact of HAB on consumers. Existing research on the impacts of HAB has focused on the direct economic impacts of the closure of marine areas. This includes economic effects on fishing communities, commercial fisheries, and aquaculture activities, as well as impacts on the recreational value of coastal areas (Chenouf et al., 2023; Jardine et al., 2020; Jin et al., 2008; Willis et al., 2018; Wolf et al., 2019; Zhang & Sohngen, 2018). While the negative health impacts of HAB have long been established in the literature, its economic costs are not as well studied. The existing studies typically estimate the health costs based on reported cases of deceases using medical costs and productivity losses (see Kouakou & Poder (2019) for a systematic review). However, HAB's impacts on consumers go beyond actual damages. The perceived HAB contamination risks could distort consumer behavior and result in welfare costs. Relatively less is known on this aspect and the results from existing literature are mixed. For example, while Wessells et al. (1995) found that consumers fear food toxicity, leading to reduced seafood consumption levels, Mao and Jardine (2020) found no evidence of negative demand impacts in the consumer market by focusing on changes in seafood prices. Besides, these studies mainly rely on market transaction data with limited exploration of nonuse and indirect use values through stated preference methods. One exception is Carias et al. (2024), who used the contingent valuation method to estimate consumers' WTP to create a fund to support monitoring systems and compensate producers for damage in the presence of HAB. They find a positive and sizable premium and a positive relationship between institutional trust and WTP. In contrast, our study implements a choice experiment approach to understand consumers' preference for avoiding HAB contamination risks in mussels by introducing a test that informs consumers about contamination. Although estimating quantitative reductions on food health risk is outside the scope of this paper, the understanding of individuals' preferences regarding the importance and the subsequent willingness to pay for having mussels tested for HAB provides relevant insights regarding potential venues for reducing food health risk exposure.

Second, this study adds to the general literature on consumers' WTP for food safety and labeling.

Existing research has examined food safety labels concerning various health risks, such as pesticide residues (Misra et al., 1991; Nitzko et al., 2024; J. Wang et al., 2022; Wendt & Weinrich, 2023) and heavy metals (Zhou et al., 2022). Such labels allow consumers to make safer and more informed food choices, thus boosting consumer confidence and potentially increasing the demand for safer food products. This study introduces a hypothetical test that reduces health risks from HAB, a naturally occurring event that has been exacerbated by marine pollution and climate change. Unlike pesticide residues, which can often be controlled through agricultural and food safety practices, HABs are unpredictable and influenced by environmental and climate factors (Lewitus et al., 2012). Unlike heavy metals, another environmental pollutant affecting seafood safety, which is linked to long-term health effects and usually requires cumulative exposure to cause poisoning (Wang et al., 2018), toxins from HABs act quickly, causing severe and sometimes life-threatening poisoning. Those differences underscore the unique and pressing nature of the risks posed by HABs compared to other food safety concerns.

Third, our research design also encompasses a framework that allows for the assessment of how knowledge and perceptions regarding HAB problems drive consumers' marginal willingness to pay (MWTP) to mitigate their risk of exposure. By augmenting the valuation questionnaire with two modules gathering consumers' understanding and experiences regarding HAB as well as mussel consumption patterns more broadly, our methodology allows a comprehensive understanding of the factors explaining not only the relative importance consumers regard to this attribute, but also understanding the extent to which consumers' valuations are driven by their internal judgments of HAB being under control in their local setting. Understanding HAB from a demand perspective sheds light on relevant aspects that are key for promoting food security locally and globally.

Finally, unlike previous literature, this paper proposes a multi-country framework for eliciting consumers' preferences and MWTP to reduce the risk of purchasing seafood products potentially contaminated by HAB in different contexts. This is done by drawing a sample of individuals in three countries, who share differences and similarities in mussel consumption patterns and are familiar with the HAB problem. To this end, we focus on consumers in two major mussel producer countries (i.e., Chile and Vietnam), and on a major mussel consumer country (i.e., China). This design allows not only to exploit heterogeneity in consumers' valuations but also to enhance external validity. The latter becomes even more important in the case of HAB, given the global scale of the problem.

The remainder of the paper is organized as follows. Section 2 describes the research design. Section 3 introduces the data collection procedure and describes the sample. Section 4 shows the results and discusses the implications of the results. Section 5 provides some robustness checks, and section 6 concludes the paper.

2. Study design

2.1. Choice experiment design

Our study is a multi-country study of two major mussel-producing countries (i.e., Chile and Vietnam) and a major mussel-consuming and producing country (i.e., China). We select mussels as the focal product of the study for two reasons. Firstly, mussels are a cost-effective and nutritious protein source that is commonly consumed worldwide (Mititelu et al., 2022). Secondly, mussels can accumulate toxins from harmful algal blooms and can retain these toxins for weeks, posing a health risk to consumers (Gibble et al., 2016).

We designed and implemented a choice experiment to elicit consumers' preferences for mussels with different attributes; amongst these was an hypothetical algal bloom test assumed capable of eliminating the risk of purchasing contaminated mussels. Choice experiments mirror real-world decision-making scenarios, revealing consumers' preferences through attribute trade-offs (James & Burton, 2003). They have been widely used to elicit consumer preferences for private goods such as seafood (Onozaka et al., 2023; Risius et al., 2017; Tanner et al., 2021; Yang et al., 2020; Yip et al., 2017; Zheng et al., 2021).

In the choice experiment, we ask the consumers to make purchasing decisions regarding medium-size mussels that are commonly available on the market. The mussels in question are characterized by five attributes, namely: (*i*) price, (*ii*) production method, (*iii*) country of origin, (*iv*) sustainable production practices, and (*v*) test certificate for algal bloom. The mussels are then characterized by their varying attribute levels, as shown in Table 1.[1]

Table 1. Choice experiment: attributes and levels

Attribute	Levels	Coding
Price (per 500g)	500; 1,500; 2,500; 3,500 (Chile, CLP) 2; 6; 10; 14 (China, CNY) 7,000; 20,000; 33,000; 47,000 (Vietnam, VND)	Linear with original values
Production method	Wild caught	Dummy (0,1)
	Farm raised	Reference
Country of origin	Imported	Dummy (0,1)
	Domestic	Reference
Production practices	Sustainable practices	Dummy (0,1)
	Standard practices	Reference
Algal bloom test	With algal bloom test	Dummy (0,1)

[1] Those attributes and their levels were decided through a literature review and consultation with experts, and were adjusted after investigations with focus groups.

None	Reference

Source: Own elaboration. The descriptions of each attribute are shown in Table A1 in the Appendix.

The key attribute, the algal bloom test, is a hypothetical test that would provide a guarantee that harmful algal blooms do not contaminate mussels. The algal bloom test is introduced to respondents as follows: "*Harmful algal blooms occur when colonies of algae grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals, and birds. Mussels can accumulate toxins through ingestion, posing severe health risks when consumed. Consumers exhibit heightened sensitivity toward seafood products affected by algal blooms. Currently, governments monitor the zones where mussels grow to discover any presence of algal bloom, but there is a testing system after mussels are harvested. This attribute identifies whether there is a certificate for the mussels stating the sampling test results of the mussels harvested in the same batch are negative for algal bloom. The test provides a guarantee that the mussels are extremely unlikely to be contaminated by the algal bloom and hence are safe to eat*."

Given the hypothetical nature of the algal bloom test[2], we emphasize its accuracy: mussels passing the test would eliminate the risk of algal bloom contamination. The absence of such a test (the *status-quo* option) serves as the reference level, where consumers would rely on existing public warning systems and preventive measures. However, from the consumer perspective, there could remain a finite risk of HAB contamination, which they might be willing to pay to reduce. Therefore, the premium that consumers are willing to pay for having the algal bloom test can be interpreted as their marginal willingness to pay to reduce potential health risks of algal bloom from their current perceived level to almost zero.

The production method attribute has two alternative levels: wild-caught and farm-raised. Wild-caught refers to harvesting mussels from their natural habitats, while farm-raised involves mussels produced in aquafarms. This attribute is regarded as a primary factor influencing seafood selection and a commonly utilized attribute in preference studies (Bronnmann & Asche, 2017; Nguyen et al., 2022; Yang et al., 2020). The country-of-origin attribute has two alternatives: domestically produced and imported. Place of origin is a significant factor in consumers' purchasing decisions, influencing perceptions of product quality and freshness (Hinkes & Schulze-Ehlers, 2018; van Osch et al., 2017; Weir et al., 2021). The sustainable production attribute indicates whether mussel production follows sustainable practices, uses marine resources responsibly, and minimizes environmental impacts (Zhang et al., 2020). The alternative levels are sustainable and standard production methods. Finally, the mussels' price denotes the market price for 500g of mussels in the three countries, with four price levels

[2] This hypothetical nature is partly dictated by the fact that there is no widely adopted tests for mussels in the three countries, and partly determined by our intention to frame the test as a reliable way to eliminate chance of contamination upon testing, which may be too a strong claim for any existing test.

established by adjusting the reference level by -66%, 66%, and 133% (Gao & Schroeder, 2009).[3] A detailed description of these attributes and their corresponding levels can be found in Table A1 in the Appendix.

Recognizing the trade-off between statistical efficiency and consistency in participants' choices, we select 20 choice sets with a D-efficient design. The choice sets are then grouped into two blocks and randomly distributed to participants to reduce cognitive load and the probability of respondent fatigue. Thus, each participant is presented with 10 choice sets. Each choice set has two alternative mussel products (Mussel A and Mussel B) with varying attribute levels and an opt-out option labeled "I would purchase neither". The opt-out option is included to simulate market practices more closely, considering that some consumers are not interested in the provided products (Kontoleon & Yabe, 2003). Table 2 provides an example of the choice sets used in the survey.

To minimize hypothetical bias, a "cheap talk" script is shown to the participants before they are assigned choice sets (Cummings & Taylor, 1999). The first section of the questionnaire introduces the survey and its objectives, followed by several demographic questions that serve as warm-up questions. Before the formal choice experiment questions, the respondents must read the explanation of the attributes and their levels, as well as the "cheap talk" script. After completing the choice experiment part, respondents proceed to answer sociodemographic information and perception questions regarding HAB contamination.

Table 2. Example of the choices set used in China

	Mussel A	Mussel B	Neither
Price (¥ per 500g)	5	8	
Producing method	Wild-harvested	Farm-raised	
Country of origin	Domestic	Imported	
Production practices	No	Yes	
Algal bloom test	Yes	No	
Your choice			

Note: The only differences for the other countries are the price attribute and price levels.

2.2. Empirical strategy

Random Utility Theory (RUT) is a fundamental framework employed in choice experiments to elicit consumer preferences. Its essential premise is that the utility an individual derives from making a choice can be systematically decomposed into observable and unobservable

[3] The reference price was determined based on the average market price for mussels in each country at the time of data collection.

components. Thus, give, that a choice set, denoted as *t*, includes *j* distinct mussel alternatives. Under the RUT framework, the utility that consumer *i* achieves from choosing option *j* in the choice set *t* can be expressed as:

$$U_{ijt} = V_{ijt} + \xi_{ijt}, \quad (1)$$

where U_{ijt} represents the aggregate utility with V_{ijt} denoting the predictable component based on observable attributes of the mussels, and ξ_{ijt} the stochastic component capturing unobserved influences on the consumers' utility.

The participants choose the option that maximizes the utility derived from the different attributes of the mussels. Following Hensher et al. (2005), and given our design, the observed utility achieved by consumer *i* by choosing option *j* in the choice set *t*, denoted by V_{ijt}, is defined as:

$$V_{ijt} = \boldsymbol{X\beta} = \beta_1 Price + \beta_2 Wild + \beta_3 Imported + \beta_4 Sustainable + \beta_5 HABtest + \beta_6 Optout, \quad (2)$$

where **X** is a matrix of the mussel attributes under analysis, including the price of mussels (*Price)*; the production technology (*Wild* denoting that mussels were wild-caught); if mussel harvesting adopts sustainable production practices (*Sustainable*); if mussels pass the algal bloom test (*HABtest*), which is the key variable for this study; and opting-out option (*Optout*). Moreover, $\boldsymbol{\beta}$ is a vector of parameter estimates.

Under the assumption that consumers aim to maximize their utility, the choice of option *j* over option *k* by consumer *i* is contingent on U_{ijt} being greater than U_{ikt} for all $j \neq k$. Consequently, the probability of consumer *i* choosing option *j* in the choice set *t* is given by:

$$P_{ijt} = Prob(\xi_{ijt} - \xi_{ikt} > V_{ikt} - V_{ijt}), \forall k \neq j. \quad (3)$$

We assume that consumers have heterogenous preferences and use the random parameters logit (RPL) model (McFadden & Train, 2000) to estimate consumers' preference parameters for different attributes of mussels. In the RPL model, the expected probability of consumer *i* choosing option *j* in choice set *t* can be expressed as:

$$E(P_{ijt}) = \int \frac{e^{V_{ijt}}}{\sum_j e^{V_{ikt}}} f(\beta) d(\beta), \quad (4)$$

where *f(.)* is the distribution of random non−price parameters. Furthermore, to analyze the heterogeneity of preferences for the algal bloom test, we incorporate interaction terms between consumer characteristics and the *HABtest* variable into the RPL model. These consumer characteristics encompass both demographic data and perceptual variables (e.g., perceptions, awareness and concerns regarding HAB contamination, trust in mussel quality, awareness of potential health effects from contaminated mussels, importance of mussel certification, etc.).

By evaluating the statistical significance of these interaction terms, we aim to estimate the impact of specific consumer traits on their preferences for the *HABtest*.

The willingness to pay for attribute *m* (WTP_m) was calculated using the minus substitution ratio of the non-price attributes' marginal utility (β_m) over the marginal utility of the price attribute (β_1). In particular, expressed using parameters in equation (2), consumers' MWTP for the algal bloom test is $MWTP_{HABtest} = \beta_5/\beta_1$.

We also use a RPL model in WTP space to get the direct MWTP measures from the estimated coefficients (Train & Weeks, 2005). The utility level of product *j* in a choice set *t* for consumer *i* is then:

$$U_{ijt} = \gamma_i\left[Pri_{ijt} + W_i x_{ijt}\right] + \epsilon_{ijt} \quad (5)$$

where γ_i is the price coefficient divided by the scale parameter, ϵ_{ijt} is the error term, Pri_{ijt} is the price level of the j^{th} product in a choice set *t* for the i^{th} consumer, x is the non-price attributes and W_i is the direct parameterization of the WTP vector for non-price attributes faced by individual *i*.

3. Data

3.1. Data collection procedure

We conducted separate surveys in three countries with important aquaculture sectors and long coastlines: Chile, China, and Vietnam. We designed and implemented a uniform questionnaire and choice experiment design for data collection purposes. However, given the local setting in each country, data collection was conducted using different -yet related- methods and sampling strategies.

In China, we collected data through an online survey using the survey platform PowerCX. PowerCX is an established survey firm with a panel pool of over 4 million respondents across the country.[4] The sample included 11 coastal provinces / direct-administered municipalities and the capital city Beijing.[5] The sampled regions cover a substantial portion of China from north to south, featuring diverse climates, geographies, and cultural backgrounds. These are also the regions with the highest per capita consumption of aquatic products in China.[6] Data was gathered from November to December 2023. The survey platform randomly distributed different versions of the questionnaire in Chinese to individuals within their subject panel. Only people over 18 years old who had consumed mussels in the past six months and were in charge

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4 More information on PowerCX can be found here: https://www.powercx.com/en/

5 The 11 coastal provinces and cities are Fujian, Guangdong, Guangxi, Hainan, Hebei, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin and Zhejiang.

6 https://www.crnews.net/cy/sc/959866_20231228104059.html

of the purchase decisions in their households were eligible for our study. The Chinese subsample contains 2,400 respondents, 200 from each province/city.

In Chile and Vietnam, the surveys were conducted in person, with the support of enumerators all of whom used the same computerized survey instrument and the same questionnaire.[7] Surveys were conducted in the primary local language (i.e., Vietnamese or Spanish) after translation from the English version. This ensured that the format of each survey was the same. While surveys were conducted in the main coastal areas around Concepción city, the second biggest city located in Central southern Chile, between November and December 2023, data from Vietnam was gathered from household representatives in the suburban districts of Ho Chi Minh City between December 2023 and January 2024. Surveyed coastal areas in Chile and Vietnam are important for mussel production and consumption, mainly through open markets and seafood restaurants, which residents and local visitors frequent throughout the year. Individuals were randomly approached at each of these localities, and the number of surveys on each locality was determined considering their size and population. These localities are representative of coastal communities in the country. In both countries, participants were only invited to participate in the study if they had purchased mussels in the past six months. The survey software facilitated randomly allocating participants to different groups, resulting in 760 collected responses for Vietnam and 503 observations for Chile.

3.2. Sample

We begin by analyzing the summary statistics of our consumer sample in the studied countries. Table 3 displays consumers' socio-demographic characteristics. Because of the online nature of the data collection process in China, respondents in this subsample are younger and better educated than the general Chinese population. The average age of respondents is 31.5, with a standard deviation of approximately 7.03, below China's average age of 38.8 years. Almost all respondents (96%) have received higher education, surpassing China's national average of 9.91 years. Two-thirds of the respondents are women, higher than the national level of 48.84% in China (National Bureau of Statistics of China, 2021). This may reflect the fact that women do most daily grocery shopping for families. Respondents in Vietnam and Chile are, on average, older than those in China. Respondents in Vietnam also have a larger share of women than at the national level, which may reflect a similar cultural background regarding household labor division as in China.[8] The Vietnamese subsample also shows a more right-skewed income

[7] Questionnaires are nearly identical, except for one question in the case of Chile. This difference is not expected to affect the analysis negatively. While information gathered from this question is not crucial for identification, there is still possible to provide related interpretations following the nature of the question in either questionnaire. Differences that may arise frm this question are discussed later on in this section.

[8] Test statisitics of the cross-sample comparisons of individual and household charactersitics are reported

distribution than China and Chile. This is consistent with the relatively larger proportion of more educated people surveyed in China. However, despite a higher relative percentage of households above the income median in Chile, there is a larger fraction of the respondents with an education level equal to or below high school. This characteristic suggests that the Chilean subsample is mainly constituted of middle-income households, which are the main consumer segment of mussels in the country.

Table 3. Summary statistics of individual and household characteristics

Variable	Chile	China	Vietnam
Age [*No. of years*]	39.4	31.5	38.4*
	(10.8)	(7.03)	(12.3)
Female [%]	51.7	67.2	58.4
Household size [*No. members*]	2.56	3.31	4.47
	(1.16)	(0.89)	(1.84)
No. of children [*No. members*]	0.49	0.86	1.12
	(0.71)	(0.63)	(1.02)
Tertiary education [%]	57.06	95.92	70.59
High-income [%]	46.92	42.46	33.42
Income level 1 [%]	1.99	0.42	11.37
Income level 2 [%]	14.31	2.79	32.68
Income level 3 [%]	36.78	15.50	22.48
Income level 4 [%]	28.83	38.83	13.20
Income level 5 [%]	9.94	34.04	8.89
Income level 6 [%]	8.15	8.42	11.37
No. of obs.	503	2,400	760

Note: Own elaboration. Tertiary education is defined as any education level above high school. The six income categories are also country-specific. In China, the six categories of household monthly income are: 2,000 CNY and lower, 2,001-5,000 CNY, 5,001-10,000 CNY, 10,001-20,000 CNY, 20,001-40,000 CNY and more than 40000 CNY; In Chile, the income categories are under 300,000 CLP, 300,001-600,000 CLP, 600,001-900,000 CLP, 900,001-1,200,000 CLP, 1,200,001-1,500,000 CLP and more than 1,500,000 (900 CLP is around 1 USD); in Vietnam, the income categories represent, under 5,000,000 VND, 5,000,000 – (under) 10,000,000 VND, 10,000,000 – under 15,000,000 VND, 15,000,000 – under 20,000,000 VND, 20,000,000 – under 25,000,000 VND and from 25,000,000 VND and above. At the time of survey, 1 USD ~ 25,000,000 VND. High-income is with-in sample relative binary indicate, which equals 1 if one's reported income level is above the level where the sample median lies. For China, it includes the highest two levels, and for Chile and Vietnam, the highest three groups.
* There are 759 obs. in age.

Table 4 shows the respondents' self-reported mussel consumption behavior. The Chinese respondents reported a higher frequency of mussel consumption than the Chilean and Vietnamese sample, probably due to the self-selected nature of the online survey. Although the survey invitation was randomly sent to the subject pool, it is presumed that those consuming more seafood, particularly mussels would be more likely to respond. This is less clear for in-

in Table A2 in the Appendix.

person surveys in Chile and Vietnam. However, the higher self-reported consumption may also reflect higher mussel consumption in Asian countries. Figures indicate that Vietnamese and Chinese purchase more mussels and consume them more frequently than the Chilean respondents, consistent with higher seafood consumption in East and Southeast Asia (FAO, 2024). In all countries, fresh mussels, rather than processed mussels, dominate consumption, with some differences across countries regarding the place of consumption. While mussels are often eaten both at home and in Vietnamese restaurants, respondents in China and Chile mainly consume them at home.

Table 4. Mussel consumption patterns in the studied countries

Variable	Chile	China	Vietnam
Consumption Frequency [%]			
> 3 times a week	1.00	5.04	7.37
2-3 times a week	4.59	23.96	13.16
3-4 times a month	13.97	31.21	17.24
1-2 times a month	60.68	25.29	35.92
< once a month	19.76	14.50	26.32
Average quantity per purchase [%]			
0.5 kg	47.50	7.50	11.58
1 kg	10.38	40.58	28.16
1.5 kg	37.92	27.67	18.95
2 kg	2.00	18.25	22.63
2.5 kg	1.80	3.92	8.16
Cannot recall	0.40	2.08	10.53
Main way of eating [%]			
Fresh mussel at home	74.25	85.33	44.40
Fresh mussel at restaurant	22.75	11.62	43.08
Takeaway/processed mussels	2.99	3.04	12.52

Note: Own elaboration. 501 obs. in Chilean sample due to missing or invalid values, and 759 obs. in Vietnamese sample for "*main way of eating*" variable.

Beyond individual and household characteristics, individuals' subjective evaluation of the HAB test could depend on their awareness of the HAB's impacts and their perceptions of the risk. The questionnaire includes a section with perception questions regarding HAB and mussel quality. These questions and the corresponding descriptive statistics are reported in Table 5.[9]

[9] Test statisitics of the cross-sample comparisons of HAB perceptions are reported in Table A3 in the Appendix.

Table 5. Attitude and Perceptions of HAB

Question	Measure	Chile	China	Vietnam
Before this study, did you know that algal bloom may contaminate mussels, making it unsafe to eat mussels produced in the area with an algal bloom outbreak? [*Aware of HAB harm*].	% of Yes	91.45	59.08	78.68
How high do you think the chance of eating a mussel contaminated by algal bloom is? [*Perception of contamination chance*].	% in China & Vietnam; 1-5 scale in Chile	2.90 (0.82)	28.11 (19.00)	41.04 (22.14)
Algal blooms are a natural phenomenon, and nothing can be done to prevent their occurrence. [*HAB cannot be stopped*].	1-5 agreement scale	3.34 (0.90)	2.95 (1.03)	2.39 (1.17)
The severity of algal blooms is reinforced by the production of other aquaculture species in the same area. [*HAB reinforced by aquaculture*].	1-5 agreement scale	3.52 (0.76)	3.63 (0.87)	2.65 (1.15)
Before this study, I was concerned about the effects of algal blooms on humans. [*Concern about HAB*].	1-5 agreement scale	3.74 (0.73)	3.62 (0.93)	2.94 (1.19)
I trust the quality/safety of the mussels sold on the market. [*Trust mussel quality*].	1-5 agreement scale	3.78 (0.69)	3.76 (0.70)	2.87 (1.16)
I think my health is easily at risk due to unsafe mussels. [*Unsafe mussel affects health*].	1-5 agreement scale	3.78 (0.77)	4.11 (0.90)	3.05 (1.24)
I agree that certified mussels be are safer than uncertified mussels. [*Certified mussel safer*].	1-5 agreement scale	4.00 (0.66)	4.35 (0.74)	3.18 (1.33)

Note: Own elaboration.

The Chilean consumers are well informed about the negative impact of HAB, with over 90% stating that they know about the negative health impact of HAB. This figure aligns with the experience of HAB's past events in the country. In contrast, the Chinese respondents, despite being younger and well-educated, are the least informed, with only less than 60% claiming to know. The Vietnamese sample lies in between. The Chilean and Chinese respondents also show stronger concern than the Vietnamese about the adverse health effects of HAB. Moreover, the Chilean respondents are more inclined to believe that HAB is a natural occurrence (59% hold positive views with an average score of 3.34), compared with the Chinese and Vietnamese respondents (37% and 23%; 2.95 and 2.39, respectively). Chilean respondents are also more likely to believe HAB is exacerbated by aquaculture, similar to the Chinese respondents, while Vietnamese respondents are less likely to think so.

People's preference for the HAB test could be affected by how seriously they perceive the health risks of HABs. We asked a question on the perceived probability that mussels on the market could be contaminated by an HAB. We expected the response to be positively correlated with the WTP for the HAB test because the HAB test would have a more significant impact in reducing HAB risk for those who believe the probability of contamination is larger. This question was asked in the form of stated numerical probabilities in China and Vietnam. We see that perceived risks are fairly high. The average likelihood stated by the Chinese respondents is 28% and the average probability in the Vietnam sample is 41%. In the Chilean survey, the question was asked on a 1-5 probability scale, but the results are similar. Only 32% of respondents think the risk is low or very low, and 23% believe the risk is high or very high. While we don't have accurate statistics on such probability in corresponding local markets, given overall food safety and HAB incident reports, it is hard to believe the risk of HAB contamination can be as high as 20%. The overall risk of HAB contamination should be relatively low, and the consumer's perception of risk may have overstated the actual risk, as well as the WTP. Such significant risk perception may be due to people's tendency to overweigh the risks they do not fully understand or that are out of their control (Slovic, 1987).

Chilean and Chinese respondents show similar levels of trust regarding mussel quality on the market, similar beliefs about the potential health impact of HAB-contaminated mussels, and similar beliefs on the effectiveness of mussel quality certification. In contrast, Vietnamese respondents show less trust and have weaker beliefs about all three questions. Serious food safety incidents in Vietnam in recent years may have shaken consumers' faith in the food safety control system (Wertheim-Heck et al., 2014).

4. Results

4.1. Consumers' preferences regarding mussel attributes in the choice experiment

First, we look at consumers' preferences over different mussel attributes in the choice experiment. The random parameter logit regression results are shown in Table 6. Dummy coding is used for the discrete attributes, with each variable equaling one if the corresponding attribute is present and zero otherwise. The price coefficient was assumed to have a linear effect on utility to simplify the calculation of the willingness to pay (Wu et al., 2016).

The significance of the standard deviations in RPL supported its assumptions, suggesting consumers had heterogeneous preferences for attributes. Across the three countries, estimated coefficients for the algal bloom test attribute are positive and statistically significant, indicating a strong preference among consumers for mussels with potentially lower health risks. This preference for the HAB test is robust concerning the differences in sampling strategies, socioeconomic status, and cultural backgrounds across the three countries. Notice that this result is also robust to the sampling strategies used to elicit consumers' preferences in the studied countries. This result aligns with heightened consumer concerns regarding food safety, and consumers are willing to pay a premium for products that reduce the likelihood of adverse health outcomes (Lusk & Coble, 2005; Ortega et al., 2011). Studies have shown a significant increase in the frequency and scope of harmful algal blooms worldwide over the recent decades (Hou et al., 2022), suggesting that mussels contaminated by algal blooms may more readily enter the market. This increases consumers' concern about the health risks of HAB contamination and their preference for products tested for HAB.

The consistent results across countries highlight globally common vulnerabilities due to favorable climatic conditions, nutrient pollution from agricultural runoff, and intense aquaculture activities, which drive HABs (Brooks et al., 2016; Wells et al., 2020; Yan et al., 2024). The pervasive nature of HABs in these regions suggests an urgent need for international cooperation in monitoring, management, and mitigation strategies to protect marine ecosystems and human health (Anderson et al., 2012; Wells et al., 2020).

The positive and statistically significant coefficients for the attribute sustainable practice suggest that consumers prefer mussels produced through certified sustainable methods. This is consistent with existing research (Ngoc et al., 2016; Onozaka et al., 2023; Risius et al., 2019; Wakamatsu & Managi, 2022). Preferences for production method and country of origin vary across the three countries. Chilean consumers prefer domestically produced mussels and show little concern for the production method. This preference can be explained by the fact that almost all mussel supply in Chile is domestically farmed. Results indicate that Chinese consumers favor aquaculture-farmed mussels largely, probably due to the perception that aquaculture may be a more sustainable and controlled method of seafood production than fishing. This preference may be supported by concerns about overfishing and environmental degradation linked to wild-caught methods (Wang & Somogyi, 2019). Chinese consumers appear indifferent to the country of origin of the mussels. This may stem from a broader trust in aquaculture processes irrespective of geographical location. In contrast, Vietnamese consumers ' coefficients for both aquaculture and origin are non-significant, possibly influenced by more immediate concerns such as the availability (Xuan et al., 2021).

The negative and statistically significant coefficients for the price attribute in the Chilean and Chinese samples evidence a preference for lower prices, consistent with the typical consumer demand curve. However, the Vietnamese respondents seem insensitive to price levels when making choices in the choice experiment. This result may correspond to an emerging eating-out trend, where more than just the result of a higher financial capacity, eating outside is becoming a means to express a new urban lifestyle trend regarding socializing (Ehlert, 2016; 2021; Hansen, 2024). The latter can make price attributes less relevant. The Vietnam survey reported a comparatively higher level of mussel consumption at restaurants. Another possible reason for this result is that the food-safety-related attributes may have captured the respondent's attention and overridden other attributes in urban Vietnam, where food safety is among the strongest social and political issues (Wertheim-Heck et al., 2014). Our data shows that Vietnamese people trust less in the quality/safety of the mussels sold on the market. This may explain why only the coefficients for the sustainable practices and the HAB test are statistically significant in this setting. In effect, consumers would not buy an "untested" option if a test was available. Finally, the estimated *opt−out* coefficient is negative and statistically significant, indicating that consumers generally did not want to avoid consuming mussels.

Table 6. Consumer's preferences over mussels attributes: RPL regressions

	Chile		*China*		*Vietnam*	
	Mean	SD	Mean	SD	Mean	SD
Price	-0.13^{***}		-0.086^{***}		0.001	
	(0.02)		(0.003)		(0.001)	
HAB test	1.231^{***}	1.489^{***}	1.197^{***}	1.512^{***}	0.675^{***}	1.062^{***}
	(0.083)	(0.089)	(0.037)	(0.039)	(0.048)	(0.053)
Wild-caught	-0.044	-0.549^{***}	-0.065^{***}	-0.071	-0.022	0.356^{***}
	(0.049)	(0.072)	(0.020)	(0.086)	(0.031)	(0.056)
Imported	-0.967^{***}	1.370^{***}	-0.462^{***}	0.751^{***}	0.000	-0.101
	(0.079)	(0.090)	(0.025)	(0.032)	(0.028)	(0.077)
Sustainable practice	0.142^{***}	-0.035	0.589^{***}	0.473^{***}	0.049^{*}	-0.109
	(0.043)	(0.105)	(0.023)	(0.038)	(0.029)	(0.081)
Opt-out	-4.275^{***}	2.467^{***}	-2.264^{***}	2.930^{***}	-2.206^{***}	1.941^{***}
	(0.286)	(0.273)	(0.084)	(0.079)	(0.127)	(0.116)
LLR	-3205.2205		-18750.716		-6280.5642	
No. obs.	15090		72,000		22800	

Note: Own elaboration. ***, ** and * indicate statistically significance at 1%, 5% and 10%. Standard errors are reported in the parentheses. The price units used in the Chilean and Vietnam samples are thousand CLP and thousand VND.

4.2 Heterogeneity in preference for HAB test

Using the random parameter model, we also find that consumers have heterogeneous preferences for the HAB test in all three countries. We are particularly interested in exploring the factors driving consumer demand for the HAB test. To explore the extent to which people's attitudes and perceptions about the HAB and the mussel market are linked to the heterogeneity in preferences, we include interaction terms between the HAB test attribute and perception variables in the mixed logit regressions. The results are shown in Table 7.

Table 7. Heterogeneity in respondents' perceptions regarding HAB (RPL model)

	Chile (1) Choice	*China* (2) Choice	*Vietnam* (3) Choice
Mean			
Price	-0.128*** (0.024)	-0.086*** (0.003)	0.001 (0.001)
HAB Test	-0.647 (0.786)	-0.086 (0.351)	-0.505*** (0.187)
Test × Aware of HAB harm	-0.467* (0.253)	-0.015 (0.074)	0.316*** (0.114)
Test × Perception of chance of contamination	-0.521*** (0.095)	-0.014*** (0.002)	0.000 (0.000)
Test × HAB cannot be stopped	0.037 (0.081)	-0.096*** (0.034)	0.011 (0.046)
Test × HAB reinforced by aquaculture	0.002 (0.104)	0.026 (0.042)	-0.055 (0.051)
Test × Concern about HAB	0.139 (0.105)	0.029 (0.041)	0.148*** (0.052)
Test × Trust mussel quality	0.183* (0.107)	-0.062 (0.053)	-0.016 (0.050)
Test × Unsafe mussel affects health	0.243** (0.098)	0.126*** (0.044)	0.058 (0.052)
Test × Certified mussel safer	0.385*** (0.121)	0.343*** (0.053)	0.153*** (0.051)
Wild-caught	-0.055 (0.049)	-0.068*** (0.020)	-0.023 (0.031)
Imported	-1.014*** (0.080)	-0.470*** (0.025)	0.001 (0.029)
Sustainable practice	0.142*** (0.043)	0.586*** (0.023)	0.049* (0.029)
Opt-out	-4.532*** (0.297)	-2.221*** (0.089)	-2.198*** (0.129)
SD			
Test	1.425*** (0.088)	1.491*** (0.041)	0.988*** (0.050)
Wild-caught	-0.559*** (0.074)	0.085 (0.054)	-0.370*** (0.052)
Imported	1.448*** (0.089)	0.747*** (0.033)	-0.132** (0.066)
Sustainable practice	0.086 (0.116)	-0.513*** (0.036)	0.104 (0.070)
Opt-out	3.056*** (0.256)	2.882*** (0.082)	1.918*** (0.117)
Log-likelihood	-3188.224	-18692.125	-6250.39
No. Obs.	15,090	72,000	22,800

Note: Own elaboration. ***, ** and * indicate statistically significance at 1%, 5% and 10%. Standard errors are reported in the parentheses.

The belief that certified mussels are safer positively correlates with consumers' preference for the HAB test in all three countries. In other words, those with stronger beliefs in mussel certification are likelier to choose mussels with the HAB test. This result evidences that a well-established certification system helps the success of an HAB test system that guarantees that products are free of contamination.

We expected that people's awareness of the harmful health impacts of HAB, their concern about such consequences, and their perceived probability that mussels are HAB contaminated, would be positively correlated with consumers' preference for the HAB test in all cases. However, this is not what we find in Table 7. The estimated coefficients of awareness and concern about the harmful health impacts of HAB are only positively significant in Vietnam. Surprisingly, the coefficients of the perceived probability of HAB contamination in Chile and China are negative and statistically significant at the 1% level. This means that consumers who perceive that mussels sold on the market have a more significant chance of being contaminated by HAB are less likely to choose mussels that pass the HAB test. One explanation for this surprising and counterintuitive result is that the WTP and perceived probability of contamination are driven by some underlying institutional trust or preference factors that are not captured by the stated belief that certified mussels are safer. In other words, those who perceive a high risk of HAB contamination lack faith in the regulation system, and this lack of faith lowers their WTP for an HAB test. Results from Table A4 in the Appendix suggest a potential non-linearity between the WTP and perceived probability of contamination, where at a lower perceived level of risk, the effect is expected and positive in both countries. The latter can be further evidence of the argument based on a lack of trust in the certification system. Carias et al. (2024) find that lacking institutional trust negatively affects the probability of supporting a policy intervention to reduce the health risks of HAB. Our results also support the critical role trust in the certification system plays in the willingness to pay for this test. This result also suggests that the likely misperception of the probability of HAB contamination does not drive the significant demand for the HAB test. Notice that, however, willingness to pay for the HAB test is higher among consumers in China and Chile as they think unsafe mussell will strongly affect their health. This result suggests that health concerns are more likely to drive results in these countries. The estimated coefficients of other attitude and perception variables are statistically significant in one or two countries, which may reflect the role of contextual factors at the country level.

Besides the perception questions, in the survey, we also asked the respondents about the importance of the mussels' attributes in their purchasing decisions on a 1-5 Likert scale. These attributes include safety, naturalness, price, nutrition, origin, appearance, environment, taste, and convenience. We also explored whether the preference for the HAB test varies with the perceived importance of different aspects of mussels by adding the interaction terms between the perceived importance and the HAB test attribute. The results are shown in Table 8.

The coefficients in these variables are largely consistent with expectations. Individuals who value food safety strongly prefer the HAB test in the choice experiment in all three countries. The sensitivity to price plays a negative role in Chile and China, but the opposite is true in

Vietnam. This may be related to the fact that Vietnamese respondents are not sensitive to prices in the choice experiment. The care for the place of origin has negative coefficients in all three countries. It is statistically significant in Chile and China, probably because those who care more about the place of origin of mussels would have paid attention to local HAB outbreaks even without the test. Nutrition concerns can strengthen the preference for the HAB test in Vietnam. The perceived importance of the appearance of mussels plays a positive role, particularly in China and Chile, but has the opposite effect among Vietnamese respondents. The concern for mussels' environmental impacts has positive coefficients in all three countries, but they are only weakly significant in China. The stated importance of taste and convenience has no significant relationship with the preference for the HAB test. This is not surprising because the HAB test does not influence these aspects.

Table 8. Heterogeneity in respondents' preferences over the HAB test

	Chile	*China*	*Vietnam*
	(1) Choice	(2) Choice	(3) Choice
Mean			
Price	-0.129***	-0.087***	0.000
	(0.024)	(0.003)	(0.001)
Test × Safety	0.516***	0.349***	0.139**
	(0.136)	(0.076)	(0.055)
Test × Naturalness	-0.197	-0.022	-0.094
	(0.121)	(0.049)	(0.062)
Test × Price	-0.284***	-0.113**	0.102*
	(0.097)	(0.048)	(0.061)
Test × Nutrition	-0.178	0.080	0.188***
	(0.150)	(0.060)	(0.061)
Test × Origin	-0.408***	-0.171***	-0.021
	(0.127)	(0.048)	(0.062)
Test × Appearance	0.313**	0.159***	-0.150**
	(0.146)	(0.046)	(0.068)
Test × Environment	0.104	0.082*	0.054
	(0.133)	(0.048)	(0.059)
Test × Taste	0.249	0.042	0.066
	(0.156)	(0.063)	(0.064)
Test × Convenience	0.044	-0.049	-0.015
	(0.112)	(0.054)	(0.061)
HAB Test	0.265	-0.603	-0.330
	(0.759)	(0.436)	(0.204)
Wild	-0.028	-0.066***	-0.024
	(0.049)	(0.020)	(0.031)
Imported	-0.987***	-0.473***	0.001
	(0.079)	(0.025)	(0.029)
Sustainable	0.146***	0.589***	0.051*
	(0.044)	(0.024)	(0.028)
Alt3	-4.801***	-2.240***	-2.195***
	(0.392)	(0.089)	(0.127)
SD			
Wild	1.351***	1.525***	1.003***
	(0.086)	(0.042)	(0.051)
Imported	0.527***	0.065	0.350***
	(0.072)	(0.056)	(0.056)
Sustainable	1.376***	0.750***	-0.132*
	(0.085)	(0.033)	(0.071)
Test	0.162*	-0.523***	0.074
	(0.097)	(0.037)	(0.085)
Alt3	3.331***	2.903***	1.886***
	(0.398)	(0.082)	(0.118)
No. Obs.	15090	72000	22740

Note: Own elaboration. Results from RPL are reported for each country. *** statistically significant at 1%. Standard errors are reported in the parentheses.

4.3. Willingness to pay for the algal bloom test

In the analysis above, we show that consumers in the three countries have a strong preference for the HAB test. Here, we would like to further quantify the demand for the HAB test by estimating the WTP for the HAB test based on the coefficients in the RPL regressions in Table 6. Because the price coefficient is insignificant in the Vietnamese sample, we can only calculate the mean WTP for the HAB test for the Chilean and Chinese samples. The monetary value of the HAB test was simulated using Krinsky and Robb's (1986) bootstrapping method with 1,000 random draws. Estimates come from two methods: WTP in the preference space method and the WTP space method.[10] The results are shown in Table 9. In the first row, we can see that the WTP estimates are rather large. In Chile, the WTP for having the HAB test is 9,453 CLP, where the benchmark market price is only 1,500 CLP per 500g. In China, the WTP is nearly 14 CNY, 3 times the benchmark price at 6 CNY per 500g. We can also convert the absolute price levels we use in the choice experiment and estimation above into relative prices and show how much more, compared with a benchmark level, a consumer would like to pay to have the mussels tested for HAB. In the second row, we show the WTP in relative terms using 1,500 CLP per 500g as the benchmark price for the Chilean sample and 6 CNY per 500g as the benchmark price for the Chinese sample. The size of the estimates is smaller than before, but the estimated WTPs are still large. The Chilean consumers are willing to pay a 335% price premium to have the test, and the Chinese consumers are willing to pay a 145% premium.

Table 9. WTP for the HAB test

	Chile (CLP)	China (CNY)
WTP from ps method	9543.45 [6704.69, 15084.51]	13.890 [12.749, 15.160]
WTP from wtps method	11983.76 [5640.609,18326.91]	12.797 [11.730, 13.864]
WTP as % of bench market price	335%	145%

Note: Own elaboration. The WTP estimates in percentage form are estimated using the second lowest price level as the benchmark market, i.e., 1,500 CLP for the Chilean sample and 6 CNY for the Chinese sample. The benchmark represents the average market price on the local markets.

The large estimated MWTP for the HAB test in absolute and relative terms may raise some concerns. It might be hard to accept that an average consumer in Chile would pay around 10,000 CLP (about 10 USD) for 500g of HAB-tested mussels. While the large MWTP for the harmful algal bloom test is consistent with many hypothetical studies on the WTP for food safety (Chalak & Abiad, 2012; Hoffmann et al., 2019; Ortega et al., 2011; Otieno & Nyikal, 2017), it may be subject to hypothetical bias or the respondents' desire to choose the "right" option. Another possible reason for this large willingness to pay is that people interpret the HAB test as a guarantee of safety, not just for HAB but also for other food safety issues. In other words, they may interpret the test as an overall food safety test. Despite this large figure, the estimated amount is in line with the price of substitutes that are affordable by families.

[10] The detailed WTP space regression results are shown in Table A5 in the Appendix.

The large MWTP can be interpreted as the welfare cost loss that consumers anticipate as a result of potential food poisoning from HAB. Because the HAB problem was negatively framed in the CE scenario, under a loss-aversion setting, it is expected that individuals tend to exhibit larger WTP to avoid negative food health risks. Existing literature suggests that loss aversion can have a significant influence on demand for food safety interventions (Britwum & Yiannaka, 2019; Nie et al., 2021). The higher importance of health concerns among Chilean and Chinese consumers in the willingness to pay for this test may align with the explanation of loss aversion. Finally, even with the large estimated premium, the price range for mussels with the HAB test as a premium product is not entirely unreasonable. In China, on online shopping platforms, the price of regular mussels can go up to 20-30 CNY per 500g. Many households may be willing to pay a high price for safe mussels.

5. Robustness checks

We have found that consumers in the three countries strongly prefer a test that helps avoid HAB contamination in mussels. The results are also robust to different sub-samples and estimation methods. In this section, we conducted several robustness checks.

First, the total sample used for the main results includes consumers with different mussel consumption types, as shown in the last three rows of Table 4, and there are significant differences between the countries, particularly for Vietnam, where the share of consumers mainly eating mussels at restaurants is much larger. Seafood procured and prepared by restaurants may come from different channels from the retail market, and the chance of contamination may also be different. Consumers who mainly eat mussels at home may have different valuations of mussels and food safety concerns from those who mainly consume mussels at restaurants, takeaway, or processed mussels. Therefore, we check if the results still hold when only using the subsample of those who mostly eat mussels at home. The results from the RPL regressions are shown in Table A6 in the Appendix. Overall, results are robust to the most preferred consumption type by consumers. We see a similarly strong preference for the HAB test in all three countries. The estimated WTP for the HAB test is smaller but on the same magnitude as the main results. For the Vietnamese sample, the price coefficient is still not statistically significant despite being negative.

Second, the underlying assumption of a discrete choice experiment is that all attributes are equally important to respondents. However, research has shown that individuals often simplify decision-making rules and focus only on a subset of attributes or assign different weights to various attributes. This phenomenon is known as attribute-non-attendance (ANA) (Scarpa et al., 2013). To assess the robustness of the results, we further considered the ANA problem and ran an extra regression. This regression follows Hess & Hensher (2010), in which the ANA statement indicator for each herder on a specific attribute equals one if the corresponding attribute is not ignored, zero otherwise. These dummy variables interact with the corresponding attributes in the utility function to run a new random parameter logit regression, which estimates each coefficient conditionally. Results are shown in Table A7 in the Appendix. Compared with the original RPL results, the new regression has a larger log-likelihood value, which indicates a better regression fit. The main results are consistent, as the signs of not ignored attributes' coefficients remain the same as those in the original random parameter logit regression, except for the "imported" variable in the Chinese sample. The adjusted willingness to pay can be calculated based on the ANA model results. In Chile, consumers' willingness to pay for the HAB test attribute is approximately 8,434 CLP, while in China, it is approximately 14.24 CNY, similar to the WTP estimates from the RPL regressions.

Finally, another concern comes from the design of the choice experiment. The evaluation of the preference for the HAB test is nested in a survey experiment where an information provision intervention was introduced for half of the participants, aiming at priming consumers' perceptions of production methods (wild-caught vs. farmed) in favor of farmed mussels. The treatment was intended to focus only on production methods and did not mention any other attributes, including HAB and HAB tests. In principle, we do not expect that the treatment would impact consumers' perceptions of the HAB risks and the valuation of the HAB test. However, one may be concerned that the treatment may have primed the respondents in specific ways that may, in turn, interfere with the evaluation of other attributes. To check if the results are robust, we first show the results of the choice model with only the control group. Second, we add interaction terms between the treatment indicator and all the non-price attributes in the RPL regressions of Table 6. The regression results of both practices can be found in Table A8 in the Appendix. Overall, the coefficients of the interaction terms are not statistically significant, except the coefficient of the interaction term with production methods in China. This result alleviates the concern for the interruption of the unrelated treatment conditions to the results in this paper. We further estimate the mixed logit regressions separately for the control and treated sub-samples. The regression coefficients in the two groups largely follow the same pattern in all three countries, except for the coefficients of production methods (wild-caught) for China. In the Chinese sample, the respondents in the control group are indifferent between wild-caught and farmed mussels, but the respondents in the treated group prefer farmed mussels, as intended. A similar pattern in the size of the coefficients can be found in the Chilean data but is not statistically significant, possibly due to the smaller sample size. These results suggest that our results for the HAB test are not confounded by the treatment of the production methods.

6. Concluding remarks

Harmful algal blooms (HAB) are an increasing global threat to safety in the seafood industry. To mitigate their impact, governments mainly adopt early warning systems, which usually result in the closure of coastal marine areas. This policy has shown substantial losses associated with the decrease in supplies, but relatively less is known about how the risk perception of HAB affects consumers and how this translates into welfare losses on the demand side. In this paper, we conducted choice experiments in Chile, China, and Vietnam to explore consumers' preferences for reducing the risk of HAB contamination in mussel consumption.

Our results shed some light on common findings across countries. Our estimates provide evidence of strong consumer demand for a test that eliminates the risk of purchasing mussels contaminated by the HABs in all countries. Sustainable practices are also a highly valued attribute by consumers in all study contexts, confirming the willingness to pay a premium for products produced using sustainable methods. We also found that a belief that certified mussels are safer and higher relative importance of food safety when choosing mussels reinforced consumers' demand for the HAB test in all three countries. This suggests that higher consumer trust in a well-established certification system that guarantees seafood safety would be a critical factor when implementing a HAB test system. These results hold under different methods and sampling strategies used in each country. This makes it more likely that our results can be generalized to alternative contexts and scenarios.

Our results also suggest that some attributes matter more in some countries than others. Chilean respondents care more about the origin of seafood products (local versus imported). Chinese consumers pay more attention to the production method (farmed versus wild-caught). The price coefficient is not significant in the Vietnamese sample.

Surprisingly, consumers of mussels in Chile and China who perceive a larger probability larger chance of being contaminated by HAB contamination are less likely to choose mussels that pass the HAB test. Consumers perceiving a higher risk of HAB contamination may be more critical of any policy mechanism to mitigate the chances of contamination. This aligns with previous evidence revealing the importance of institutional trust, particularly in the food certification system, to explain WTP for a HAB test.

Our empirical findings have several policy implications. Firstly, a strong consumer demand for the HAB test underscores the critical need to promote and support certification systems. Establishing a robust certification system that labels mussels as tested for safety could significantly enhance consumer trust in the safety of mussel products. Such an initiative is likely to increase the overall consumption of mussels and simultaneously reduce the social externalities associated with algal bloom poisoning. These dual benefits highlight the importance of implementing effective regulatory measures. They would both safeguard public health and foster industry growth. Furthermore, given the high relative importance of food safety, and that consumers' confidence in the safety of certified mussels reinforces consumers' preferences for HAB testing, governments should enhance the transparency and credibility of seafood certification processes. It is important to implement strict auditing and compliance measures to ensure that certifications are reliable indicators of food safety. Secondly, to enhance consumers' confidence in these labels, the government should devote more efforts to designing and implementing information campaigns to educate consumers about the meanings and processes behind these certifications. Thirdly, the variations in consumer preferences and perceptions across different countries also necessitate tailored policy formulations. For instance, while the policy needs to focus on the country of origin of seafood in Chile, the emphasis should be more on the production method in China. Developing specific market and regulatory strategies that address the unique needs of consumers in various countries can maximize the effectiveness of these policies.

To conclude, this work does not come without a caveat. One limitation of this study is the use of self-reported knowledge and perception factors across countries to explore heterogeneity in attribute valuation. These factors may reflect unobserved cultural factors. In addition, one could suggest that actual experiments based on revealed preference (such as auctions) can elicit a more objective measure of health risk perception. However, we find it difficult to construct the risk-reducing attribute in a salient way in non-hypothetical scenarios. Lastly, focusing on individual preferences over the existence of a HAB test that may reduce/eliminate the risk of seafood contamination prevents us from estimating willingness to pay for quantitative reductions on food health risk, which may also relate to specific country characteristics. Thus, understanding individual preferences for a range of health risk reductions arise as a potential venue for future research.

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Appendix

Table A1. Description of the attributes of the choice experiment (English version)

Attributes	**Description**
Price	Price of whole fresh mussels with shells, measure in RMB per 0.5kg. There are four different price levels Chile: 500; 1,500; 2,500; 7,000 in CLP China: 2; 6; 10; 14 in CNY Vietnam: 7,000; 20,000; 33,000; 47,000 inVND
Production Method	There are two production methods to produce mussels: farmed-raised and wild-harvested. **Farm-raised**: mussels produced from mussel farms where mussels are seeded, fed and harvested under artificially control environment on a mussel farm alone the shore. **Wild-harvested**: mussels that are harvested from their natural habitat.
Country of origin	This attribute states where the mussels are produced. There are two levels: domestic and imported. **Domestic**: produced in Chile/China/Vietnam **Imported**: produced in other countries and imported to Chile/China/Vietnam
Sustainable Production practices	Whether the production practices adopt sustainable practices in mussel farming or not. Some examples of sustainable practices are: -Fulfilling the minimum size for harvesting. -Monitoring oceanographic and biological conditions -Using local and environmentally friendly materials, avoiding, for example, plastic There are two level here: **Sustainable** or **Standard**
Algal bloom test	Harmful algal blooms occur when colonies of algae grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. Mussels can ingest these toxins. Then eating mussels containing toxins can lead to serious illness. Currently, governments monitor the zones where mussels grow to discover any presence of alga bloom, but there is not a testing system after mussels are harvested. This attribute identifies whether there is a certificate for the mussels stating the sampling test results of the mussels harvested in the same batch are shown negative for Algae bloom. The test provides a guarantee that the mussels are extremely unlikely to be contaminated by the algae bloom and hence are safe to eat. There two statuses: **Yes (having the test)** and **No (no test)**.

Table A2. Test: Individual characteristics between countries

Variable	Chile vs. China	Chile vs. Vietnam	China vs. Vietnam
Age [*No. of years*]	t = 20.635***	1.546	-19.135***
Female [%]	z = -6.613***	-2.357**	4.428***
Household size [*No. members*]	t = -16.093***	-20.722***	-23.711***
No. of children [*No. members*]	t = -11.515***	-12.173***	-8.811***
Tertiary education [%]	z = -25.509***	-4.865***	20.238***
High-income [%]	z = 1.836*	4.817***	4.426***
Income level	z = -14.399***	7.171***	21.017***

Note: Own elaboration. This table show results of equality test of individual characterisitcs between samples, corresponding to the sample mean comparisons in in Table 3. The t-statistics from t-tests are reported in the cells for continuous variables including age, household size and number of children. The z-statistics from Mann-Whitney ranksum tests are reported for dummy and categorical variables including female dummy, tertiary education dummy, high-income dummy and income levels.
***, ** and * indicate statistically significance at 1%, 5% and 10%.

Table A3. Test: Attitudes and Perceptions towards HAB

Question	Chile vs. China	Chile vs. Vietnam	China vs. Vietnam
Before this study, did you know that algal bloom may contaminate mussels, making it unsafe to eat mussels produced in the area with an algal bloom outbreak? [*Aware of HAB harm*].	z = -13.808***	-6.021***	9.797***
How high do you think is the chance of eating a mussel contaminated by algal bloom? [*Perception of contamination chance*].			t = -15.6597***
Algal blooms are a natural phenomenon, and nothing can be done to prevent its occurrence. [*HAB cannot be stopped*].	z = 8.159***	14.266***	11.827***
The severity of algal blooms is reinforced by the production of other farmed species in the same area. [*HAB reinforced by aquaculture*].	-2.909***	13.785***	21.034***
Before this study, I am concerned about the effects of algal blooms on humans? [*Concern about HAB*].	3.203***	12.511***	13.391***
I trust the quality/safety of the mussels sold on the market. [*Trust mussel quality*].	2.121**	15.108***	19.971***
I think my health is easily at risk due to unsafe mussels. [*Unsafe mussel affects health*].	-9.400***	11.276***	21.715***
I agree that certified mussels be safer than uncertified mussels. [*Certified mussel safer*].	-11.552***	11.010***	23.135***

Note: Own elaboration. his table show results of equality test of individual characterisitcs between samples, corresponding to the sample mean comparisons in in Table 5. The table shows the z-statitics from Mann-Whitney ranksum tests, except for *Perception of contamination chance*. Because *Perception of contamination chance* was measures measures in Chile on a1-5 scale, but in numeric probability figures in China and Vietnam, we only report t-test results between China and Vietnam.

Table A4. Consumer's preferences over mussels attributes: perception of contamination probability, using dummies

	Chile		China		Vietnam	
	(1)	(2)	(3)	(4)	(5)	(6)
Mean						
Price	-0.124***	-0.124***	-0.087***	-0.087***	0.000	0.001
	(0.024)	(0.024)	(0.003)	(0.003)	(0.001)	(0.001)
HAB test × Perception of chance of contamination	-0.385***		-0.015***		0.005**	
	(0.091)		(0.002)		(0.002)	
HAB test × prob 1		0.100		0.693***		0.161
		(0.416)		(0.098)		(0.149)
HAB test× prob 2		0.471**		0.384***		-0.392***
		(0.188)		(0.094)		(0.114)
HAB test× prob 4		-0.385*		-0.137		-0.076
		(0.198)		(0.141)		(0.132)
HAB test× prob 5		-1.284***		-0.154		0.258
		(0.480)		(0.280)		(0.205)
HAB Test	2.319***	1.177***	1.629***	0.858***	0.480***	0.777***
	(0.283)	(0.123)	(0.066)	(0.075)	(0.098)	(0.080)
Wild	-0.033	-0.030	-0.066***	-0.066***	-0.020	-0.024
	(0.048)	(0.048)	(0.020)	(0.020)	(0.030)	(0.031)
Imported	-0.943***	-0.941***	-0.469***	-0.470***	0.005	0.002
	(0.077)	(0.077)	(0.025)	(0.025)	(0.028)	(0.029)
Sustainable	0.136***	0.138***	0.589***	0.590***	0.047*	0.048*
	(0.043)	(0.043)	(0.023)	(0.024)	(0.028)	(0.028)
Alt3	-4.851***	-4.842***	-2.260***	-2.261***	-2.172***	-2.252***
	(0.372)	(0.365)	(0.088)	(0.088)	(0.124)	(0.132)
SD						
Test	1.455***	1.456***	1.524***	1.527***	1.043***	1.019***
	(0.088)	(0.089)	(0.041)	(0.042)	(0.052)	(0.050)
Imported	0.511***	0.513***	0.064	0.054	0.301***	-0.364***
	(0.073)	(0.073)	(0.055)	(0.057)	(0.064)	(0.051)
Sustainable	1.374***	1.380***	0.745***	0.745***	-0.075	-0.126*
	(0.085)	(0.086)	(0.033)	(0.033)	(0.071)	(0.066)
Wild	0.174**	0.176**	-0.522***	-0.526***	0.062	0.080
	(0.088)	(0.089)	(0.036)	(0.036)	(0.085)	(0.072)
Alt3	3.378***	3.361***	2.864***	2.866***	1.862***	1.981***
	(0.335)	(0.325)	(0.077)	(0.078)	(0.123)	(0.119)
No. Obs.	15090	15090	72000	72000	22650	22800

Note: Own elaboration. *** statistically significant at 1%. Standard errors are reported in the parentheses.

Table A5. RPL regressions in WTP space

	Chile		*China*	
	Mean	SD	Mean	SD
HAB test	11983.758***	11983.758***	12.797***	16.795***
	(3236.360)	(3236.360)	(0.544)	(0.623)
Wild-caught	-620.436	-620.436	-0.714***	0.097
	(518.209)	(518.209)	(0.208)	(0.344)
Imported	-10465.482***	-10465.482***	-5.292***	8.053***
	(2614.849)	(2614.849)	(0.291)	(0.394)
Sustainable practice	1313.585***	1313.585***	6.517***	5.374***
	(477.885)	(477.885)	(0.306)	(0.364)
Opt-out	-70919.153***	-70919.153***	-25.558***	32.876***
	(18720.313)	(18720.313)	(1.106)	(1.280)
LLR	-3178.9487		-18753.654	
No. obs.	15090		72000	

Table A6. Consumer's preferences over mussels attributes: Mainly eat at home subsample

	Chile		*China*		*Vietnam*	
	Mean	SD	Mean	SD	Mean	SD
Price	-0.148***		-0.088***		-0.001	
	(0.029)		(0.003)		(0.002)	
HAB test	1.441***	1.494***	1.216***	1.599***	0.830***	1.207***
	(0.103)	(0.108)	(0.042)	(0.047)	(0.081)	(0.088)
Wild-caught	-0.074	0.551***	-0.058***	0.019	0.030	-0.325***
	(0.058)	(0.085)	(0.021)	(0.065)	(0.047)	(0.074)
Imported	-1.067***	1.509***	-0.492***	0.814***	-0.061	-0.009
	(0.099)	(0.110)	(0.028)	(0.035)	(0.043)	(0.081)
Sustainable	0.176***	-0.171	0.603***	0.514***	0.005	-0.056
practice	(0.052)	(0.116)	(0.026)	(0.041)	(0.043)	(0.084)
Opt-out	-4.182***	2.616***	-2.345***	3.060***	-3.585***	2.777***
	(0.332)	(0.261)	(0.092)	(0.099)	(0.318)	(0.228)
LLR						
No. obs.	372		2048		337	

Note: Own elaboration. ***, ** and * indicate statistically significance at 1%, 5% and 10%. Standard errors are reported in the parentheses. Price units used in the Chilean and Vietnam samples are thousand CLP and thousand VND. We use sub-sample of respondents who reported that they mainly eat mussels at home.

Table A7. Estimation results of ANA model

	Chile				China				Vietnam			
Choice	Not ignored		Ignored		Not ignored		Ignored		Not ignored		Ignored	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Price	-0.152*** (0.0248)	-	0.229*** (0.0854)	-	-1.21*** (0.00274)	-	-0.0366*** (0.00967)	-	0.000697 (0.00130)		0.000722 (0.00262)	
HAB test	1.282*** (0.0813)	1.392*** (0.0798)	0.888** (0.435)	1.352*** (0.371)	1.210*** (0.0359)	1.421*** (0.0361)	0.476*** (0.110)	0.544*** (0.153)	0.718*** (0.0520)	1.075*** (0.0550)	0.320*** (0.0818)	0.364** (0.155)
Wild-caught	-0.0495 (0.0496)	0.562*** (0.0684)	0.0531 (0.233)	0.604* (0.337)	-0.0574*** (0.0194)	0.00470 (0.113)	-0.260*** (0.0855)	0.0195 (0.117)	-0.0287 (0.0351)	0.391*** (0.0553)	-0.0228 (0.0609)	-0.0515 (0.134)
Imported	-0.945*** (0.0785)	1.393*** (0.0881)	-0.136 (0.257)	0.528** (0.251)	-0.493*** (0.0271)	0.726*** (0.0360)	-0.291*** (0.0502)	0.417*** (0.0797)	-0.00926 (0.0308)	-0.0277 (0.0789)	0.0762 (0.0663)	0.179 (0.164)
Sustainable practice	0.126*** (0.0435)	0.0672 (0.0920)	0.229 (0.244)	0.273 (0.295)	0.561*** (0.0212)	0.293*** (0.0398)	0.138 (0.0905)	0.0138 (0.222)	0.0584* (0.0304)	-0.0483 (0.0749)	-0.0415 (0.0710)	0.104 (0.178)
Opt-out	-4.560*** (0.323)	2.431*** (0.232)			-2.129*** (0.0784)	2.676*** (0.0750)			-2.220*** (0.125)	1.798*** (0.110)		
Log-likelihood	-3184.779				-18878.391				-6262.749			
Number of obs.	503				2400				760			

Note: Own elaboration. *** statistically significant at 1%. Standard errors are reported in the parentheses.

Table A8. Consumer's preferences over mussels attributes: Sub-sample control and treated

	Chile		*China*		*Vietnam*	
	(1) Control subsample only	(2) Full sample, interact with Treatment status	(3) Control subsample only	(4) Full sample, interact with Treatment status	(5) Control subsample only	(6) Full sample, interact with Treatment status
Mean						
Price	-0.158***	-0.125***	-0.067***	-0.087***	0.001	0.001
	(0.035)	(0.024)	(0.004)	(0.003)	(0.002)	(0.001)
HAB Test	1.153***	1.089***	1.218***	1.191***	0.739***	0.758***
	(0.117)	(0.119)	(0.053)	(0.053)	(0.074)	(0.070)
Wild	0.022	0.026	0.009	0.029	-0.006	-0.009
	(0.074)	(0.069)	(0.028)	(0.028)	(0.045)	(0.046)
Imported	-1.037***	-1.073***	-0.468***	-0.487***	0.031	0.030
	(0.120)	(0.111)	(0.037)	(0.035)	(0.042)	(0.042)
Sustainable	0.120*	0.121**	0.542***	0.572***	0.078*	0.075*
	(0.063)	(0.061)	(0.032)	(0.032)	(0.044)	(0.042)
Alt3	-4.042***	-5.057***	-1.647***	-2.023***	-1.966***	-2.212***
	(0.308)	(0.410)	(0.104)	(0.114)	(0.166)	(0.162)
HAB test * Treatment		0.213		-0.004		-0.140
		(0.159)		(0.072)		(0.094)
Wild-caught * Treatment		-0.116		-0.185***		-0.026
		(0.097)		(0.039)		(0.062)
Imported * Treatment		0.244		0.028		-0.053
		(0.149)		(0.049)		(0.057)
Sustainable * Treatment		0.032		0.037		-0.050
		(0.085)		(0.044)		(0.056)
Opt-out * Treatment		0.365		-0.390***		-0.049
		(0.377)		(0.147)		(0.180)
SD						
HAB Test	1.535***	1.466***	1.511***	1.569***	1.137***	1.046***
	(0.148)	(0.086)	(0.057)	(0.042)	(0.078)	(0.050)
Wild	0.632***	0.529***	-0.186**	0.080	-0.322***	-0.364***
	(0.101)	(0.071)	(0.073)	(0.053)	(0.078)	(0.051)
Imported	1.611***	1.350***	0.845***	0.755***	0.079	-0.117*
	(0.141)	(0.081)	(0.048)	(0.033)	(0.097)	(0.067)
Sustainable	-0.122	0.146	0.475***	-0.519***	-0.228**	0.071
	(0.104)	(0.097)	(0.052)	(0.037)	(0.089)	(0.073)
Alt3	1.798***	3.428***	2.751***	2.876***	1.578***	1.964***

	(0.208)	(0.421)	(0.127)	(0.081)	(0.154)	(0.117)
No. Obs.	7380	15090	36000	72000	10710	22800

Note: ***, ** and * indicate statistically significance at 1%, 5% and 10%. Standard errors are reported in the parentheses. Price units used in the Chilean and Vietnam samples are thousand CLP and thousand VND. Column (1) (3) and (5) are random parameter logit regression results as in Table 6 using only the subsample of the control group. Column (2) (4) and (6) are random parameter logit regression results of adding interaction terms between the treatment indicator and all the non-price attributes to random parameter logit regressions using the full sample.