There is market potential for circular farming food in Europe due to consumers’ willingness to purchase and pay a premium for circular-labeled food

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Abstract

Circular farming, as a sustainable agricultural system, contributes to the reuse of waste and optimizes the recovery of nutrients (C, N, P). By circular farming we refer to farming activities that focus on using minimal amounts of external inputs, closing nutrient loops, and minimizing environmental impacts. Here we employed open-ended choice experiments (OECEs) to analyze consumers’ willingness to pay (WTP) and demand for food products obtained from circular farming with a questionnaire involving 5,591 participants from 6 EU countries. We chose three product categories: pork, milk, and bread. We found that a market niche existed for the food products produced from circular farming, with consumers exhibiting a willingness to pay a premium for circular products compared to conventional products. Spanish consumers displayed the highest WTP premium (>26%), whereas Hungarian consumers exhibited the lowest in all categories. Socio-demographic characteristics, environmental attitudes, and price levels influenced the quantity of circular products consumers are willing to purchase.

Introduction

Current intensive agricultural systems not only provide feed and food, but also make a major contribution to greenhouse gas emissions. The expansion of the intensive production related to animal husbandry has, directly and indirectly, led to air and water pollution and, in the long run, is a major threat to the environment. Furthermore, conventional agriculture is largely based on a linear economy model (an open-loop system) of “take-make-dispose”, i.e., taking resources from nature, making them into goods, and disposing of goods that humans do not need. This model is based on the intensive consumption of natural resources, which damages agroecosystems and the environment and is turning out to be environmentally unsustainable. In addition, the world population is expected to reach 9.7 billion in 2050, when agriculture will be under enormous pressure. Therefore, to alleviate the pressure arising from future population growth, it is important to improve soil quality, reduce greenhouse gas emissions, and increase agricultural sustainability and future output capacity. In this context, the emergence of the circular economy concept (a closed-loop system) and the application of resulting pattern of agriculture is essential in order to reduce the negative impact of conventional agricultural systems. The circular economy model helps to achieve sustainability by preventing environmental degradation and ensuring the economic and social well-being of present and future generations. Kirchherr et al. collected 114 definitions of the circular economy concept, and concluded that “the circular economy is a system that replaces the concept of ‘end-of-life’ with reduction, alternative reuse, recycling, and recovery of materials in production, distribution, and consumption, which is enabled by new business models and responsible consumers”. The central idea of agriculture is to promote the recycling of agricultural resources. Notably, in the case of circular agriculture, it is more important to use resources effectively than just to recycle them.

In order to achieve efficient use of agricultural resources and ensure sustainable agricultural development, the European Union (EU) is pushing for a zero-waste economy by 2030 in terms of reusing
agricultural waste and achieving sustainable development. The European Commission promoted an
initiative entitled the Green Deal in December 2019 to accelerate the transition to a circular economy for a
cleaner and more competitive Europe. In addition, academic research on circular agriculture has
gradually increased in recent years. Many studies have focused on the development strategy of circular
agriculture, technical tools, or have investigated farmers’ perceptions and attitudes from a
producer’s perspective. For example, Atinkut et al. explored farmers’ willingness to pay (WTP) for a
circular agriculture model under the “polluter pays” principle in central China, and found that education,
infrastructure, trust in family/neighbors, and environmental attitudes had a significant effect on WTP.
Egan et al. investigated 1,225 farmers in seven Northwest European countries about their perceptions
and preferences regarding the properties and parameters for recycling-derived fertilizers (RDFs). They
found that the most desirable properties were common across the participating countries, including
known nutrition, high organic content, product cost, and ease of use of RDFs. In addition, income,
sustainable recycling behavior, environmental perceptions, perceived usefulness-simplicity, and trust in
government positively influenced farmers’ WTP. Danso et al. applied a choice experiment to assess
African farmers’ WTP for manure sludge and municipal solid waste-based (FSM) compost products, and
concluded that product price and quality, gender, experience, and household size could influence the WTP
for recycled compost. However, few researchers have analyzed WTP and demand with regard to food
produced by circular agriculture from the consumers’ perspective. Suárez-Cáceres et al. examined
consumers’ WTP for aquaponic products in Spain and Latin America, and realized that consumers’
income, environmental concerns, and knowledge of aquaponics affect their willingness to pay higher
prices for aquaponics products; 60.5% of participants were willing to pay a higher price for such products.
Nevertheless, evidence on consumers’ WTP for other circular agricultural products is sparse. Moreover,
the role of consumers is essential in the transition to a circular economy in making sustainable
choices. Furthermore, it is vital for governments to introduce related policies, and for producers and
marketers to understand consumers’ WTP for food products produced from a circular system which
promotes sustainable agriculture. In this context, to fill this gap, we measured consumers’ WTP and
demand at a European level by using an open-ended choice experiment, an approach which proved to be
both new and useful. A large sample of consumers from six EU countries was collected, and three food
categories in the form of three case studies, i.e., pork from pig production, milk from cattle production,
and bread from cereal production, were considered. In conclusion, using open-ended choice experiments,
here we attempted to examine consumers’ WTP and demand in six EU countries with regard to three
types of food products produced by circular agriculture.

Results
Aggregated and average demand for circular food products

The socio-demographic characteristics of the samples are displayed in the Supplementary Information.
We summed individual demand at each price level for these three products from three farming systems,
and aggregated total quantities (Supplementary Tables 4 to 6). The demand curves for circular products
are plotted based on this result, and are displayed in Fig. 1. The results showed that the demand for the three circular products, both total and average, decreased with the increase in price in all six EU countries. This was consistent with the “law of demand”.

**Consumers’ environmental attitudes**

We analyzed consumers’ environmental attitudes by employing Principal Component Analysis (PCA) as presented in the Methods section. The details of the PCA results are displayed in the Supplementary Information. Figure 2a illustrates the distribution of consumers in each country in both dimensions. We found that consumers in the second and fourth quadrants had a clear environmental attitude: consumers in the second quadrant (-ecocentric, +anthropocentric) had an anthropocentric attitude. They agreed more with anthropocentric statements and less with ecocentric statements; consumers in the fourth quadrant (+ecocentric, -anthropocentric) had an ecocentric attitude. They agreed less with statements related to anthropocentric attitudes and more with ecocentric statements. However, the environmental attitudes of consumers in the first and third quadrants were less clear and undetermined. Consumers in the first quadrant (+ecocentric, +anthropocentric) agreed with both attitude-related statements, while those in the third quadrant (-ecocentric, -anthropocentric) disagreed with both attitude-related statements. However, although respondents in these two quadrants had non-explicit environmental attitudes, their results were not exactly equal across the two potential factors, meaning that one of the two attitudes was more pronounced than the other. Our results showed that the respondents from Italy, Hungary, and Croatia were more concentrated in the fourth quadrant, highlighting their ecocentric attitudes, which meant that these consumers displayed pro-environmental behaviors and recognized the value of nature in itself and not only as a means of producing a good to satisfy their needs. They displayed an environmentally-collaborative consumption behavior. However, consumers in Spain, Poland, and Belgium were more dispersed, with slightly more in the second quadrant, indicating that they hold anthropocentric attitudes. That is, they regarded humans as the most important component of life, and reflected an attitude related to carrying out actions that satisfy needs and achieve human well-being above everything else, and their consumption behavior was not focused on the environment.

Our results suggested that an anthropocentric attitude was more pronounced in Spain, Poland, and Belgium with 54.48%, 54.62%, and 56.01%, respectively (Fig. 2b). However, in Italy, Hungary, and Croatia, the proportion of ecocentric attitudes was higher than that of anthropocentric attitudes with 51.52%, 50.91%, and 53.16%, respectively. From an overall perspective, 52.18% of the respondents exhibited an anthropocentric attitude, and 47.82% of them displayed an ecocentric attitude.

**WTP for circular food products**

Fig. 3 shows consumers’ median maximum WTP (in monetary and percentage terms) for circular food products in six EU countries. Supplementary Tables 7 to 9 display the summary statistics of the demand for quantities of circular sliced pork, milk, and sliced bread demanded in six EU countries. These are the
basis for Figures 3a, c, and e. Fig. 3a suggests that the median maximum price that participants were willing to pay for a unit of circular pork (500g) was €6.50 in Spain, €3.73 in Poland, €5.80 in Italy, €3.72 in Hungary, €4.95 in Croatia, and €7.50 in Belgium. In the case of circular milk (Fig. 3c), the median maximum price consumers were willing to pay for a liter of circular milk was €0.95 in Spain, €0.67 in Poland, €0.86 in Italy, €0.90 in Croatia, and €1.05 in Belgium. As for circular bread (Fig. 3e), the median maximum WTP of consumers for a pack of circular bread (450g) was €1.50 in Spain, €1.70 in Poland, €1.15 in Italy, €1.06 in Hungary, €1.29 in Croatia, and €1.65 in Belgium.

In terms of the maximum WTP premium (median) in percentage terms compared to the price of a conventional pork loin of the same size (Fig. 3b), consumers in Spain had the highest WTP premium (in percentage terms) with 44.44% for 500 grams of circular pork loin, followed by Italy with 38.10%, Poland with 30.88%, Croatia with 23.13%, and Belgium with 15.38%, while consumers in Hungary showed the lowest with 12.05%. The maximum WTP of respondents in Spain for 1 liter of circular milk was the highest with 26.67%, followed by Poland with 24.07%, Croatia with 21.62%, Italy with 19.05%, and Belgium with 10.53%, while Hungarian consumers were willing to pay a premium percentage of 0%, i.e., the WTP for circular milk was equal to the price of conventional milk (Fig. 3d). In addition, the maximum WTP premium of participants in Spain for circular bread was the highest with 36.36%, followed by Poland with 24.09%, Italy with 21.05%, and Belgium with 6.45%. Respondents in Hungary and Croatia had the lowest with 0% (Fig. 3f). Regarding these three products, Spanish consumers displayed the highest WTP premium (in percentage terms), whereas Hungarian consumers exhibited the lowest. In addition, the WTP premiums of consumers in Spain and Italy were higher than those in Belgium.

Factors affecting the demand for the circular products

Supplementary Tables 10 to 15 present the results of the Negative Binomial (NB) regression for all countries, and Fig. 4 summarizes the results for the three circular products in all countries. Our results revealed that age, employment status, income availability to cover monthly expenditure, environmental attitude, and price of circular products were key factors related to quantity demanded of the circular products considered in this study in all six countries. Specifically, in all countries, younger consumers expressed a willingness to purchase more circular products than older people. Employment status was associated with quantities desired of circular products. As expected, respondents whose monthly income rarely and never covered their household expenditure expressed a willingness to purchase a lower number of circular products when compared to those whose income always covered expenditure. Consistent with expectations, the price of circular products was negatively associated with the number of circular products purchased.

In contrast to the consistent findings of the six countries mentioned above, there were some mixed results across these countries. For example, ecocentric consumers expressed a willingness to purchase a greater number of circular products in Spain, Hungary, and Belgium. Nevertheless, in Poland, Italy, and Croatia,
ecocentric consumers expressed a willingness to purchase a lower number. Results from Supplementary Table 16 reveal that ecocentric consumers had a positive correlation with vegetarian, vegan, and flexitarian, and a negative correlation with non-restricted diets in all countries. Ecocentric consumers perceived vegetarianism, veganism and flexitarianism to be more environmentally sustainable, while those on non-restricted diets were perceived as less sustainable. Supplementary Table 16 also shows that there was a positive correlation between ecocentric consumers and organic, circular farming and a negative correlation with conventional farming in five countries, while in Italy it was found that there was a negative correlation between ecocentric attitudes and circular farming.

Somewhat surprisingly, our results revealed that males tended to report a willingness to purchase more circular products than females in five countries (except Croatia). As expected, people with a high level of education expressed a willingness to purchase more circular products than those with a low level of education (except Poland). The stated financial situation was found to influence the quantities of purchases (except Italy). Participants who stated that they were in a good financial situation expressed a willingness to purchase higher quantities of circular products than those who stated that they were in a difficult financial situation in Spain, Poland, Hungary, and Croatia. Nevertheless, consumers who stated that they were in a good financial situation expressed a willingness to purchase lower quantities in Belgium.

**Discussion**

In general, circular agriculture production has higher costs than conventional agriculture; therefore, it is interesting and informative to compare it with the premium of WTP for circular food to see if it pays off. We found that for circular pork loin, consumers in EU countries were willing to pay an average premium of 27.33% ((44.44+30.88+38.10+12.05+23.13+15.38)/6); for circular milk, they were willing to pay an average premium of 16.99%; and for circular bread, on average they were willing to pay a premium of 14.66%. Consequently, it would be valuable to further investigate the cost of inputting these three types of circular production in terms of how much higher it would be than the cost of conventional agricultural production. In addition, the largest portion of consumer prices is defined by retail and gross-sales margins (and those of other intermediaries, such as slaughterhouses). The margin of the farmer in this is extremely slim. In fact, if the premium profit for added-value products (e.g., organic or circular) could be fully passed to the farmer, then price increases for such products could be kept to a minimum and their effects on farmers (and the environment) would be maximized. That is, it would enable the farmer to obtain the majority of the profit from the premium portion of the price in the context of ensuring the cost of circular production.

There was market potential for circular farming food in Europe as consumers expressed a willingness to purchase and pay a premium for food products with circular labels. Among these three products, Spanish consumers showed the highest WTP premium (in percentage terms), whereas Hungarian consumers exhibited the lowest. In addition, the WTP premiums of consumers in Spain and Italy were higher than those in Belgium. This may be because consumers in Spain and Italy were more likely to state they paid
attention to the environmental impact of their food choices when compared to those in Belgium. A higher premium on the relative WTP in Spain compared to Belgium could also be due to the higher average cost of food items in Belgium compared to Spain. In other words, pork loin, milk, and bread were already expensive in Belgium compared to Spain, and people were less likely to be willing to pay more.

Our results indicated that younger consumers expressed a willingness to purchase more circular products than older people. This supported the findings of numerous studies indicating that young consumers tended to purchase more sustainable food products. Younger consumers are more sensitive and concerned about issues related to sustainable development than older consumers, and they are increasingly interested in more sustainable behavior, such as buying green products. In addition, the younger generation has acquired relevant environment-related knowledge through environmental education and is inclined to adopt practices that respect the natural environment. As expected, respondents whose monthly income rarely and never covered their household expenditure expressed a willingness to purchase fewer circular products when compared to those whose income always covered expenditure. Likewise, previous research has showed that disposable income plays a major role in the quantity of organic products purchased. The stated financial situation was found to influence the quantities of potential purchases (except Italy). Participants in Spain, Poland, Hungary, and Croatia who stated that they were in a good financial situation expressed a willingness to purchase greater quantities of circular products than those who stated that they were in a difficult financial situation. Similarly, this finding tied in with the idea that consumers with a higher income might purchase more sustainable foods. Nevertheless, the results also revealed that consumers who stated that they were in a good financial situation expressed a willingness to purchase lower quantities in Belgium, which was different from our expectations. It may be related to the fact that some consumers in Belgium did not properly assess and state their financial situation. As expected, the price of circular products was negatively associated with the number of circular products purchased, demonstrating that the higher the price, the lower the demand, which was in line with demand theory. This also supported the findings of many other scholars.

We found that ecocentric consumers tended to express a willingness to purchase more circular products in Spain, Hungary, and Belgium. This result may be because individuals with an ecocentric attitude are more likely to wish to protect the environment based on their values compared with those with an anthropocentric attitude. Nevertheless, ecocentric consumers expressed a willingness to purchase less in Poland, Italy, and Croatia. These results may be driven by different forces. Firstly, there is the attitude-behavior gap. Ecocentric consumers always have pro-environmental attitudes; however, there is a gap between favorable attitudes and actual purchase of sustainable food products, i.e., an attitude-behavior gap. Secondly, some ecocentric people perceived that sustainability can be achieved through measures other than through food innovation. It could also be related to the fact that they had a greater understanding of environmental sustainability and therefore believed that sustainability could be achieved in other ways, which is supported by Supplementary Table 16. Policymakers and authorities in Poland, Italy, and Croatia could emphasize the ecological contribution of circular products among
ecocentric consumers and increase their knowledge of circular food products through activities such as education and training. This is important as previous research has shown a positive correlation between consumers’ sustainable behavior and sustainability education and knowledge 33.

Somewhat surprisingly, our results revealed that males expressed a willingness to purchase more circular products than females in most countries (except Croatia), contrary to many studies’ conclusions which indicated that women were more likely to buy eco-products 34,35. However, this result was similar to those of the study by Castro & Chambers 36, who estimated consumers’ willingness to eat an insect-based product in thirteen countries and found that in most countries, men were more willing to try new sustainable products than women. Similarly, Verbeke 37 concluded that men were two times more likely than women to adopt insects (new sustainable foods) as a meat substitute. This reflected that men were more open to new eco-foods and had more positive attitudes. This result may also be a reflection of changing roles in modern society, with more men taking on the responsibility for purchasing food 38. In addition, several studies have pointed out that men were more aware and concerned about environmental issues and had a more positive attitude towards sustainable purchasing than women 39.

Overall, this study identified new purchasing segments for circular food products in the European market: 1) young consumers; 2) men; 3) higher-income consumers; 4) consumers with higher levels of education; and 5) business owners and employees. Retailers could target young consumers, men, business owners, and employees in particular when promoting food products with circular labels in supermarkets (or other marketplaces). EU food policymakers and authorities could promote circular food products among higher-income groups and better-educated groups or communities, to make them aware of the availability of circular food products in the marketplace.

Encouraging more visible displays of circular food products in supermarkets (or other marketplaces) and spreading knowledge about circular foods may increase consumers’ likelihood with regard to trying these food products. In addition, this study recommends that the European Commission should take into account three decades of technological progress and innovation, and address the inflexible and anachronistic requirements and definitions of the Nitrates Directive (91/676/EEC) to allow the refining of manure into fertilizer products as an alternative to chemical fertilizers. This is essential as it could encourage and facilitate the transition from “waste” to “organic fertilizer”, contributing to the achievement of circular agriculture. It is necessary for EU policymakers and authorities to differentiate food products from circular production by allowing food policies to define what is circular, as is done in organic farming.

Methods

Selection of food products

We measured three food categories, in the form of three case studies, i.e., pork from pig production, milk from cattle production, and bread from cereal production. One of the reasons we selected these particular food products was the relative importance of each of the sectors involved within the EU from a
production point of view. The 142 million pigs reared across the EU are the largest livestock category before cattle (76 million), and the EU pork sector alone accounts for nearly half of the EU's total meat production. In addition, the EU is the world's second-biggest producer of pork after China and the biggest exporter of pork and pork products. The dairy sector is the second-largest agricultural sector in the EU, accounting for over 12% of total agricultural output. The harvested production of cereals (including rice) across the EU was 299.4 million tons in 2019, with 119.1 million tons of common wheat and spelt, equivalent to 44% of all cereal harvests. Another reason for selecting these three products was that they were well-known and frequently purchased by participants, which reduced the novelty bias when making choices in the contingency market. In addition, these sectors have high levels of emissions; thus, it is interesting and valuable to focus on them.

Definition of food produced by circular agriculture in our case study

In agriculture, carbon, nitrogen, phosphorus, and potassium are essential to maintain fertile and healthy soils, and to allow plants to grow and develop to their full potential. However, in our current system, soils are being depleted of carbon and losing valuable nutrients, leading to pollution of our rivers and air, and contributing to greenhouse gas emissions. This is because of the inefficient use of nutrients in our systems. More than half of the nitrogen and phosphorus entering our agricultural systems comes from non-renewable sources, yet only one out of every five tons of nitrogen entering the EU agri-food chain is actually converted into food for human consumption; the situation is similar in the case of phosphorus and potassium. In addition, poor soil management practices have led to carbon loss from the soil, worsening the situation. Our project aimed at closing C-N-P loops by reconnecting nutrient and carbon flows between conventional agro-pillars (three pillars: agro-processing, animal husbandry, and plant processing) through agro-processing. In addition, understanding consumers' WTP and demand is essential when it comes to incorporating these innovations.

Circular production in the pig industry as studied in our research refers to the treatment of pig slurry and manure to produce bioenergy (biogas) and bio-based fertilizer using a combination of technologies. In the case of circular cattle farming, dairy farms use wastewater to produce algae as a new source of protein (animal feed), and residues from the food industry (dairies and dairy plants) are used to produce fertilizer and build soil fertility. The microalgae biomass used for animal feed not only improves food security for humans and animals, but also reduces greenhouse gases produced by agriculture. In the case of circular bread, grains for flour are grown using an integrated crop management system that uses low carbon footprint techniques such as no-till, crop rotation, and cover crops to increase soil fertility and organic matter content, and fertilizes the crop with recycled bio-based fertilizer.

Design of the open-ended choice experiment (OECE)
The WTP estimates represent the price premium or the maximum amount that a current or potential consumer is willing to pay for a product or good. The use of open-ended choice experiments (OECEs), as an approach to measure WTP, combine the advantages of experimental auctions (EA) and discrete choice experiments (DCE). Respondents are presented with multiple products sold at different prices (as in DCE) and asked to indicate the number of products they would be willing to purchase at different price combinations; thus, their responses are open-ended (as in EA), which could simulate a realistic scenario of consumer purchases. Therefore, OECE has been employed by some scholars in food-related research. The major difference between the OECE and DCE is that in the latter, participants are asked to choose only the product they prefer, whereas in OECEs participants select both product and quantity. Since respondents can purchase any non-negative quantity at different price levels, researchers are able to estimate not only the respondents' WTP for a unit of the product, but also the participants' entire demand curve.

We designed three OECEs for pork loin, milk, and bread. In addition to circular food products, organic and conventional products (substitutes and competitive agricultural systems) were also introduced, since previous studies have suggested that novel products should be evaluated in the context of substitute and competitive commodities that consumers can purchase in the market, which could simulate the real market to reduce hypothesis bias. There was a common text across these three products, and in the case of circular agriculture, we introduced three innovations. There were five purchase situations in each case, and in each purchase situation, these products were presented at different prices. However, in all purchase situations, the price level of organic and conventional products was fixed (average local market price), while the price of products from circular farming varied across purchase situations. Price levels and product size were identified after a deep review and comparison with similar products at the market level in each country. The price vectors were presented in Supplementary Table 1. For example, in Spain, participants were offered an array of potentially binding prices for 500g packages of pork loin (ranging from €2.50 to €6.50 in €1.00 increments) and conventional and organic pork loin would always be available at the €4.50 and €10.50 field prices, respectively. All respondents were presented with this information and the definitions of different farming systems (see Extended Data Fig. 1) and were asked to indicate how many products they would purchase in each purchase situation. If they were not interested in these products, they could indicate a “zero” quantity (no purchase). In the case of the circular farming systems, because the products analyzed were not available in market place compared with conventional and organic, the price levels were identified to be set close to the average price level of conventional products (which are the products to be compared with) by including some variation downwards and upwards. As a result, the identified price vector for products from circular farming was considered to be relatively closer to the average price of the conventional alternative in the real market place. The prices were in the local currency of each country when collecting the data, and the currencies of Poland, Hungary, and Croatia were converted into Euros when analyzing the data. An example of sliced pork loin in the OECE is displayed in Extended Data Fig. 1. Examples of milk and bread are presented in Supplementary Figures 1 and 2.
Questionnaire design and data collection

To measure consumers’ WTP and demand with regard to circular pork loin, bread, and milk, we developed a semi-structured questionnaire. The questionnaire consisted of four parts: 1) open-ended choice experiments (OECEs); 2) consumers’ environmental attitudes; 3) opinions on the sustainability of different production systems and dietary patterns; and 4) socio-demographic information, including gender, age, employment status, education, and income status. The full questionnaire is available in the Supplementary Information.

The original questionnaire was in English, and it was translated into the local language, and back-translated into English. The study was conducted in six EU countries: Spain, Italy, Belgium, Poland, Croatia, and Hungary (Supplementary Figure 3). A pilot survey was conducted in each country using a sample of 50 consumers to identify potentially confusing points allowing the researchers to modify it and check for consistency before the formal distribution of the questionnaire. Finally, a total of 5,591 respondents participated in the survey in these six EU countries. Excluding invalid questionnaires (e.g., participants who selected the same option for almost every question or those whose response time was too short), the remaining 5,289 valid questionnaires were used for analysis. The total number of consumers surveyed was stratified by gender and age according to the demographic characteristics of each of the six countries. The data from all countries were collected from June 2021 to January 2022 through the Qualtrics’ consumer panel and Netpanel Marketing in Hungary. The respondents participated in this survey voluntarily and anonymously. Participants were provided with written informed consent at the beginning of the questionnaire, which described the main content and purpose of the survey, their right to withdraw from the survey at any time, and that their privacy would be protected (for more details, please see the full questionnaire in the Supplementary Information). The questionnaire was authorized by the Ethics Committee of our university and was conducted following the ethical norms of social science research. The selection criteria were respondents who were at least 18 years old and food purchase decision-makers in their households.

Measuring consumers’ WTP and factors affecting demand for food products from circular farming

Measuring consumers’ environmental attitude: the NEP scale

Attitude can be regarded as a psychological tendency expressed through a certain degree of favor or disfavor towards a particular entity. Environmental attitudes were defined as “evaluative beliefs, affect, and/or behavioral intentions about environmentally related activities or issues.” Many studies have identified environmental attitudes as a crucial antecedent that influences environmental behavior; therefore, in this research we used consumers’ environmental attitude to explore consumers’ sustainable behavior and food choices. Most studies measured environmental attitudes using scales such as the
Environmental Concerns (EC) scale, the Value Orientations scale, and the New Ecological Paradigm (NEP) scale. The NEP scale is becoming increasingly popular and has been widely used.

We employed a reduced version of the original NEP scale to measure consumers’ attitudes towards the environment, including only the statements relating to ecocentric and anthropocentric attitudes. It consisted of 8 statements expressing positive (4 statements) and negative (4 statements) attitudes and evaluations of the environment, which analyzed relationships between subjects’ beliefs about humans and nature. The respondents were asked about their environmental attitude via a 9-point Likert scale (from 1=disagree very strongly to 9=agree very strongly; 5=neutral) (Q: How much do you agree or disagree with the following statements?).

We applied Principal Component Analysis (PCA) to analyze environmental attitudes. The 8 specific items on the reduced NEP scale enabled the identification of latent dimensions related to consumers’ behavior towards the environment. Ecocentric consumers and anthropocentric consumers were identified in this way, which was consistent with Torres et al. The first component was identified as the ecocentric attitude, which was mainly defined by the statements from items 5 to 8, i.e., “Item 5. Plants and animals have as much right to exist as humans”; “Item 6. The balance of nature is very delicate and easily alterable”; “Item 7. If things continue as they are, we will soon face a major ecological catastrophe”, and “Item 8. Despite our special abilities, humans are still dependent on the laws of nature”. This first component (ecocentric) reflected a pro-environmental attitude. Ecocentric attitudes were nature-centered; they indicated a belief that non-human nature had intrinsic value, that humans were one of the components of the whole natural system, and that humans should obey the laws of nature. They sought to strike a balance between human beings and natural ecosystems. The second component was the anthropocentric attitude, which was reflected in the statements from items 1 to 4, i.e., “Item 1. The balance of nature is strong enough to deal with the impact caused by economic development”; “Item 2. Over time, humans can learn how nature works to be able to control it”; “Item 3. Human ingenuity will ensure that we do not make the earth an uninhabitable place”, and “Item 4. Humans have the right to modify the environment to adapt it to their needs”. Anthropocentric attitudes were human-centered; they indicated a belief that humans were the most important entity on earth and that humans could transform nature to suit their needs. The Kaiser-Meyer-Olkin (KMO) test and Bartlett’s test were performed before conducting the PCA.

Consumers’ socio-demographic factors and food-related characteristics

A large number of studies have shown that consumers’ socio-demographic variables (e.g., gender, age, income, employment status, and education level) play a key role in consumers’ sustainable behavior towards food products. For example, Li & Kallas undertook a meta-analysis of 80 papers to measure consumers’ WTP for sustainable food products, and found that females exhibited a higher WTP than males. In addition, females and young consumers exhibited a higher intensity (the frequency or quantity
of organic food consumed) of organic food consumption \textsuperscript{20,21}. However, some studies have suggested that older people display more sustainable consumption behavior than young adults. This may be because when young adults buy food, they prefer cheap and tasty takeaways without really considering the production line \textsuperscript{65}. Some studies have found that monthly income positively affected the WTP of organic food \textsuperscript{66}, while others have shown that income mostly influenced the quantities of organic products purchased, rather than their WTP \textsuperscript{28}. In contrast, previous research has indicated that age, gender, and income do not significantly affect sustainable consumption behavior \textsuperscript{67}.

Another factor that has been commonly studied is the level of education. Past studies suggested that consumers with a higher level of education bought a greater quantity of organic food \textsuperscript{68}. It was also a matter of affordability in the frame of income, and not only a reflection of whether they were less educated (which could be interpreted as less informed or less knowledgeable). Moreover, education level and employment status (employed) positively influenced the likelihood of buying organic food \textsuperscript{21}. In addition, empirical studies have provided substantial evidence on the influence of food-related factors on consumer purchase decisions. For instance, numerous papers have demonstrated that price is a crucial factor influencing consumers' behavior towards sustainable food products \textsuperscript{69,70}.

Based on the existing literature, we included consumers’ socio-demographic variables (gender, age, income status, education level, and employment status), environmental attitudes, and the prices of circular, organic, and conventional food products in the questionnaire to explore how they affect consumers’ sustainable behavior. Regarding income status, we introduced two questions. Firstly, respondents were asked to state their perceptions regarding their current financial situation using a 10-point Likert scale (from 1=very difficult to 10=very good). Secondly, they were asked to state their opinions about the frequency with which their monthly income could cover their household expenditure (1=always; 2=very often; 3=sometimes; 4=rarely; and 5=never).

Data Analysis

In our study, Principal Component Analysis (PCA) was employed to analyze the environmental attitude variable. Descriptive analysis was also adopted. Demand analysis and WTP analysis were conducted. Individual demand at each price level for sliced pork loin, milk, and sliced bread was summed, and the aggregated quantities were presented. The market demand curve for each product was the horizontal sum of the individual demand curves \textsuperscript{71}. Due to the count nature of the quantity demanded, Poisson regression, Negative Binomial (NB) regression, Zero-inflated Negative Binomial regression (ZINB), Zero Inflated Poisson (ZIP), or Double-hurdle model could be employed \textsuperscript{53}. In our study, the variance and mean of the dependent variables (the quantity desired) were different, and there was overdispersion; therefore, negative binomial (NB) regression was more flexible and appropriate than Poisson regression. The traditional NB regression model was based on a Poisson-gamma mixture distribution \textsuperscript{72}. We used STATA 17.0 software to conduct NB regression. In the models, the dependent variables were the quantity desired.
for three circular products in each country. The independent variables were gender, age, education level, employment status, income covers expenditure, stated financial situation, environmental attitude (using the NEP scale), and price (price of circular, conventional, and organic products).

**Calculation of willingness to pay (WTP) for circular products**

We obtained the summary statistics for individual quantities of circular sliced pork, milk, and sliced bread demanded in six countries. The consumer's maximum WTP was measured, and it was estimated as the highest price at which they indicated a positive quantity of the products. In addition, the following formula was used.

\[
WTP\% = \frac{WTP_{\text{sustainable}} - P_{\text{conventional}}}{P_{\text{conventional}}} \times 100\%
\]

where \(WTP_{\text{sustainable}}\) referred to the maximum WTP of circular food products in our study, and \(P_{\text{conventional}}\) denoted the price of conventional food products. This formula calculated the premium (in percentage terms) that respondents were willing to pay for circular food (over conventional food), allowing for tackling currency differences.

**References**


**Figures**
Figure 1

Observed aggregate and average demand for circular food products in six countries. a, b, c, Aggregated total quantity of circular food products. d, e, f, Average quantity of circular food products. It was calculated in terms of the total quantity divided by the sample size of each country.
Figure 2

Consumers’ environmental attitudes in each country. a, Distribution of consumers in ecocentric and anthropocentric dimensions in each country. b, Proportion of ecocentric and anthropocentric environmental attitudes in each country and overall.
Figure 3

Consumers’ median maximum WTP (in monetary and percentage terms) for circular food products in six EU countries. **a, c, e**, Respondents’ median maximum WTP (€). They are based on the results in Supplementary Tables 7 to 9. As described in the Methods section, it is estimated as the maximum price for which they indicate a positive product quantity. **b, d, f**, WTP premium in percentage terms (over
conventional products). They are based on the Formula 1 mentioned in the Methods section. The size of the circle in our figures represents the size of the WTP. The larger the circle, the higher the WTP value.

<table>
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**Figure 4**

**Summary of Negative Binomial (NB) results of three circular food products in all countries.** The y-axis represents the significant factors influencing consumers’ demand, and the x-axis represents the quantity of circular products that consumers in each country are willing to buy. “+” implies a positive relationship between the factors and quantities, while “-” denotes a negative relationship.

**Supplementary Files**

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryInformation.docx
- ExtendedDataFig.1.docx