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Are consumers willing to pay for *in-vitro* meat? An investigation of naming effects

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Abstract

Currently, there is an ongoing debate about whether '*in-vitro* meat' (IVM) should be labelled and communicated differently from conventional meat. Naming and labelling IVM can have significant implications and consequences for consumers' acceptance of this new product as well as for future labelling policies. We provide, for the first time, information on how the use of different terms (i.e., 'cultured', 'lab-grown' and 'artificial') shapes US consumers' preferences and marginal willingness to pay for IVM. Using a choice experiment involving chicken meat products that vary across four attributes (i.e., production method, carbon trust label, antibiotics use and price), our results show that consumers prefer chicken meat produced through the conventional production method and tend to generally reject IVM. However, the term 'cultured' is less disliked than the terms 'lab-grown' and 'artificial', and 'artificial' is less disliked than 'lab-grown'. Results also indicate that consumers' valuations are heterogeneous over differing consumer attitudes. Our findings provide insights into the psychology of consumers' level of acceptance and attitudes, which can be useful in communicating the nature of the IVM to the public. They also have important implications for future labelling policies.

KEYWORDS

chicken meat, consumers' willingness to pay, *in-vitro* meat, labelling policy, naming effects, United States

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1 | INTRODUCTION

Continuing growth in world population, incomes and urbanisation has significantly increased the demand for meat products (OECD-FAO, 2013). Meat production, however, can generate large greenhouse gas (GHG) emissions (Gerber et al., 2013), and is a major user of land, energy and water (FAO, 2006). There are also increasing societal concerns about food safety, human health issues related to meat consumption (Godfray et al., 2018) and animal welfare (Lymbery & Oakeshott, 2014).

For these reasons, there is increasing interest in innovative alternatives to conventional meat. Although plant-based food, mycoproteins or insect food products are starting to enter the food market, consumer desires for meat similar to conventional meat is encouraging the development of what is termed '*in-vitro* meat' (IVM) (Post & Hocquette, 2017). IVM is the result of recent scientific advances in regenerative medicine techniques, where muscle-specific stem cells are taken from an animal and then grown to form muscle tissue as edible meat (Yuan, 2018).

In the last few years, a growing number of new start-up businesses (e.g., Memphis Meat, Mosa Meat) as well as large companies such as Tyson Foods Inc., Google, and Cargill have invested large amounts in developing IVM (CBS News, 2018; Garfield, 2018). While several companies are aiming to sell IVM in the coming years (Shapiro, 2018), Singapore has recently approved the sale of IVM chicken produced by the company Eat Just, Inc. (Noyes, 2020).[1]

One of the key advantages of IVM technology is that it could produce meat in unlimited quantities that could potentially be produced more sustainably in terms of lower greenhouse gas emissions, land use and water use (Mattick et al., 2015).[2] In addition, IVM should not raise any animal welfare concerns (Chriki & Hocquette, 2020). However, in addition to current technical challenges and high production costs, some researchers are claiming that consumers' acceptance is the most relevant barrier to market development for IVM (Sharma et al., 2015). A few studies have investigated consumers' acceptance of IVM and find that a majority of consumers would at least be willing to try IVM, and a substantial number would consume it regularly or as a replacement for conventional meat, suggesting the existence of potential markets in North America, Europe and Asia for IVM (for an extensive review on consumers' acceptance of IVM, see Bryant & Barnett, 2018, 2020).

One of the most critical issues related to IVM consumers' acceptance is its nomenclature (Friedrich, 2016; Ong et al., 2020), which affects marketing and communication strategies as well as labelling policies for IVM and hence could be a major factor in its success (Watson, 2020). Furthermore, before IVM goes to market, regulators will likely first have to decide how to term IVM products (Johnson et al., 2018), with substantial implications for both IVM and conventional meat producers. For example, several farm groups and the conventional meat-processing interests have affirmed their allegiance to traditional meat by loudly voicing their opposition to IVM and demanding that it not be called 'meat' at all.[3] In addition, the lack of regulations and standardisation of IVM have generated several ambiguities in terms of its nomenclature (Ong et al., 2020).

[1]On 16 December 2020, the first world commercial sale of IVM chicken was served in the restaurant '1880' in Singapore (Ho, 2020).

[2]However, recent research has been inconclusive as to the environmentally sustainable advantages of IVM over conventional meat (Lynch and Pierrehumbert, 2019). Specifically, the lower environmental impact of IVM compared to conventional meat production depends on the availability of decarbonised energy generation and the specific production systems that are realised. Indeed, initially IVM results in less warming compared to conventional meat production, but this gap narrows in the long term and in some cases the latter causes far less warming. This is because CH_4 emissions from conventional meat production do not accumulate, unlike CO_2 which is the type of GHG mainly produced by IVM (Lynch and Pierrehumbert, 2019).

[3]This issue is now one of the US National Cattlemen's Beef Association's top policy priorities, with the purported goal of protecting people from what they called misleading labels (USCA, 2018).

To our knowledge, few studies have investigated consumers' preferences regarding IVM and whether these are influenced by the terminology used to identify IVM products. Bryant and Barnett (2019) found that the term 'clean meat' led to higher acceptance than 'lab-grown meat', whereas the terms 'cultured meat' and 'animal-free meat' scored in the middle (Bryant & Barnett, 2020). Two other non-refereed consumer studies on how nomenclature affects consumers' acceptance of IVM have also been carried out. The Good Food Institute found that the terms 'slaughter-free', 'craft', 'clean' and 'cultured' held some appeal. The terms 'slaughter-free' and 'cell-based' performed best in terms of descriptiveness and differentiation, whereas the terms 'slaughter-free' and 'craft' performed best in regard to the likelihood of trying and purchasing IVM (Szejda, 2018). In addition, the Animal Charity Evaluators found that the term 'clean' led to significantly greater consumer acceptance than 'cultured' (Greig, 2017). None of these studies, however, has examined consumers' valuation of IVM products using different terminology.

Our study fills this gap by using a choice experiment (CE) to investigate consumers' willingness to pay (WTP) for hypothetical IVM fresh skinless boneless chicken breast products, hereafter called 'chicken products'. Specifically, we performed an online experiment with consumers in the United States using different treatments to test how sensitive consumers' preferences and marginal WTP (mWTP) for the chicken product attributes are to different terms associated with IVM (i.e., cultured, lab-grown and artificial). Although other terms are also widely used (e.g., clean meat, synthetic meat, etc.), we decided to test terms that are conceptually different from each other and that have been used by several published studies, advocacy groups and the media. We chose fresh skinless boneless chicken breast products for three main reasons: (i) chicken breast is one of the most consumed meats in the United States (National Chicken Council, 2018b); (ii) the US chicken industry is the largest in the world (National Chicken Council, 2018a); and (iii) several large companies and startup businesses (e.g., Tyson Foods, Eat Just Inc.) are investing in IVM chicken (Tyson Foods, 2018; Lucas, 2019).

2 | MATERIALS AND METHODS

2.1 | CE design

In the CE, four attributes were used in all treatments to describe the different types of chicken products, as follows: production method, Carbon Trust label, antibiotics use and price (Table 1). First, we included production method because we wished to test consumers' mWTP for different chicken production methods. Thus, two levels of production method were specified 'conventional', and 'IVM'. We randomly assigned respondents to three treatments to test the effect of different IVM terms. Thus, IVM was termed 'cultured' for treatment 1, 'lab-grown' for treatment 2 and 'Artificial' for treatment 3. Specifically, the term 'cultured' may evoke associations to science, which are not rated negatively (Bryant & Barnett, 2019). Moreover, it has been widely used in the IVM community, including by the NGO New Harvest as well as by a number of studies (e.gBryant & Barnett, 2019; The Golden Food Institute, 2019), and it seems to be preferred by IVM companies (Ong et al., 2020). 'Lab-grown meat' is a term often used by the media, perhaps because it intuitively describes the concept in lay terms, and is, perhaps, more sensational compared to other terms (Bryant & Barnett, 2019; Smith, 2014). In addition, the 'lab-grown meat' term may serve as shorthand to distinguish IVM from meat harvested from slaughtered animals (Watson, 2020), and it seems to be preferred by traditional meat producers (Ong et al., 2020). 'Artificial' is a lesser-used term typically deployed by opponents of the IVM technology (Watson, 2020), and used in the media (Dahlgreen, 2013; Heid, 2016).

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TABLE 1 Attributes and levels

Attributes	Levels
Production method	'Conventional' 'IVM' (i.e., 'cultured', 'lab-grown' and 'artificial')
Carbon Trust label	No label reported Carbon Trust label
Antibiotics use	No information reported 'No antibiotics ever'
Price	\$2.50/lb \$5.50/lb \$8.50/lb \$11.50/lb

Second, we included information about the environmental impact of meat production because it is currently one of the top key concerns of the conventional meat production method (Godfray et al., 2018). Specifically, we used the Carbon Trust label, referring to the environmental impact of food production, transportation and use of the food products in terms of CO_2 emissions, against no label. Third, we included the information about antibiotics use, given the fact that antibiotics might be used during chicken production (Chriki & Hocquette, 2020). This information is a top concern when consumers are purchasing meat (Boyer et al., 2017). Therefore, 'antibiotics use' was specified by the phrase 'No antibiotics ever', or no information about this was reported. Lastly, four price levels were specified based partly on the current market prices for chicken products in retail stores in the United States (\$2.50/lb, \$5.50/lb, \$8.50/lb and \$11.50/lb).[4]

The selected attributes and their levels were then used to generate an orthogonal, fractional factorial design that resulted in the creation of 24 choice sets,[5] which were then divided into two blocks of 12 choice tasks each to prevent respondents' fatigue. We used the Ngene 1.2 software to generate our choice design. Specifically, we used a sequential orthogonal design approach. In the sequential method, an orthogonal design is first generated for the first alternative, and then the allocation of attributes and attribute levels is derived based on the first alternative (Choice Metrics, 2018). This type of design is implemented for unlabelled designs like ours, where the utility function of each alternative has the same attributes and attribute levels.[6] Each choice task was composed of two product alternatives (options A and B) and an 'opt-out' option (option C) (see example in Appendix SA). The choice tasks within each block, and the products within each choice task (options A and B) were randomly ordered.

The CE was introduced to the respondents with an explanation, and description of the attributes and levels. Before the choice tasks, respondents were asked to read a cheap talk (CT) script in an attempt to mitigate the possible hypothetical bias that typically affects

[4]The prices for fresh skinless boneless chicken breast products were based on prices recorded in different US stores, including grocery stores, farmers' markets, specialty stores, organic stores and supermarkets.

[5]The suitability of the adoption in this study of an orthogonal design approach with no prior information is given by the use of treatments differing in terms of the naming frame, that is, the production method. As we expected, the use of different naming frames might have affected consumers' evaluation of the products' attributes. As such, the use of an experimental design based on prior information might have more efficiently worked in the case of one treatment (i.e., the treatment where the same naming frame was specified) but not for all them (Bliemer and Collins, 2016).

[6]In the generation of the orthogonal design, interaction terms between the production method and the remaining non-price attributes were included. However, in this study we focused on the treatment effect on the attributes' main effect; hence we did not take into account the interaction terms in our model estimation.

WTP estimates in stated preference studies (Cummings & Taylor, 1999) (see Appendix SB, for the CT script). Upon completion of the 12 choice tasks, the respondents were then asked to fill out a questionnaire to collect several consumers' attitudes. A pre-test involving 50 consumers was performed to test the survey. The complete questionnaire is available in Appendix SC.

2.2 | Experimental treatments and research hypotheses

To test our research hypotheses, we implemented a between-subjects design based on the use of three CE treatments. Hence, each respondent was randomly assigned to only one of the CE treatments. The three treatments differed only in terms of the name given to the IVM. Specifically, in treatment 1, 'Cultured', 210 consumers were exposed to chicken products with the IVM product being termed *cultured*. In treatment 2, 'Lab Grown', 208 respondents were exposed to chicken products with the IVM product being termed *lab-grown*. In treatment 3, 'Artificial', 207 respondents were exposed to chicken products with the IVM product being termed *artificial*. To avoid providing information that could potentially bias consumers' responses, we provided the same definition of IVM across all the treatments (see Appendix SD).

With these CE treatments, we were able to test a series of hypotheses aimed at testing whether the term used for the IVM affected consumers' mWTP for the IVM technology. To determine the effect of terms on individuals' mWTP, the estimates from the three treatments were compared. Accordingly, we conducted the following three tests:

First, we tested Treatment 1 (Cultured) versus Treatment 2 (Lab Grown) to investigate whether the two naming frames affected consumers' WTP for cultured versus lab-grown meat. Thus, we tested the following hypothesis:

$$H_{01}: (mWTP^{LABGROWN} - mWTP^{CULTURED}) = 0$$

$$H_{11}: (mWTP^{LABGROWN} - mWTP^{CULTURED}) \neq 0$$

Second, we tested Treatment 1 (Cultured) versus Treatment 3 (Artificial) to investigate whether consumers are willing to pay different price premiums for cultured versus artificial meat. Thus, we tested the following hypothesis:

$$H_{02}: (mWTP^{ARTIFICIAL} - mWTP^{CULTURED}) = 0$$

$$H_{12}: (mWTP^{ARTIFICIAL} - mWTP^{CULTURED}) \neq 0$$

Third, we tested Treatment 2 (Lab Grown) versus Treatment 3 (Artificial) to investigate whether consumers' evaluations for lab-grown versus artificial meat differ. Thus, we tested the following hypothesis:

$$H_{03}: (mWTP^{ARTIFICIAL} - mWTP^{LABGROWN}) = 0$$

$$H_{13}: (mWTP^{ARTIFICIAL} - mWTP^{LABGROWN}) \neq 0$$

Moreover, the existing literature shows that attitudinal factors may shape consumers' perceptions of IVM. For this reason, we also tested hypotheses related to the effect of attitudinal variables on respondents' mWTP formation for the different IVM chicken products. We particularly focused on six major factors.

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1. The effect of having heard or not heard about IVM (*HEARING*). Following past studies, our hypothesis is that consumers who have heard about IVM have a higher mWTP for IVM products in the case of 'Cultured' but a lower mWTP in the case of 'Lab Grown', and 'Artificial'. This is because studies have shown that 'cultured' may evoke positive associations to science (Bryant & Barnett, 2019), while 'lab-grown' (Bryant & Barnett, 2019) and 'artificial' may sound more sensational and may be negatively associated with human manipulation of nature (Bryant & Barnett, 2019; Watson, 2020).
2. The effect of pro-animal welfare attitude (*AAS*). Our hypothesis is that consumers who have a higher pro-animal welfare attitude have a higher mWTP for IVM since by using IVM technology no animal is slaughtered, and previous consumer research found that animal welfare is one of the most important perceived benefits of IVM (Bryant & Barnett, 2018). We do not expect differences among the IVM terms for this effect.
3. The effect of the degree of neophobia toward new food technologies (*FTNS*). Previous research has shown that a high degree of neophobia toward new food technologies may reduce consumers' acceptance of foods produced using new technologies (Asioli et al., 2019). However, prior consumer studies on IVM show ambiguous results (Dupont & Fiebelkorn, 2020; Gómez-Luciano, 2019). Thus, given the previous literature, we are unsure of what to expect.
4. The effect of pro-environmental attitude (*NEP*). Authors have reported that environmental benefits are one of the major perceived benefits of IVM (Bryant & Barnett, 2018), whereas others have found that consumers perceive that IVM can be harmful to the environment (Gómez-Luciano et al., 2019; Specht et al., 2020). Thus, given the previous literature, we are unsure of what expect. We do not expect differences among the IVM terms for this effect.
5. The effect of religious orientation (*RELIGION*). Prior research has shown that religion could affect consumers' acceptance of IVM. Indeed, Marcu, (2014) found that consumers characterise IVM as 'playing God', whereas other authors found that, in principle, religious people were open to IVM if it comes from animal species allowed in their religion (Bryant, 2020). Thus, given the previous literature, we are unsure of what to expect.
6. The effect of political preferences (*POLITICS*). Previous research has found that left-wing/liberal consumers tend to accept IVM more than right-wing/conservative people (Bryant & Barnett, 2018). Thus, we hypothesise that left-wing/liberal consumers have a higher mWTP for IVM. We do not expect differences among the IVM terms for this effect.

Specifically, we aim first at testing within each treatment whether attitudinal factors shape mWTP formation for IVM. Second, we test the above hypotheses related to naming effects across different attitudinal subsamples in order to investigate how the naming of the IVM impacts the evaluations of individuals with different attitudinal characteristics.

2.3 | Data

The data[7] used in this study are drawn from an online survey involving 625 consumers in the United States using the online platform Qualtrics LLC (Provo, USA), carried out in the autumn of 2017. Consumers were randomly recruited by Qualtrics using sampling quotas in terms of age, gender and income based on official statistics (United States Census Bureau, 2015). Only consumers who were at least 18 years old were included in the study.

Given the randomisation to treatments, we checked if we had achieved balance for the observable characteristics across the treatments. The results are presented in Table A1, and show

[7]We obtained informed consent from all the participants in the study. Our study was approved by an institutional review board (IRB).

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that the hypotheses of equality of means between socio-demographic characteristics across treatments failed to be rejected at the 0.05 level.

After the choice tasks described above, we included questions to test our hypotheses concerning attitudinal factors, as described in Section 2.2.

3 | ECONOMETRIC ANALYSIS

To test the research hypotheses, we estimated the effect of the treatments on mWTP formation using discrete choice models, which are typically used to analyse choice data (Hensher et al., 2015). Specifically, discrete choice models are based on modelling 'utility', that is to say, the net benefit a subject obtains from selecting a specific product in a choice situation as a function of the attributes that are embedded in the product under consideration (Hensher et al., 2015). There are different specifications of discrete choice models, from multinomial logit (MNL), which assumes homogeneity in individuals' tastes, to the mixed logit model (MIXLM), which accounts for preference heterogeneity.

In addition, in discrete choice models, it is necessary to specify the utility function, which could be in either preference space or WTP space (Train, 2009). In preference space models, mWTP values are derived by dividing the coefficients of the non-price attributes by the negative of the price coefficient, whereas in WTP space models, the attributes' coefficients enter the utility function directly as mWTP. Studies have shown several advantages of WTP space models over preference space models, including accounting for interpersonal scale variations (Scarpa & Willis, 2010), greater stability in the WTP estimates (Balcombe et al., 2009), and more reasonable WTP distribution (Train & Weeks, 2005). Hence, we opted for the MILXLM, with the specification of the utility function in the WTP space. Consistent with the Lancaster Theory (Lancaster, 1966), discrete choice models assume that the total utility consumers derive from a product can be segregated into the marginal utilities given by the attributes of a product. As such, the specification of the utility (U) function in our study can be defined as follows:

$$U_{njt} = \alpha_n (ASC - PRICE_{njt} + \theta_{n1} PRODUCT_{njt} + \theta_{n2} CARBON_{njt} + \theta_{n3} ANTIBIOTICS_{njt}) + \in_{njt}, \quad (1)$$

where n refers to the individual, j denotes each of the three options available in the choice set, t is the number of choice occasions, and α_n is the price scale parameter that is assumed to be random and to follow a log-normal distribution. The ASC is the alternative constant indicating the selection of the opt-out option. The price ($PRICE_{njt}$) attribute is represented by four experimentally defined price levels (i.e., \$2.50/lb, \$5.50/lb, \$8.50/lb and \$11.50/lb). $PRODUCT_{njt}$ is a dummy variable representing the production method, taking the value of 0 if the production method is 'conventional' and 1 if it is 'cultured' for $CULTURED_{njt}$, 'lab-grown' for $LABGROWN_{njt}$, and 'artificial' for $ARTIFICIAL_{njt}$. $CARBON_{njt}$ is a dummy variable representing the Carbon Trust label, taking the value of 0 if no label is reported and 1 if the Carbon Trust label is reported. $ANTIBIOTICS_{njt}$ is a dummy variable for information about antibiotics use, taking the value of 0 if no information is reported and 1 if the phrase 'No antibiotics ever' is reported. θ_{n1}, θ_{n2}, and θ_{n3} are the coefficients of the estimated mWTP values for the production method, the Carbon Trust label, and the 'No antibiotics ever' claim, respectively. Finally, $\in_{njt}$ is an unobserved random term that is distributed following an extreme value type I (Gumbel) distribution, independent and identically distributed (i.i.d.) over alternatives.

The parameters corresponding to the three non-price attributes were modelled as random parameters assumed to follow a normal distribution, and the opt-out parameter was modelled as a fixed parameter.

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The differences in the mWTP among the three treatments involved in our hypotheses (i.e., H_{01}, H_{02}, and H_{03}) can be tested by conducting pairwise tests using data from the two respective treatments involved in the particular hypothesis. Then, following Bazzani et al. (2017) and De-Magistris et al. (2013), we created interactions between the non-price attributes and the treatment (*dtreat)* parameters, which were modelled as a fixed parameters. Precisely, the interaction effects were specified as dummy variables to differentiate one treatment over another (*dtreat*). Accordingly, the model can be specified as follows:

$$\begin{aligned} U_{njt} &= \alpha\left(ASC - PRICE_{njt} + \theta_{n1} PRODUCT_{njt} + \theta_{n2} CARBON_{njt} + \theta_{n3} ANTIBIOTICS_{njt}\right) \\ &+ ð_1(PRODUCT_{nj} \times dtreat) + ð_2(CARBON_{nj} \times dtreat) + ð_3(ANTIBIOTICS_{nj} \times dtreat) + \in_{njt}, \end{aligned} \tag{2}$$

where *dtreat* is coded as 1 for the first treatment in the analysed hypothesis (i.e., 'Lab Grown' for H_{01}, 'Artificial' for H_{02}, and 'Artificial' for H_{03}), and 0 otherwise. The significance of the estimated ð coefficients and their signs indicate the effect of the treatment on the mWTP for the attribute of interest.

Finally, to test our hypotheses concerning consumer attitudinal factors, we conducted subsample analyses based on the factors described in Section 2.2 above. Again, the estimated mWTP for the different subsamples as well as the differences in mWTP for the different subsamples among the three treatments can be tested using the same models, (1) and (2), used for the pooled samples.

All the models were estimated using STATA 16.1 software (Stata-Corp LP, College Station, USA).

4 | RESULTS

4.1 | WTP estimates: Pooled samples

The results from the estimation of the mixed logit models using Equation (1) in the WTP space for the three treatments are shown in Table 2. Specifically, we report the estimates (mWTP) of the production method, Carbon Trust label, antibiotics use, price and opt-out parameters.

In all three treatments, the mean estimate for the opt-out option is negative and significant, suggesting that consumers tend to prefer one of the two product alternatives as opposed to the 'opt-out' option. On average, consumers prefer chicken products produced through the conventional production method, branded with the 'Carbon Trust label' and labelled with the claim 'No antibiotics ever'. Specifically, if we look at the mWTP magnitudes for the individual attributes, we notice that the production method has the highest magnitude, suggesting that it is the attribute that mostly influences consumers' mWTP. The second most important attribute that affects the mWTP is antibiotics use. On average, consumers prefer chicken products with the label claiming 'No antibiotics ever', with relatively similar mWTP across the treatments. The Carbon Trust label is the least valued attribute, with relatively similar mWTP across the treatments. The estimated price coefficients indicate that the 'cultured' description is less rejected than 'lab-grown' or 'artificial', with consumers being willing to pay a higher price (or less lower price) for IVM on average when it is termed 'cultured' rather than 'lab-grown' or 'artificial'.

Next, we test the hypothesis that the different terms associated with IVM significantly affect mWTP estimates using the model specified in Equation (2). Specifically, we estimated three separated models to test: (1) our first null hypothesis (H_{01}: $mWTP^{LABGROWN} - mWTP^{CULTURED} = 0$) using pooled data from the Lab-grown and Cultured treatments; (2) our second null hypothesis (H_{02}: $mWTP^{ARTIFICIAL} - mWTP^{CULTURED} = 0$) using pooled data from the Artificial and Cultured treatments; (3) our third null hypothesis (H_{03}: $mWTP^{ARTIFICIAL} - mWTP^{LABGROWN} = 0$), using pooled data from Artificial and Lab-grown treatment. Table 3 reports the estimates of the main effects and the interaction between the production

TABLE 2 Estimated mWTP from the MLXLM models for the three treatments: Cultured, lab grown and Artificial

	Cultured ($N = 210$)		Lab Grown ($N = 208$)		Artificial ($N = 207$)	
Variables	**mWTP ($/lb) (SE)**	**SD**	**mWTP ($/lb) (SE)**	**SD**	**mWTP ($/lb) (SE)**	**SD**
Production method	−2.60*** (0.41)	5.72*** (0.45)	−8.69*** (0.80)	8.67*** (0.70)	−7.49*** (0.61)	6.94*** (0.52)
Carbon Trust label	1.19*** (0.26)	3.36*** (0.27)	1.05*** (0.35)	4.24*** (0.40)	0.52* (0.32)	4.27*** (0.41)
Antibiotics use	2.19*** (0.34)	3.35*** (0.24)	2.52*** (0.51)	4.47*** (0.48)	1.57*** (0.38)	3.73*** (0.34)
Price	−0.75*** (0.08)	0.81*** (0.08)	−1.14*** (0.08)	0.92*** (0.08)	−0.85*** (0.08)	0.78*** (0.08)
Opt-out	−7.08*** (0.28)	/	−7.67*** (0.37)	/	−6.71*** (0.29)	/
Model fit statistics						
N. obs.	7,560		7,488		7,452	
Wald chi^2	1385.13		776.93		928.09	
Prob > chi^2	0.00		0.00		0.00	
logL	−1933.67		−2001.94		−1883.65	
df	9		9		9	
AIC	3885.34		4021.88		3785.30	
BIC	3947.72		4084.17		3847.54	

Abbreviations: AIC, Akaike's information criterion; BIC, Bayesian information criterion; df, degree of freedom; logL, log likelihood function; mWTP, marginal willingness to pay; N. obs., number of observations; SD, standard deviation; SE, standard error; Wald chi^2, Wald test.

***, **, * significance, respectively, at 1%, 5%, 10% levels.

method, the Carbon Trust label, antibiotics use and the interaction parameters accounting for treatment effect (*dtreat*). From column 1, we observe that our first null hypothesis (H_{01}: $mWTP^{LABGROWN} - mWTP^{CULTURED} = 0$) is rejected, since the interaction effect between the production attribute and the treatment variable is statistically significant. Specifically, consumers' mWTP is significantly lower when the production method for IVM chicken products is termed 'lab-grown' rather than 'cultured' (–$4.82/lb). The statistically significant parameter of the 'Lab Grown' treatment interaction indicates that our second null hypothesis (H_{02}: $mWTP^{ARTIFICIAL} - mWTP^{CULTURED} = 0$) is also rejected. Specifically, the negative sign of the treatment parameter indicates that consumers' mWTP is significantly lower when IVM chicken products are termed 'artificial' rather than 'cultured' (–$4.03/lb). Finally, we reject our third null hypothesis (H_{03}: $mWTP^{ARTIFICIAL} - mWTP^{LABGROWN} = 0$) since the treatment parameter is statistically significant. Specifically, consumers' mWTP is significantly higher when the production method for IVM chicken products is termed 'artificial' rather than 'lab-grown' (+$2.19/lb).

4.2 | WTP estimates: Subsample analysis

The results from the estimation of the MIXLM models using Equation (1) in the WTP space for the subsample analysis of the three treatments are shown in Table 4 (see also Table F1, for

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TABLE 3 WTP hypothesis tests

Variables	Coefficient	H_{01}: ($WTP^{LABGROWN}$ – $WTP^{CULTURED}$) =0	H_{02}: ($WTP^{ARTIFICIAL}$ – $WTP^{CULTURED}$) =0	H_{03}: ($WTP^{ARTIFICIAL}$ – $WTP^{LABGROWN}$) =0
Opt-out	mWTP	−7.14***	−6.85***	−6.65***
	(SE)	(0.23)	(0.20)	(0.27)
Production method	mWTP	−2.57***	−2.22***	−9.19***
	(SE)	(0.42)	(0.34)	(0.60)
	SD	6.74***	6.14***	7.30***
	(SE)	(0.42)	(0.39)	(0.44)
Carbon Trust label	mWTP	1.08***	1.53***	1.50***
	(SE)	(0.31)	(0.33)	(0.35)
	SD	3.98***	3.73***	4.05***
	(SE)	(0.28)	(0.26)	(0.27)
Antibiotics use	mWTP	2.19***	2.76***	2.34***
	(SE)	(0.34)	(0.34)	(0.33)
	SD	4.09***	3.60***	4.12***
	(SE)	(0.28)	(0.21)	(0.28)
Price	mWTP	−0.89***	−0.80***	−1.01***
	(SE)	(0.06)	(0.05)	(0.06)
	SD	0.93***	0.81***	0.92***
	(SE)	(0.06)	(0.05)	(0.07)
Interactions with treatments				
Production method ×dtreatment	mWTP	−4.82***	−4.03***	2.19***
	(SE)	(0.85)	(0.64)	(0.65)
Carbon trust label ×dtreatment	mWTP	−0.21	−1.13**	0.31
	(SE)	(0.44)	(0.45)	(0.37)
Antibiotics use ×dtreatment	mWTP	0.03	−1.46***	−0.51
	(SE)	(0.45)	(0.44)	(0.55)
Model fit statistics				
N. obs.		15,048	15,012	14,940
Wald chi2		2672.44	2335.29	1599.61

(Continues)

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TABLE 3 (Continued)

Variables	Coefficient	H_{01}: $(WTP^{LABGROWN} - WTP^{CULTURED}) = 0$	H_{02}: $(WTP^{ARTIFICIAL} - WTP^{CULTURED}) = 0$	H_{03}: $(WTP^{ARTIFICIAL} - WTP^{LABGROWN}) = 0$
Prob >chi2		0.00	0.00	0.00
logL		−3950.52	−3824.08	−3905.23
Df		12	12	12
AIC		7925.03	7672.17	7834.46
BIC		8016.46	7763.56	7925.80

Abbreviations: AIC, Akaike's information criterion; BIC, Bayesian information criterion; df, degree of freedom; logL, log likelihood function; mWTP, marginal willingness to pay; N. obs., number of observations; SD: standard deviation; SE, standard error; Wald chi^2, Wald test.

***, **, * significance, respectively, at 1%, 5%, 10% levels.

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the model fit statistics). We performed the analysis in three steps. First, for each treatment, we identified subsamples based on the attitudinal factors described above (Section 2.2 see Table E2 in Appendix SE, for details on how the subsamples were created). For each subsample, we extracted the conditional individual mWTP (i.e., mWTPi) to check for significant differences across the subsamples within each treatment by using the non-parametric Mann Whiney U test (Mann & Whitney, 1947). Specifically, Table 4 reports the estimates of the production method[8] and the corresponding standard errors. The reported *p*-values are the results of the Mann Whiney U tests, which explain the statistical differences in terms of mWTP for the IVM attribute across the attitudinal subsamples.

Some interesting findings can be identified. First, we observe that consumers who have heard and who have not heard (H/NH) of the IVM term prior to the study have different mWTP depending on the IVM term. Specifically, in Treatment 1 'Cultured', consumers who have heard (H) the term 'cultured' have a higher mWTP than those who have not heard (NH) the term (+\$4.09/lb). Interestingly, there are no significant differences in mWTP between the two subsamples in Treatments 2 'Lab Grown', and 3 'Artificial'. Second, for the subsamples identified by pro-animal welfare attitude (AAS), we find that in Treatment 3 'Artificial', consumers who have a higher pro-animal welfare attitude (HAAS) have a lower mWTP (–\$4.73/lb) than those who have a lower pro-animal welfare attitude (LAAS). We find no significant differences, however, in mWTP for the IVM product across the two subsamples in Treatments 2 'Lab Grown', and 3 'Artificial'. Third, as for the subsamples related to the degree of neophobia toward the adoption of new food technologies (FTNS), the results indicate that consumers who have a lower degree of food technology neophobia (LFTNS) have a higher mWTP for cultured (+\$5.11/lb), lab-grown (+\$10.63/lb), and artificial (+\$6.11/lb) meat than consumers who have a higher degree of food technology neophobia (HFTNS). Fourth, the results suggest that there is no heterogeneity in results in all three treatments across those who have a higher versus a lower pro-environmental attitude (HNEP vs. LNEP). Fifth, as for religiosity (REL/NREL), we find that consumers who are not religious in 'Cultured' and 'Lab Grown' have a higher mWTP for cultured (+\$1.12/lb) and lab-grown (+\$2.03/lb) meat, respectively, than those who are religious. In addition, we find significant differences in terms of mWTP across the two subsamples in Treatment 3 'Artificial' but at the 0.10 level of significance. Finally, as for political preferences, the results suggest that moderate consumers tend to have a higher mWTP for artificial meat than conservatives (+\$1.46/lb) and liberals (+\$3.52/lb) and that conservatives have a higher mWTP for artificial meat than liberals (+\$2.06/lb).

Finally, for each subsample, we tested the hypothesis that the different terms associated with IVM significantly affect the mWTP estimates using Equation (2). Specifically, Table 5 (see also Table F2 in Appendix SF for the model fit statistics) reports the estimates of the production method parameters, the standard errors, and the corresponding significance (i.e., at 1%, 5%, 10% level *p*-value) of the *t* tests for the dummy variables. The findings reveal that in all the subsamples, the term 'cultured' is less rejected than the terms 'lab-grown' and 'artificial'. In addition, in some subsamples, such as hearing (H), religious (REL) and moderate (MOD), the term 'artificial' is less rejected than the term 'lab-grown' at the 5% level *p*-value.

[8]In Table 5, we included only the production method estimates because it is the only attribute that differs across the treatments and that we are interested to test. In addition, adding all the other estimates would have created an information overload. However, the complete results are available upon request.

TABLE 4 Estimated mWTP from MLXLM models for IVM from the subsample analyses

Attribute	**Cultured (*N* = 210) mWTP($/lb) (SE)**			**Lab Grown (*N* = 208) mWTP($/lb) (SE) H vs. NH**
	H (*N* = 65)	**NH (*N* = 145)**	***p*-value[a]**	**H (*N* = 84)**
Production method	0.28 (0.40)	−3.81*** (0.27)	0.00	−8.92*** (1.28)
	LAAS vs. HAAS			
	LAAS (*N* = 106)	**HAAS (*N* = 104)**		**LAAS (*N* = 90)**
Production method	−2.80*** (0.35)	−2.32*** (0.55)	0.39	−9.25*** (1.21)
	LFTNS vs. HFTNS			
	LFTNS (*N* = 114)	**HFTNS (*N* = 96)**		**LFTNS (*N* = 86)**
Production method	−0.50 (0.31)	−5.61*** (0.47)	0.00	−4.26*** (0.65)
	LNEP vs. HNEP			
	LNEP (*N* = 100)	**HNEP (*N* = 110)**		**LNEP (*N* = 112)**
Production method	−1.18** (0.44)	−3.82 (0.39)	0.06	−9.25*** (1.31)
	NREL vs. REL			
	NREL (*N* = 67)	**REL (*N* = 143)**		**NREL (*N* = 72)**
Production method	−1.68*** (0.26)	−2.80*** (0.41)	0.02	−8.08*** (1.15)

	LIB vs. MOD vs. CON								
Attribute	**LIB (*N* = 59)**	**MOD (*N* = 63)**	**CON (*N* = 73)**	***p*-value[a] LIB vs. MOD**	***p*-value[a] LIB vs. CON**	***p*-value[a] MOD vs. CON**	**LIB (*N* = 58)**	**MOD (*N* = 67)**	**CON (*N* = 68)**
Production method	−4.21*** (0.47)	−2.12*** (0.64)	−2.25*** (0.51)	0.74	0.90	0.97	−8.23*** (0.93)	−8.06*** (1.36)	−9.90*** (1.41)

Note: For the sake of brevity, we did not report the standard deviations.

Abbreviations: CON includes consumers who are extremely or slightly conservative; H includes consumers who have heard the terms 'cultured', 'lab-grown' and 'artificial' meat, respectively, for Cultured, Lab Grown, and Artificial, prior to the study; HAAS includes consumers who have a high pro-animal welfare attitude; HFTNS includes consumers who have high fears toward food products produced with novel food technologies; HNEP includes consumers who have a high pro-ecological worldview; LAAS includes consumers who have a low pro-animal welfare attitude; LFTNS includes consumers who have low fears toward food products produced with novel food technologies; LIB includes consumers who are extremely or slightly liberal; LNEP includes consumers who have a low pro-ecological worldview; MOD includes consumers who are moderate; mWTP: marginal willingness to pay; NH includes consumers who have not heard the terms 'cultured', 'lab-grown' and 'artificial' meat, respectively, for Cultured, Lab Grown, and Artificial, prior to the study; NREL includes consumers who do not follow religion; REL includes consumers who follow religion; SE: standard error.

[a]*p*-values were measured using the Kruskall-Wallis test.

5 | DISCUSSION

Our goal was to investigate the sensitivity of US consumers' evaluations of *in-vitro* meat (IVM) chicken products to different descriptive names (cultured, lab-grown or artificial). We found some interesting results. First, consumers value IVM chicken products less than

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		Artificial (*N*=207) mWTP($/lb) (SE)		
NH (*N* = 124)	***p*-value[a]**	**H (*N* = 101)**	**NH (N = *106*)**	***p*-value[a]**
−8.18*** (0.76)	0.20	−8.10*** (0.85)	−6.01*** (0.59)	0.81
HAAS (*N* = 118)		**LAAS (*N* = 108)**	**HAAS (*N* = 99)**	
−8.25*** (0.60)	0.89	−6.03*** (0.58)	−10.76*** (1.21)	0.00
HFTNS (*N* = 122)		**LFTNS (*N* = 82)**	**HFTNS (*N* = 125)**	
−14.89*** (1.47)	0.00	−3.30*** (0.45)	−9.41*** (1.39)	0.00
HNEP (*N* = 96)		**LNEP (*N* = 101)**	**HNEP (*N* = 106)**	
−8.24*** (0.96)	0.75	−6.80*** (1.12)	−6.88*** (0.95)	0.29
REL (*N* = 136)		**NREL (*N* = 78)**	**REL (*N* = 129)**	
−10.11*** (1.04)	0.02	−7.45*** (0.69)	−7.90*** (0.73)	0.08

***p*-value[a] LIB vs. MOD**	***p*-value[a] LIB vs. CON**	***p*-value[a] MOD vs. CON**	**LIB (*N* = 58)**	**MOD (*N* = 67)**	**CON (*N* = 65)**	***p*-value[a] LIB vs. MOD**	***p*-value[a] LIB vs. CON**	***p*-value[a] MOD vs. CON**
0.93	0.13	0.07	−8.29*** (1.36)	−4.77*** (0.38)	−6.23*** (0.83)	0.01	0.04	0.00

conventional chicken, confirming the results of Van Loo et al. (2020) for beef. Second, the name given to IVM can significantly affect consumers' mWTP values. Overall, the term 'cultured' gets the least negative mWTP valuation compared to the terms 'artificial' and 'lab-grown'. This finding is corroborated by Bryant and Barnett (2019), who found that the term 'lab-grown' meat was evaluated more negatively than the term 'cultured'. We speculate that the terms 'lab-grown' and 'artificial' have stronger negative connotations than the term

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TABLE 5 mWTP hypothesis tests from MLXLM models for the subsamples analysis

Attribute	Cultured vs. Lab Grown mWTP ($/lb) (SE)	Cultured vs. Artificial mWTP ($/lb) (SE)	Lab Grown vs. Artificial mWTP ($/lb) (SE)	Cultured vs. Lab Grown mWTP ($/lb) (SE)	Cultured vs. Artificial mWTP ($/lb) (SE)	Lab Grown vs. Artificial mWTP ($/lb) (SE)
	NH (*N* = 375)			**H (*N* = 250)**		
Production method	−4.72*** (0.97)	−3.95*** (0.56)	−3.95 (0.96)	−7.65*** (0.89)	−6.14*** (0.97)	2.07** (0.74)
	LAAS (*N* = 304)			**HAAS (*N* = 321)**		
Production method	−3.26*** (0.48)	−3.13*** (0.66)	−0.27 (0.76)	−5.98*** (0.79)	−6.15*** (1.14)	1.12 (1.22)
	LFTNS (*N* = 282)			**HFTNS (*N* = 343)**		
Production method	−2.43*** (0.68)	−4.04*** (0.64)	−0.24 (0.54)	−7.77*** (1.25)	−3.26*** (0.76)	−1.55* (0.82)
	LNEP (*N* = 313)			**HNEP (*N* = 312)**		
Production method	−5.01*** (0.65)	−5.30*** (0.95)	0.65 (1.50)	−5.38*** (0.63)	−5.85*** (0.57)	1.23* (0.65)
	NREL (*N* = 217)			**REL (*N* = 408)**		
Production method	−3.25*** (0.56)	−3.40*** (0.48)	−0.57 (1.22)	−4.71*** (0.84)	−4.50*** (0.66)	3.68*** (0.73)

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TABLE 5 (Continued)

Attribute	LIB (*N* = 175) Cultured vs. Lab Grown mWTP ($/lb) (SE)	Cultured vs. Artificial mWTP ($/lb) (SE)	Lab Grown vs. Artificial mWTP ($/lb) (SE)	MOD (*N* = 197) Cultured vs. Lab Grown mWTP ($/lb) (SE)	Cultured vs. Artificial mWTP ($/lb) (SE)	Lab Grown vs. Artificial mWTP ($/lb) (SE)	CON (*N* = 206) Cultured vs. Lab Grown mWTP ($/lb) (SE)	Cultured vs. Artificial mWTP ($/lb) (SE)	Lab Grown vs. Artificial mWTP ($/lb) (SE)
Production method	−2.77*** (0.63)	−4.73*** (0.54)	−1.45 (1.04)	−6.32*** (1.07)	−3.53*** (1.01)	1.50** (0.53)	−4.90*** (0.95)	−4.90*** (0.91)	−0.65 (1.13)

Note: For the sake of brevity, we did not report the standard deviations.

Abbreviations: CON includes consumers who are extremely or slightly conservative; H: includes consumers who have heard the terms 'cultured', 'lab-grown' and 'artificial' meat, respectively, for Cultured, Lab Grown and Artificial, prior to the study; HAAS includes consumers who have a high pro-animal welfare attitude; HFTNS includes consumers who have high fears toward food products produced with novel food technologies; HNEP includes consumers who have a high pro-ecological worldview; LAAS includes consumers who have a low pro-animal welfare attitude; LFTNS includes consumers who have low fears toward food products produced with novel food technologies; LIB includes consumers who are extremely or slightly liberal; LNEP includes consumers who have a low pro-ecological worldview; MOD includes consumers who are moderate; mWTP: marginal willingness to pay; NH: includes consumers who have not heard the terms 'cultured', 'lab-grown' and 'artificial' meat, respectively, for Cultured, Lab Grown and Artificial, prior to the study; NREL includes consumers who do not follow religion; REL includes consumers who follow religion; SE: standard error.

***, **, * significance at 1%, 5%, 10% level, respectively.

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‘cultured’ because consumers might perceive the former terms as less natural than ‘cultured’ due to perceptions related to human manipulation and intervention. Third, we found that consumers who have heard of the name ‘cultured’ meat prior to the study are willing to pay more for IVM than those who have not heard the term, whereas we found no significant differences in mWTP for the terms ‘lab-grown’ and ‘artificial’ in this respect. This finding corroborates our conjecture, based on the study of Bryant and Barnett (2019), that the term ‘cultured’ may evoke associations to science, which are not rated negatively. Fourth, we observe ambiguous findings about pro-animal welfare attitudes. Indeed, consumers who have a higher pro-animal welfare attitude have a lower mWTP than those who have a lower pro-animal welfare attitude only in the case of IVM termed as ‘artificial’. Fifth, in all the treatments, we found that consumers who have a high degree of neophobia toward the adoption of new food technologies have a lower mWTP for IVM than those who have lower food technology neophobia, which contrasts with Gómez-Luciano et al. (2019) for IVM. Sixth, in all treatments, we found that consumers’ pro-environmental attitude does not affect consumers’ mWTP for IVM, which contradicts previous consumer research pointing out that environmental benefits are one of the major perceived benefits of IVM (Bryant & Barnett, 2018; Weinrich et al., 2020), although other studies indicate that consumers negatively perceive IVM because it can be harmful to the environment (Gómez-Luciano et al., 2019; Specht et al., 2020). Seventh, we found that in all three treatments, consumers who are not religious have a higher mWTP for IVM. This finding could be explained by the fact that some consumers characterise IVM as ‘playing God’ (Marcu et al., 2014). Eighth, as for political preferences, we found ambiguous results. Indeed, political moderates tend to have a higher mWTP for artificial meat than conservatives and liberals and, in turn, conservatives have a higher mWTP for artificial meat than liberals. This finding is in contrast with previous research showing that liberal consumers tend to accept IVM more than conservative consumers (Bryant & Barnett, 2018; Wilks et al., 2019). Finally, we found that, consistent with the pooled samples, the term ‘cultured’ is less rejected than the terms ‘lab-grown’ and ‘artificial’ in all the subsamples, while only in some subsamples (i.e., hearing, religion and moderate), the term ‘artificial’ is less rejected than the term ‘lab-grown’.

6 | CONCLUSIONS

Our results give some insights into the growing controversy over whether IVM products should be labelled differently in the market. While plant-based foods that look like meat can now be bought in supermarkets, it could be just a matter of time before retailers stock their shelves with IVM, as illustrated by the recent approval in Singapore for the commercialisation of IVM chicken (Noyes, 2020). This obviously worries many conventional meat producers. Verbeke, (2015) found that consumers want regulations that would require IVM to be clearly labelled as such, whereas Van Loo et al. (2020) found that the majority of consumers prefer that the use of the label ‘beef’ should be prohibited for IVM. If consumers value IVM significantly differently than conventional meat, this indicates a need for labelling regulations to help consumers make more informed purchase decisions by allowing them to identify IVM specifically. Thus, it is of crucial importance to have an established regulatory framework controlled by authorities to ensure effective and standardised IVM labelling that consumers can trust and use to make more informed choices (Ong et al., 2020). Our results generally imply that consumers’ valuation of IVM is quite different (i.e., lower) from that of conventional meat, at least in the context of our choice experiment. This suggests that consumers will likely demand the right to know whether or not the product they are buying is produced *in vitro*. In other words, consumers will likely demand that IVM be labelled differently from conventional meat. At the same time, however, our results indicate

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that the term that consumers find on the package of IVM on the supermarket shelves could have a strong effect on consumers' acceptance or rejection of IVM. However, we should note that our sample size for our choice experiment is relatively small for an online study performed in a large country, such as the United States.

In terms of the future of the IVM market, the significantly lower valuations given by consumers to IVM compared to conventional meat could pose a non-trivial challenge for IVM producers given the higher production costs currently associated with IVM (Post, 2012). Our results suggest that different names for IVM could affect consumers' rejection of this food technology, and that consumers who are less neophobic toward new food technologies and are not religious could be the initial consumer segments to target for IVM.

Although this study represents a first investigation of how consumers value IVM descriptions in terms of their marginal willingness to pay, more research is needed to definitively answer questions about the market potential of IVM. Moreover, given lobbying efforts from the meat industry to persuade the government to enact policies that would disallow the naming of IVM as 'meat', future studies should investigate how such policies would influence consumers' valuation of IVM products. Finally, it would also be interesting to test the robustness of our results for other types of meat (i.e., beef, pork, lamb) and in other countries, given the expected increase in meat demand in many parts of the world.

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