TRansition paths to sUstainable legume-based systems in Europe

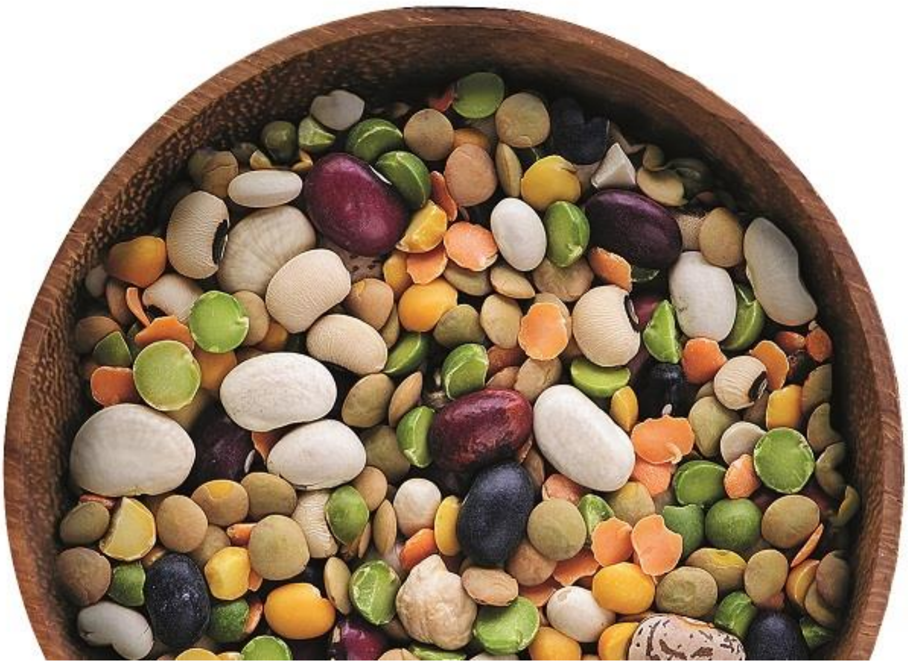
Behavioural analysis of farmers' and consumers' choice for legume uptake

Work Package: 6

Deliverable: 6.2 (37)

Lead Authors: Luiza Toma, Faical Akaichi (SRUC)

Date Submitted: 20th March 2020



The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Deliverable Description & Contributors

- **Due date**: March 31st 2020
- **Actual submission date**: March 20th 2020
- **Project start date**: April 1st 2017
- **Duration**: 48 months
- **Work Package**: WP6
- **Work Package leader**: Luiza Toma
- **Deliverable (D) Title**: D6.2 (D37)
  Behavioural analysis of farmers uptake and consumers choice
- **Nature of Deliverable**: Report
- **Dissemination level**: Public

- **Deliverable Description:** This report presents the impact of key factors influencing decision making of farmers and consumers to uptake legume cultivation and, respectively, the choice to include legumes into diets. Results provide guidance on determinants of positive behavioural change towards legume inclusion. Farmer and consumer analyses are based on survey data for the UK farmers and consumers, and findings are discussed comparatively in the context of European production and consumption and main factors potentially influencing behaviours and trends. The report informs how we may operate more effectively to affect behavioural change positively towards legume inclusion.

- **Contributors**

- Luiza Toma, Faical Akaichi, Shailesh Shrestha, Andrew Barnes (SRUC),
- Beate Zimmermann, Christine Oré Barrios, Tatjana Krimly, Elisabeth Angenendt, Christian Lippert (UHOH),
- Damian Bienkowski, Pietro Iannetta (JHI)

- **Key words**

- Legume; Farmer; Consumer; Diet; Choice Experiments; Structural Equation Modelling.

Contents

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

List of figures

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

List of tables

Executive Summary

1. This report presents the impact of key factors influencing decision making of farmers and consumers to uptake legume cultivation and, respectively, the choice to include legumes into diets. Results provide guidance on determinants of positive behavioural change towards legume inclusion. Farmer and consumer analyses are based on survey data for the UK farmers and consumers, and findings are discussed comparatively in the context of European production and consumption and main factors potentially influencing behaviours and trends. The report informs how we may operate more effectively to affect behavioural change positively towards legume inclusion.

2. The study on farmer behaviour towards legume cultivation analyses the impact of main factors on farmers' current uptake of legumes and their intentions to start/increase legume cultivation on their farms. We use panel data comprising 176 observations for crop, mixed and livestock farmers who cultivate legumes and/or intend to change to legume cultivation. We use structural equation modelling; a statistical method used to test hypotheses and assess the strength of the causal relationships between variables.

3. The model has a good fit according to the measures of absolute, incremental and parsimonious fit. The model explains 59 per cent of the variance in intentions. While the share of variance in behavioural intentions explained by the behavioural determinants included in the model is reasonably high, further research is needed to identify other factors potentially influencing behaviour.

4. Results indicate that significant influences on intentions to start or increase legume cultivation are: (1) changes during the past five years in the level of diversification, amount of agri-environmental activity and amount invested in new technologies by farmers, explaining 44% of the variance in intentions *ceteris paribus*; (2) intentions to change the level of diversification, amount of agri-environmental activity and amount invested in new technologies, with 69%; (3) changes to farming activities during the past five years to include legume cultivation, with 21%; (4) perceived impact of commodity prices, land availability and technological change on

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

business management, with 17%; (5) education, with 14%; (6) uptake of technologies such as precision farming, new tillage, nitrogen fixing plants and/or legumes, with 13%; (7) plans to continue farming during the next five years, with 9%; (8) profit orientation, with 3%; and (9) perceived usefulness of information sources explaining 3% of the variance in intentions to uptake legume cultivation *ceteris paribus*.

5. The main determinants of intentions to uptake legumes are past changes and intentions towards diversification, agri-environment and investment in new technologies, and current legume uptake (following changes towards legume cultivation during the past five years). Variables with lower but still significant effects on intentions are education, technological uptake behaviour, perceived influences on business management from prices, land availability and technological change, plans to continue with farming, profit and perceived usefulness of information sources.

6. Current legume uptake (following changes towards legume cultivation during the past five years) is influenced mostly by changes towards diversification and agri-environment, investment in new technologies, crop technological uptake, perceived influence of prices, land availability and technological change on business management, and educational level. Lower but still significant influences on legume uptake are profit, perceptions about usefulness of information sources, and plans to continue in farming.

7. The results are supported by findings from the literature on the path dependence of uptake of multiple innovations. Farmers involved in agri-environmental activities such as membership in agri-environmental schemes, who have diversified agricultural production into a larger range of crops and/or livestock or have added non-agricultural activities to their farming operations, and/or who have increased technological investment and adopted innovative technologies such as precision farming, new tillage practices, biological control methods, elicitors, varieties of nitrogen fixing plants, are more likely to have included legume cultivation among their farming activities during the past five years and to continue on this path during the next five years and possibly afterwards through increase in the area cultivated with legumes or starting cultivation of legume crops. Specialisation and decreased livestock production

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

reduced interest in growing legumes, which supports our findings that farmers who diversify are more likely to intend to increase legume cultivation.

8. Economic factors have always influenced uptake of innovations and results of this analysis confirm that. Farmers with larger businesses i.e. higher profits and more likely to be in the farming business in the longer term, who are more aware of the influences from output markets i.e. product prices and factors of production i.e. land availability when planning and managing their businesses, are more likely to be able to invest in legume cultivation as part of their farming activities.

9. Education and knowledge have been causally linked to farmers' uptake of innovation throughout the adoption literature. Our findings confirm this causal link as both education and perceived usefulness of information sources were found to significantly influence both current uptake and intentions to uptake legume cultivation. This suggests that farmers with a higher level of education and more likely to source and follow useful information to their businesses are more likely to exhibit positive legume cultivation uptake and intentions.

10. Except for current legume uptake and diversification and agri-environmental intentions, which have a direct effect, the other factors influence intentions to uptake legumes indirectly through different variables, which take alternative roles in the different causal relationships, either being influenced or influencing others. Perceived influence of prices, land availability and technological change on business management has an indirect effect on uptake and intentions to uptake legumes through its effect on past and intended changes towards diversification, agri-environment and technological investment. Similarly, uptake of innovative technologies will influence intentions to start or increase legume cultivation through awareness of market factors for business management and current legume uptake behaviour. The factors which only act as independent variables in the model, i.e. education, profit, perceived usefulness of information sources, and plans to continue in farming during the next five years, will influence intentions to introduce or increase cultivation of legumes indirectly through technological uptake, changes in agri-environment, diversification and technological investment, and current legume uptake.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

11. The findings advocate the need for careful coordination between policies encouraging the adoption of some innovations with those promoting others to account for uptake of interrelated agricultural innovations, and endorse policies supporting development of markets for legumes through creation and fostering of demand. The results support and compare very well with findings from the literature as regards factors influencing legume cultivation in other parts of Europe, thus portraying the potential legume adopter. The results suggest that legume cultivation may start with a farmer who has already adopted other innovations linked to agri-environment, diversification and technology, is aware of and acts to market influences, has a profit-oriented approach to farming and is planning to remain in farming in the longer term, is well-educated and tuned to information.

12. To assess the demand for pulses in the UK, we used a Kantar Worldpanel dataset including data of the weekly purchases of pulses in the UK between 2013 and 2016 to investigate the sensitivity of demand for pulses to variation in retail prices. In particular, we estimated the demand elasticities of pulses to assess whether decreasing the retail price of pulses can significantly foster the demand for pulses. The data were found to contain information on 1546 pulses and pulse-based products. These products were aggregated into seven groups of products: beans, peas, lentils, other pulses, mix of different pulses, and pulse-based products (i.e., pulses are used as an ingredient). We used Almost Ideal Demand System (AIDS), which is the most widely used system of demand equations (known as a demand system) to analyse consumer demand.

13. Overall, the results suggest that moderately discounting the retail prices of the major consumed pulses in the UK (i.e., beans and peas) is unlikely to result in a significant increase in their demand. Nonetheless, the high sensitivity of the demand for pulse-based products to price changes as well as their superiority to conventional dry pulses in terms convenience makes them a stepping-stone to foster the consumption of pulses in the UK.

14. Additionally, we used primary survey data of 1880 primary grocery shoppers in the UK collected in a national web-based choice experiment to estimate consumer acceptance of innovative pulse-based food products by (1) assessing consumers' preferences and willingness to pay (WTP) for pulse-based mince substitute as compared to other alternatives

(i.e., beef mince, mix of beef mince and pulse-based mince, mix of vegetables); (2) assessing consumers' preferences and WTP for other desirable food attributes (i.e., "Organic", "Low Fat", "British", and "Chilled") and their role in fostering the demand for pulse-based products; and (3) investigating how the results vary across three consumer segments (i.e., regular consumers of meat, flexitarians, and vegetarian and pescatarians). The data collected were analysed within a random utility framework using Random Parameter Logit modelling.

15. The results that the value that regular consumers of meat, who represent the majority of UK consumers, place on pulse-based mince is significantly lower than their value for beef mince. This suggests that at a retail price difference of less than £6.78, it is unlikely that regular meat-eaters would choose lasagne with pulse-based mince over a lasagne that contains beef mince instead. Nonetheless, there is an opportunity to increase the consumption of pulse-based meat substitutes by regular consumers of meat. In fact, the results show that regular meat-eaters are willing to pay a price premium of £2.05 for a lasagna that contains a mix of beef and pulsed-based mince than a lasagna that only contain pulse-based mince. Therefore, a way to foster the demand for pulse-based products is to use pulses as a partial substitute of meat (e.g., a mix of the two).

16. Promoting the benefits of consuming pulse-based products as well as addressing the barriers that are hindering their intake could also foster their consumption. We found that 75% of regular meat-eaters revealed to mainly eat pulse-based products because they are a good source of proteins. This is signalling the importance of promoting the well-documented richness of pulses in proteins and fibre. In other words, pulse-based products should be clearly labelled as high in proteins and fibre.

17. We found that the majority of regular meat consumers revealed that the lack of knowledge on how to cook pulses is the main barrier to the purchase and consumption of pulses. This result suggests that regular meat consumers are more likely to buy and consume pulses and pulse-based products if they are already cooked (e.g., baked beans, ready-to-eat soups) or are available in forms that do not require specific cooking knowledge and skills (e.g., ingredients in an easy-to-cook meal such as lasagne).

18. The results show that the acceptance of pulse-based products can be fostered if they are also labelled as "Organic", "Low Saturated Fat", and/or "British". Regular consumers of meat are willing to pay a considerable price premium for the use of the labels "Organic", "Low Saturated Fat", and "British". Labelling pulse-based meat substitutes as "Organic", "Low Saturated Fat", and/or "British" could increase their desirability as well as reduce the preference gap between them and meat. Nonetheless, it is noteworthy that since desirable food attributes (e.g., organic, low fat, local) are not exclusive to meat substitutes, they can be used by meat producers and marketers to increase the desirability of meat vis-à-vis meat substitutes (e.g., organic and British beef mince versus British pulse-based mince).

19. Flexitarians, vegetarians, and pescatarians were found to be more likely to buy pulse-based meat substitutes in comparison with regular meat consumers. In particular, flexitarians were found to be indifferent between the use of beef mince, pulse-based mince and a mix of beef and pulse-based mince in lasagne. This suggests that marketing strategies that increase the value of the lasagne with pulse-based lasagne in the eyes of flexitarians could foster its consumption. These strategies include selling the pulse-based lasagne at a retail price lower than the retail price of beef lasagne, promoting the high protein and fibre content of the pulse-based meat substitutes, labelling pulse-based lasagne as "Organic", "Low Saturated Fat", and/or "British".

20. The results also showed that vegetarians and pescatarians are potential buyers of pulse-based lasagne. In fact, they are the only sampled consumers who are willing to pay a price premium for the use of pulse-based mince as a beef mince substitute in lasagne. We also found that their demand for pulse-based lasagne can be fostered if the lasagne is labelled as having low saturated fat. Analysing the questionnaire data, we found that vegetarians and pescatarians mainly consume pulses and pulse-based products because they are suitable for vegetarians and they are high in proteins and fibres. This suggests that promoting the high protein and fibre content of pulse-based lasagne as well as clearly labelling it as suitable for vegetarians can increase its consumption by vegetarians and pescatarians.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

21. Finally, it is noteworthy that the use of vegetables (other than pulses) as a meat substitute is a potential competitor of pulse-based meat substitutes. In fact, we found that regular meat-eaters, flexitarians, vegetarians, and pescatarians value more the use of vegetables to substitute beef mince in lasagne than the use of pulse-based mince. Therefore, when valuing the use of pulses as a meat substitute, it is recommended to consider not only how consumers trade off meat and pulse-based meat substitutes but also how this later is traded off with other meat substitutes such vegetables.

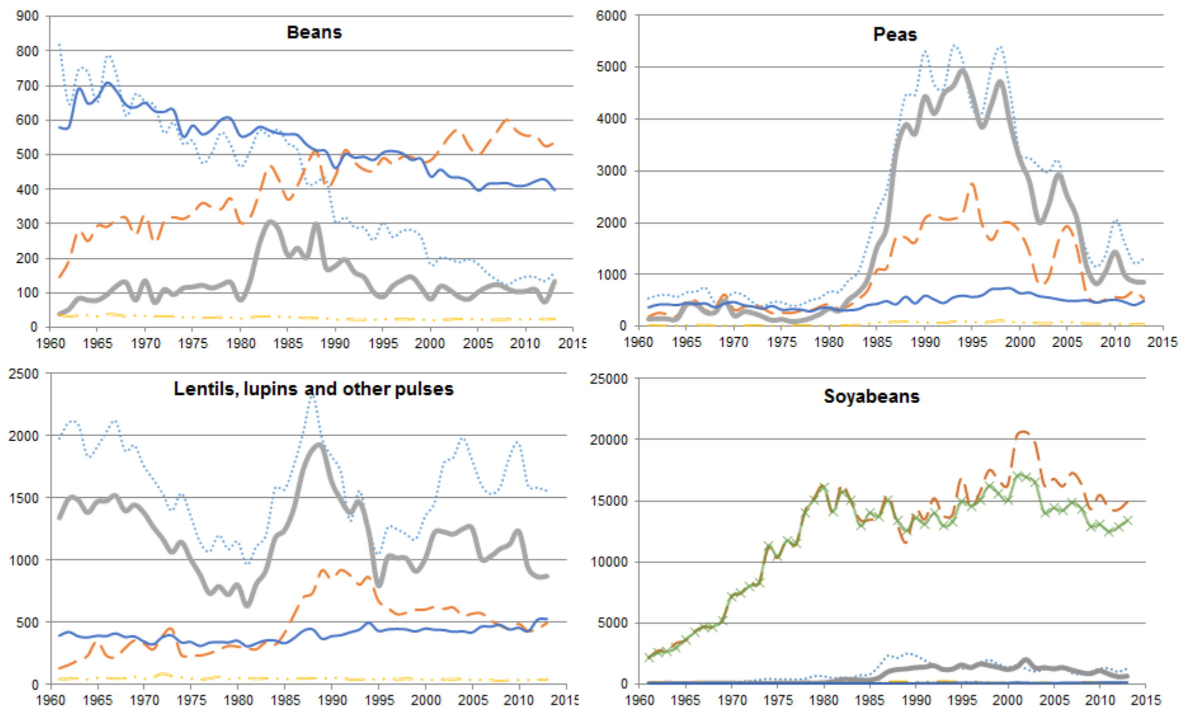
The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

1. Introduction

Agricultural production faces multiple calls in the context of food security, sustainable intensification, climate change and changes in consumer diets, all demanding the restructuring of food systems. A stronger shift towards legume cultivation will contribute to meeting these demands as legumes provide nutrient rich diets for humans and livestock and contribute to lowering environmental footprint of agriculture through nitrogen fixation and improved soil quality and biodiversity.

The economics of legumes analyses the factors influencing the equilibrium between supply (farmers) and demand (consumers). Farmers' and consumers' behaviours towards legume cultivation uptake and, respectively, inclusion of legume-based products into diets are reflected in the supply and demand trends for legumes (Figure 1).

Figure 1. Legume production and imports, uses and losses in the European Union



Source: Own creation based on FAOSTAT data (extracted November 2019)

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

As is the case of any other agricultural industries but even more so due to their public good benefits (European Parliament 2013), changes to the equilibrium between the supply and demand of legumes translates into strong long term wider effects, and as such, an analysis of legume production e.g. assessment of farm profitability is incomplete and potentially incorrect if not coordinated with an analysis of demand.

The economics of legumes in the European Union (EU) shows a production trend closely correlated to the different types of subsidies and payments linked to the Common Agricultural Policy (CAP) reforms, and the global market prices for fertilisers (Figure 1). Linked to similar factors affecting livestock production, feed demand mirrors production trends for dry pulses (only starting in the 80's in the case of beans). Imports of legumes mirror the demand for processing in the case of soya beans, and the production trends for peas and other dry pulses, while showing an opposite trend to the domestic production of beans (to follow the timid potential rise in its use for feed and food).

The cultivation of dry pulses (i.e. grain legumes except soya) is significantly more frequent in regions with higher receipt of voluntary coupled CAP support to protein crops, regions with higher shares of organic farming, regions with a more important role of legume consumption in regional diets, regions with relatively deep soils, and regions displaying lower competition for land use with sunflower. Livestock density and share of irrigable agricultural area are significantly negatively correlated with the share of dry pulses. Up to a certain temperature sum maximum, also higher temperature sums seem to be beneficial for the cultivation of dry pulses. In contrast to dry pulses, regional soya shares in arable area are positively correlated with a region's distance to the next main port and with the share of irrigable agricultural area. Agglomeration and spill over effects (i.e. farms located in the neighbourhood of dry legume producers are also more likely to commence cultivation of dry legumes and regions with a high share of dry pulses tend to be close to each other) may matter as in the case of dry pulses where a significant spatial lag coefficient was found. Such effects, however, are likely to be effective on a spatial scale smaller than the regional level underlying this analysis, Potentially significant causal factors, not tested due to poor data availability, which may be positively linked to legume production include proximity to processing facilities and trading companies, and access to extension services and regional networks and training programs (Oré Barrios et al., 2020). Other factors well acknowledged in the literature (European

Parliament 2013) with positive causal effects on cultivation of legumes are market factors i.e. producer prices for outputs (pulses) and inputs (nitrogen fertilisers).

The economic circumstances of farms cultivating legumes are linked to some of the factors mentioned above, e.g. larger organic farms show higher profitability. There are also indirect economic benefits of legume cultivation such as the lower cost of agricultural inputs (nitrogen and tillage cost saving) and yield effects on other crops e.g. cereals included in the rotation. While profits and the economic sustainability of the farm are necessary, they may not always be sufficient and farmers' decision-making may be influenced by non-economic factors, such as their perceptions of how what they create affects others beyond farmgate such as environment and human health.

Similarly, consumers' choices may be influenced by environmental and health concerns as opposed to purely economic reasons and assessing the weight of the different attributes of choice would help predict sustainable changes in shopping habits and subsequent consumption patterns. As represented in Figure 1, while the consumption trend for beans has been in a stable decrease, the consumption of peas, lentils, lupins and other dry pulses shows a gentle but steady increase, likely correlated to a slow change in consumer diets reflecting a healthier pattern.

While slow, changes in consumption patterns to include more legumes are apparent and need to be translated in production patterns following prices and non-market incentives such as environmental and technological support through changes in agri-environmental and innovation policies.

In the aforementioned European context of supply and demand trends and factors, this report presents results of an analysis of farmer and consumer behaviour and estimates the causal relationships between behavioural determinants and farmers' and consumers' decision-making to uptake legume cultivation and, respectively, include legumes into diets.

2. Determinants of farmers' intentions to uptake legumes

2.1. Introduction and research hypotheses

This study builds on the existing literature and analyses the impact of *a priori* identified factors such as uptake of innovative crop technologies on farmers' intentions to uptake legumes or further expand legume production on farm. We used a dataset collected through a stratified telephone survey and structural equation modelling (SEM) to test a conceptual model based on behavioural economics theory.

Based on a review of the literature and expert opinion, we have identified potential commonalities between the factors influencing uptake of legume cultivation and those which may impact on agri-environmental or technological uptake behaviours. Hence we have built and tested the following research hypotheses:

Hypothesis 1: Education, knowledge and access to information influence uptake and intentions to uptake legumes.

From the establishment of the literature on the adoption of new techniques, technologies and other innovations in farming, there has been a confirmed effect of education and knowledge gained through access to information sources on farmer behaviour (Hägerstrand, 1952; Rogers and Shoemaker, 1971; Läpple et al., 2015; Toma et al., 2018). Whether this causal relationship is positive or negative, and any specific level of (statistical) significance will depend on the type of innovation involved as different innovations have different information requirements (Shapiro et al., 1992; Wu and Babcock 1998; Soule et al. 2000; Larson et al. 2008), and also on the specific source of information and their perceived value to farmers (Ghadim and Pannell, 1999; Sanyang et al., 2009; Wheeler, 2009).

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Hypothesis 2: Endogenous and exogenous economic factors such as profit, agricultural land and markets influence uptake of and intentions to uptake legumes.

A higher farm income may be a necessary condition for the adoption of innovations which involve higher implementation costs than others, and as such, uptake might be more difficult to smaller businesses rather than to larger and profit-oriented farms (Adrian et al. 2005). Larger farms with e.g. more land available to use as collateral can take advantage of returns to scale and may be better prepared to cope with credit constraints. Farmers' income depend on markets and output prices and literature shows that uptake of innovations has a higher probability of happening if there is a guarantee of a higher income after adoption (Areal et al. 2011; Adrian et al. 2005). Other studies showed that choice of crops is profit driven and that economic factors are a strong motivation for farmers in European countries, with the markets influencing farmers' decision to uptake legume cultivation through demand and prices (Mills et al., 2019).

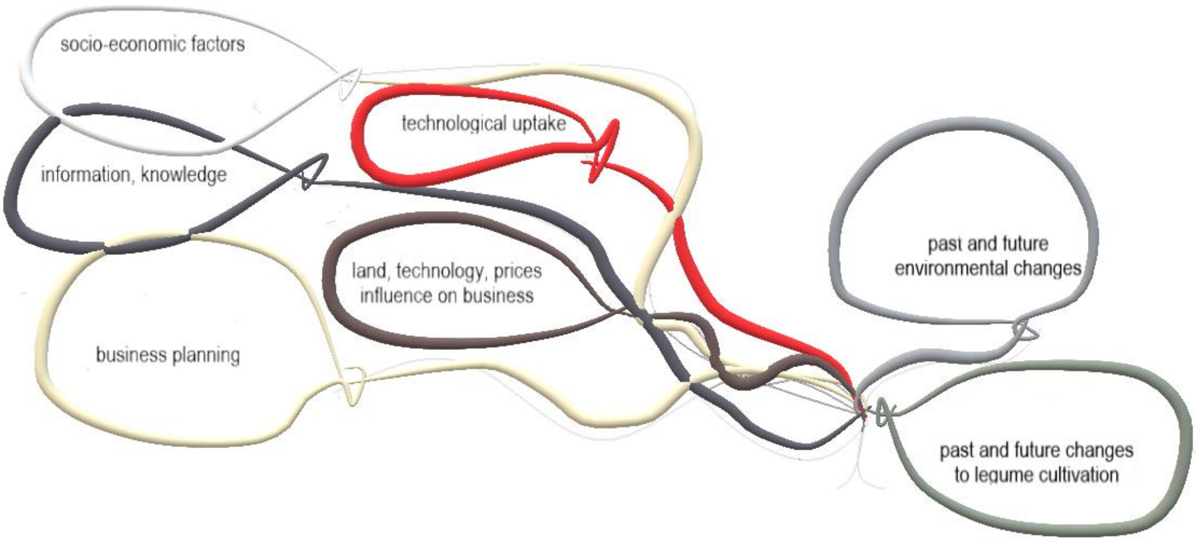
Hypothesis 3: Agri-environmental, technological and diversification uptake behaviour influence uptake and intentions to uptake legumes

The literature acknowledges the possibility of a dependence path, i.e., farmers' uptake behaviour may be partially explained by earlier choices (Wu and Babcock 1998; Khanna 2001; Teklewold et al. 2013; Toma et al., 2018). Analysing uptake behaviour in a multiple innovation/technology framework may contribute to clarify the interdependence between adoption decisions (Dorfman 1996). The same unobserved factors could influence decisions to uptake different technologies and other innovations (Khanna, 2001; Rauniyar and Goode, 1992). Thus farmers who have adopted agri-environmental activities and technologies in the past are more likely to be aware of the environmental benefits of legumes and thus more inclined to include legume cultivation among farming activities.

The conceptual model based on the aforementioned hypotheses is depicted in Figure 2.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Figure 2. Conceptual model



2.2. Methods and data

2.2.1. Structural equation model

We used a structural equation model (SEM) with observed and latent variables to test the conceptual model and assess the strength of the research hypotheses, namely the effects the behavioural determinants have on intentions to uptake legumes and on each other. As each variable might influence behaviour and intentions both directly or indirectly (through their effect on other variables in the model, which subsequently directly influence behaviour), the variance explained by the model is higher than when other methods, e.g., regression analysis, are used.

The model consists of two parts: the measurement model (which stipulates the relationships between the latent variables and their component indicators), and the structural model (which describes the causal relationships between the latent variables). The model is defined by the following system of three equations in matrix terms (Jöreskog and Sörbom 2007):

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

The structural equation model: $\eta = B\eta + \Gamma\xi + \zeta$

The measurement model for y: $y = \Lambda_y \eta + \varepsilon$

The measurement model for x: $x = \Lambda_x \xi + \delta$

Where: η is an m*1 random vector of endogenous latent variables; ξ is an n*1 random vector of exogenous latent variables; B is an m*m matrix of coefficients of the η variables in the structural model; Γ is an m*n matrix of coefficients of the ξ variables in the structural model; ζ is an m*1 vector of equation errors (random disturbances) in the structural model; y is a p*1 vector of endogenous variables; x is a q*1 vector of predictors or exogenous variables; Λ_y is a p*m matrix of coefficients of the regression of y on η; Λ_x is a q*n matrix of coefficients of the regression of x on ξ; ε is a p*1 vector of measurement errors in y; δ is a q*1 vector of measurement errors in x.

We estimate the model using the Diagonally Weighted Least Squares (DWLS) method and the statistical package Lisrel 8.80 (Jöreskog and Sörbom 2007). We combine Prelis to calculate the asymptotic covariance matrix (Muthén 1984; Bollen 1989) and Lisrel to compute test statistics for the estimation of the significance of causal relationships (Jöreskog and Sörbom 2007). DWLS estimation method is consistent with the types of variables included in the model (ordinal and categorical) and the deviation from normality in these variables (Finney and DiStefano 2006). The model is validated using absolute (root mean square error of approximation and goodness of fit index), incremental (adjusted goodness of fit index, non-normed fit index, normed fit index, relative fit index, comparative fit index and incremental fit index) and parsimonious (normed chi-square) goodness of fit (GoF) indicators (Hair et al. 2006).

An acceptable level of overall goodness-of-fit does not guarantee that all constructs meet the requirements for the measurement and structural models. The validity of the SEM is assessed in a two-step procedure, the measurement model and the structural model. Model selection is performed through a nested model approach, in which the number of constructs and indicators remains constant, but the number of estimated relationships is changed iteratively. SEM is applied on a panel dataset, where variables from period t-1 are observed and assumed time-invariant and

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

as such there are no longitudinal aspects to the modelling, i.e. we use cross-section SEM and not a longitudinal structural equation model.

2.2.2. Data

Due to the lack of information on the exact number of farmers growing legumes (which is partially related to the different classifications in use, e.g. some legume growers are classified as vegetable growers), the likelihood of developing a reliable sample when selecting specifically for legume growers is reduced. This, combined with the high probability of achieving a low rate of response inadequate for modelling purposes, led us to using a subset of data drawn from representative surveys of different farm types, i.e. livestock, crop and mixed farms.

The data used in this study were drawn from two representative surveys of Scottish agricultural holdings completed in 2018 (2,494 responses from livestock, crop and mixed farms) and 2013 (2,416 responses from livestock, crop and mixed farms). The aim of the two surveys was to identify the impact of CAP reforms (2013) and Brexit (2018) on farmers' intentions to make (structural) changes to their business, with additional focus on uptake of technologies, agri-environmental and diversification behaviours. The sampling frame (over 10,000 farms in each of the two surveys) was derived from the June Agricultural Census (JAS) and stratified by region, activity, size and farming enterprise. A potential limitation of the study is related to the JAS under-representation of the category of 'very very small' farms (business holdings with less than 0.5 standard labour requirements), which may have excluded the views of 'very very small' legume growers.

We selected a panel subset of data from the two surveys comprising 176 observations for crop, mixed and livestock farmers who cultivate legumes and/or intend to change to legume cultivation. While data on the actual areas cultivated with legumes by each farm is only available for a third of the selected panel sample (where area cultivated with legumes includes peas for combining, beans for combining, peas, beans, lupins or lucerne), the subsample is based on combined information from JAS, and farmers' responses to close-ended and open-ended (qualitative) questions in both 2013 and 2018 surveys as regards types of activities employed on farm, changes to these activities during

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

the past five years and intentions to change during the next five years (where we selected responses specifically related to cultivation of legumes).

The selected sample includes farms with legume cultivation, among other activities, corresponding to the following categories according to the EUROSTAT classification: 151 'specialist cereals (other than rice), oilseeds and protein crops'; 162 'cereals, oilseeds, protein crops and root crops combined'; 166 'various field crops combined'; 213 'mixed horticulture indoor specialist'; 450 'specialist dairying'; 460 'specialist cattle - rearing and fattening'; 611 'horticulture and permanent crops combined'; 612 'horticulture and field crops combined'; 615 'mixed cropping, mainly field crops'; 616 'other mixed cropping'; 832 'dairying combined with field crops'; 833 'field crops combined with non-dairying grazing livestock'; 834 'non-dairying grazing livestock combined with field crops'; 844 'various mixed crops and livestock'. While inconsistencies exist e.g. some farms being classified in different categories between the survey years, which may be related to either an actual change in farm type or due to recording errors, the sample composition portrays a pattern of legume cultivation as one of the many farming activities and more often than not, secondary to others.

The variables included in the model are consistent with the aim of testing the research hypotheses and the use of SEM. They are based on close-ended questions on the following: socio-economic characteristics (education, profit orientation, plans to continue farming during the next five years); perceived usefulness of information sources (agricultural consultants or farm advisory; business advisor, accountant, lawyer; family and friends); uptake of technologies (precision farming technologies; new tillage practices; new or novel crops; biological control methods, elicitors; varieties of nitrogen fixing plants and/or legumes); influences during the past five years on the way farming business is managed (changes in commodity prices; land availability; technological change); changes to farming activities during the past five years (level of diversification; amount of agri-environmental activity; amount invested in new technologies); intentions to make changes to farming activities during the next five years (level of diversification; amount of agri-environmental activity; amount invested in new technologies); changes in the commodities produced (legumes) during the past five years; intentions to make changes in the commodities produced (legumes) during the next five years.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Most variables introduced in the model are based on responses from the 2018 survey. The only variables based on responses from the 2013 survey are observed variables related to uptake of innovative crop technologies. Without specific information on the status of technological uptake for the 2018 survey, and due to the relatively short (as regards technological development) period of time between the two surveys, we assume that technological uptake variables are time-invariant covariates, i.e. that farmers' stated uptake of technologies in 2013 has remained unchanged in 2018.

Variables on past and intended changes to legume cultivation are based on recoded qualitative information (responses to open ended questions) and show 5% of farmers having increased the area cultivated with legumes or having started legume cultivation during the past five years, with a further 3% intending to start or increase legume cultivation during the next five years.

Farmers have stated different reasons for their business decisions to uptake or increase legume cultivation. Some were linked to crop rotation planning, ('[…] more crop rotation, beans, green cover, more grass' or '[…] we grow wheat, peas and potatoes under the new regulations' or '[…] it turned out we don't need a third crop - the joys of Europe - but we've decided to introduce field beans'). Some were linked to lower requirements for agricultural inputs, '[…] to cut down on spray and fertiliser costs'. Some farmers specified having changed production from certain crops to legumes e.g. '[…] from certain wheats to peas', '[…] dropped potato growing and cattle and started growing vining peas' or '[…] less oilseeds, more oats and beans'. Some stated intentions to (further) changes e.g. '[…] possibly drop oil seed rape and grow two other different crops, probably peas and beans' or '[…] at the moment we are only producing cereals, but we might start producing beans as well' or '[…] we will grow more beans and potatoes instead of what we grow currently and also increase the amount of poultry'. Most popular legumes are peas and beans, then lucerne, with some cultivating lupins ('[…] we have increased pea area' or '[…] introduced peas and beans'). As mentioned, most farmers growing legumes do that among other farming activities, many in the sample being categorised as vegetable growers ('[…] we produce daffodils, carrots, potatoes and peas'), however some produce legumes on a larger scale ('[…] we are growing beans for Africa which they use to make flour there'). The latter is a much less common instance and on this matter we have tested correlations between past changes and intentions to change to/increase legume cultivation and the variables representing farmers' involvement in export (of agricultural

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

produce) and import (of agricultural inputs) activities, however no significant coefficients were flagged.

Table 1 presents a description of the latent variables and their corresponding indicators included in the SEM model.

Table 1. Description of latent variables and their corresponding indicators

Latent variables	Indicators (statements)	Values and labels
educs	educ (educational level)	1 (school), 2 (college), 3 (university or higher)
contins	contin (Do you plan to continue farming for the next five years?)	0 (no); 1 (unsure); 2 (yes)
profits	profit (Taking all your sources of income into account, does this business usually make a profit?)	0 (no, it makes a loss); 1 (no, but it breaks even); 2 (yes – £25,000 or less); 3 (yes – more than £25,000)
info	How helpful to you are the following sources of advice for developing your business? info1 (family and friends) info2 (agricultural consultant or farm advisory) info3 (business advisor, accountant, lawyer)	0 (no help), …., 10 (most helpful)
tech	Since 2005 have you applied/started to apply on your business/holding any (technological) innovations: techpre (precision farming technologies) techtil (new tillage practices) technew (new or novel crops) techpes (biological control methods, elicitors)	0 (no), 1 (in process), 2 (yes)

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

	technit (varieties of nitrogen fixing plants and/or legumes)	
inflch	In the last five years, have any of the following changed the way you manage your business: inflch3 (changes in commodity prices) inflch5 (land availability) inflch9 (technological change)	1 (no); 2 (slightly); 3 (significantly)
change	In the last five years, have you changed: chgdive (level of diversification) chgtech (amount invested in new technologies) chgaenv (amount of agri-environmental activity)	1 (decrease); 3 (no change); 5 (increase)
intent	During the next five years, do you intend to change: ichgdive (level of diversification) ichgtech (amount invested in new technologies) ichgaenv (amount of agri-environmental activity)	1 (decrease); 3 (no change); 5 (increase)
chglegum	chgleg (In the last 5 years, have you changed the commodities you produce to include legumes (recoded from qualitative responses)	0 (no); 1 (yes)
intlegum	ichgleg (During the next five years, do you intend to change the commodities you produce to include legumes (recoded from qualitative responses)	0 (no); 1 (yes)

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

2.3. Results

The model explains 59 per cent of the variance in intentions to uptake legumes. All variables included in the model have a statistically significant effect on intentions to uptake legumes. The model has acceptable fit according to the measures of absolute, incremental and parsimonious fit (Hair et al. 2006). The main goodness of fit (GoF) indicators (estimated and recommended values) for the estimated model are presented in Table 2.

Table 2. Goodness of fit indicators

GoF indicators	Estimated value	Recommended value
Degrees of Freedom (df)	196	-
Satorra-Bentler Scaled Chi-Square	251.33	-
Normed chi-square (Chi-Square / df)	1.28	[1-3]
Root Mean Square Error of Approximation (RMSEA)	0.040	0.00-0.10
Standardized Root Mean Square Residual (RMR)	0.071	0.00-0.10
Goodness of Fit Index (GFI)	0.88	0.90-1.00
Non-Normed Fit Index (NNFI)	0.91	0.90-1.00
Comparative Fit Index (CFI)	0.92	0.90-1.00
Adjusted Goodness of Fit Index (AGFI)	0.87	0.90-1.00
Incremental Fit Index (IFI)	0.93	0.90-1.00

Additional testing of the appropriateness of the model was achieved by comparing the estimated model with four other models that acted as alternative explanations to the proposed model in a competing models strategy using a nested model approach. The results across all types of goodness-of-fit measures favoured the estimated model in most cases. Therefore, we confirmed the accuracy of the proposed model and discarded the competing ones.

After assessing the overall model and aspects of the measurement model, the standardised structural coefficients were examined for both empirical and theoretical implications. Table 3 presents the standardised total effects between the latent variables in the model.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Table 3. Standardised total (direct and indirect) effects *ceteris paribus* (t-values in parentheses)*

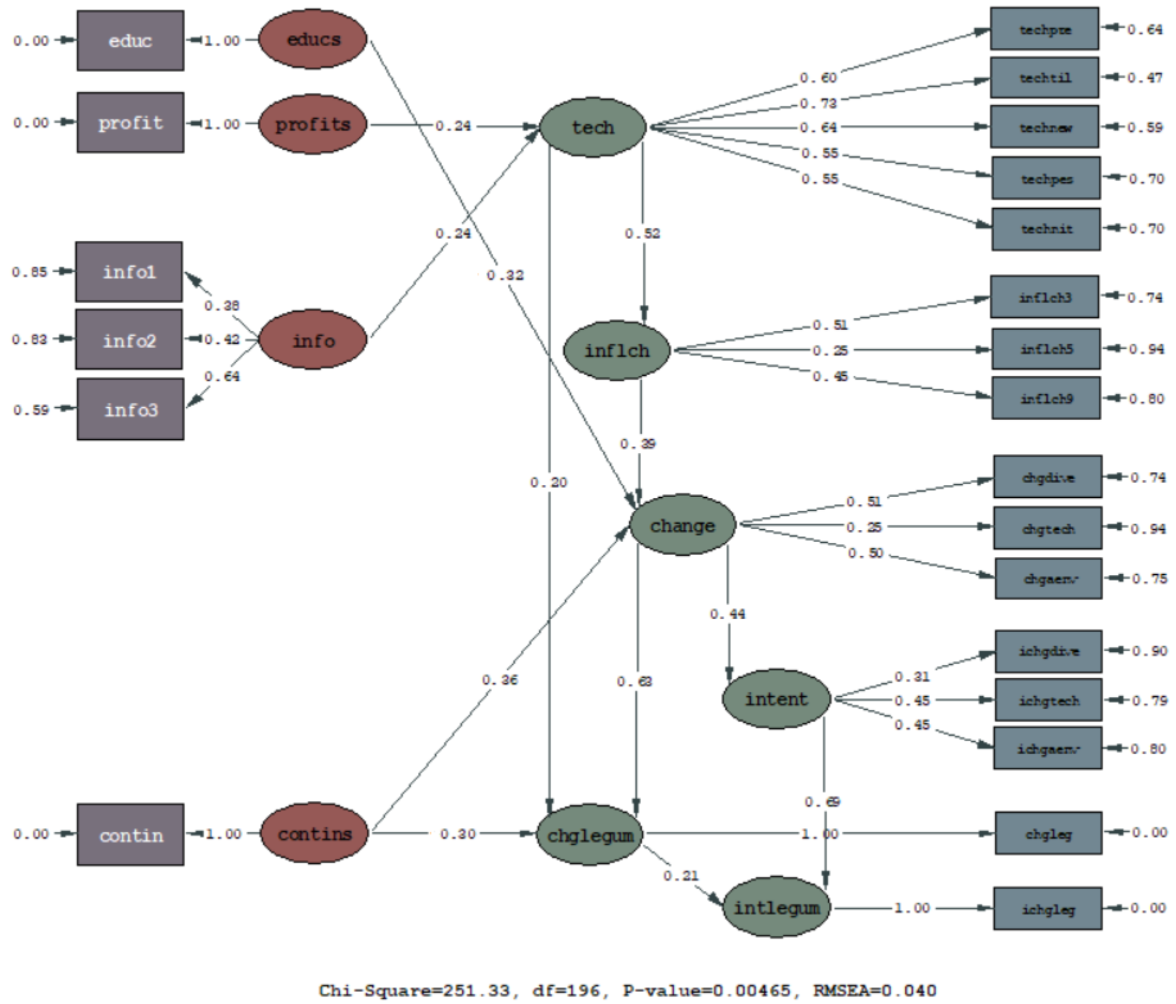
Observed/ latent variables	Total effects on 'tech'	Total effects on 'inflch'	Total effects on 'change'	Total effects on 'intent'	Total effects on 'chglegum'	Total effects on 'intlegum'
educs	-	-	.32 (3.14)	.14 (2.09)	.20 (3.33)	.14 (3.10)
contins	-	-	.36 (3.19)	.16 (2.10)	.07 (3.46)	.09 (1.98)
profits	.24 (2.77)	.13 (2.23)	-	-	.08 (2.42)	.03 (2.19)
info	.24 (2.11)	.13 (1.98)	.05 (1.98)	-	.08 (1.98)	.03 (1.98)
tech	-	.52 (3.18)	.20 (2.19)	.09 (1.98)	.33 (3.83)	.13 (3.06)
inflch	-	-	.39 (2.21)	.17 (1.98)	.24 (2.15)	.17 (2.15)
change	-	-	-	.44 (2.31)	.63 (3.93)	.44 (3.89)
intent	-	-	-	-	-	.69 (2.83)
chglegum	-	-	-	-	-	.21 (2.73)
R-square	0.12	0.27	0.37	0.20	0.46	0.59

* The latent variable scores and observational residuals depend on the unit of measurement in the observed variables. As some of these units are the result of subjective scaling of the observed variables the observational residuals were standardised (rescaled such that they have zero means and unit standard deviations in the sample) (Jöreskog and Sörbom 2007). Total effects represent how much a one-unit change in an independent variable will change the expected value of a dependent variable.

The path diagram for the estimated SEM model is presented in Figure 3.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Figure 3. SEM path diagram (direct effects – standardised solution)



Results presented in Table 3 indicate that significant influences on intentions to start or increase legume cultivation are (1) changes during the past five years in the level of diversification, amount of agri-environmental activity and amount invested in new technologies by farmers, explaining 44% of the variance in intentions *ceteris paribus*; (2) intentions to change the level of diversification, amount of agri-environmental activity and amount invested in new technologies, with 69%; (3) changes to farming activities during the past five years to include legume cultivation, with 21%; (4) perceived impact of commodity prices, land availability and technological change on business management, with 17%; (5) education, with 14%; (6) uptake of technologies such as precision farming, new tillage, nitrogen fixing plants and/or legumes, with 13%; (7) plans to continue farming

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

during the next five years, with 9%; (8) profit orientation, with 3%; and (9) perceived usefulness of information sources explaining 3% of the variance in intentions to uptake legume cultivation *ceteris paribus*. Except for current legume uptake and diversification and agri-environmental intentions, which have a direct effect, the other factors influence intentions to uptake legumes indirectly through different variables.

2.4. Discussion and conclusions

The study analysed the impact of factors on Scottish farmers' intentions to start/increase legume cultivation on their farms. We used structural equation modelling and panel data comprising 176 observations for crop, mixed and livestock farmers who cultivate legumes and/or intend to change to legume cultivation. The model has a good fit according to the measures of absolute, incremental and parsimonious fit and explains 59 per cent of the variance in intentions. While the share of variance in behavioural intentions explained by the behavioural determinants included in the model is reasonably high, further research is needed to identify other factors potentially influencing behaviour.

The main determinants of intentions to uptake legumes are past changes and intentions towards diversification, agri-environment and investment in new technologies, and current legume uptake (following changes towards legume cultivation during the past five years). Variables with lower but statistically significant effects on intentions are education, technological uptake behaviour, perceived influences on business management from prices, land availability and technological change, plans to continue with farming, profit and perceived usefulness of information sources.

Current legume uptake (following changes towards legume cultivation during the past five years) is influenced mostly by changes towards diversification and agri-environment, investment in new technologies, crop technological uptake, perceived influence of prices, land availability and technological change on business management, and educational level. Lower but still significant influences on legume uptake are profit, perceptions about usefulness of information sources, and plans to continue in farming.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

The results are supported by findings from the literature on the path dependence of uptake of multiple innovations (Wu and Babcock 1998; Khanna 2001; Teklewold et al. 2013; Toma et al., 2018). Farmers involved in agri-environmental activities such as membership in agri-environmental schemes, who have diversified agricultural production into a larger range of crops and/or livestock or have added non-agricultural activities to their farming operations, and/or who have increased technological investment and adopted innovative technologies such as precision farming, new tillage practices, biological control methods, elicitors, varieties of nitrogen fixing plants, are more likely to have included legume cultivation among their farming activities during the past five years and to continue on this path during the next five years and possibly afterwards through increase in the area cultivated with legumes or starting cultivation of legume crops. Specialisation and decreased livestock production reduced interest in growing legumes (Mills et al., 2019), which supports our findings that farmers who diversify are more likely to intend to increase legume cultivation.

Economic factors have always influenced uptake of innovations (Adrian et al., 2005; Areal et al., 2011; Mills et al., 2019) and results of this analysis confirm that. Farmers with larger businesses i.e. higher profits and more likely to be in the farming business in the longer term, who are more aware of the influences from output markets i.e. product prices and factors of production i.e. land availability when planning and managing their businesses, are more likely to be able to invest in legume cultivation as part of their farming activities.

Education and knowledge have been causally linked to farmers' uptake of innovation throughout the adoption literature (Läpple et al., 2015; Toma et al., 2018). Our findings confirm this causal link as both education and perceived usefulness of information sources were found to significantly influence both current uptake and intentions to uptake legume cultivation. This suggests that farmers with a higher level of education and more likely to source and follow useful information to their businesses are more likely to exhibit positive legume cultivation uptake and intentions.

Except for current legume uptake and diversification and agri-environmental intentions, which have a direct effect, the other factors influence intentions to uptake legumes indirectly through different variables, which take alternative roles in the different causal relationships,

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

either being influenced or influencing others (Figure 3). Perceived influence of prices, land availability and technological change on business management has an indirect effect on uptake and intentions to uptake legumes through its effect on past and intended changes towards diversification, agri-environment and technological investment. Similarly, uptake of innovative technologies will influence intentions to start or increase legume cultivation through awareness of market factors for business management and current legume uptake behaviour. The factors which only act as independent variables in the model, i.e. education, profit, perceived usefulness of information sources, and plans to continue in farming during the next five years, will influence intentions to introduce or increase cultivation of legumes indirectly through technological uptake, changes in agri-environment, diversification and technological investment, and current legume uptake.

The findings advocate the need for careful coordination between policies encouraging the adoption of some innovations with those promoting others to account for uptake of interrelated agricultural innovations, and endorse policies supporting development of markets for legumes through creation and fostering of demand. The results support and compare very well with findings from the literature as regards factors influencing legume cultivation in other parts of Europe, thus portraying the potential legume adopter. The results suggest that legume cultivation may start with a farmer who has already adopted other innovations linked to agri-environment, diversification and technology, is aware of and acts to market influences, has a profit-oriented approach to farming and is planning to remain in farming in the longer term, is well-educated and tuned to information.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

3. Consumers' demand for pulses and pulse-based food products

3.1. Introduction

To meet the challenges of lowering the risk of climate change and obesity prevalence, a policy framework needs to be developed in which the production and consumption of sustainable and healthy food products become central. In this context, pulses and pulse-based products have a considerable potential to substitute red and processed meat in humans' diet while reducing the effect of climate change and poor diets.

Indeed pulses have a low-energy density and are nutrient dense (e.g., high in proteins and fibre and low in saturated fat), making them a valuable healthy alternative to meat and meat products (Robello et al., 2014; Mudryj et al., 2014; Stagnari et al., 2007). Recognising the health benefits of pulses and the increasing deficit in plant protein consumption in both developed and developing countries, FAO launched the 'International Year of Pulses' in 2016 that aimed to increase pulse consumption by encouraging people to eat 60g to 100g serving of pulses 3-5 times a week (FAO, 2016).

In addition to its considerable health benefits, pulses also offer significant environmental benefits. The production and consumption of pulses can significantly reduce the emissions of GHG by agriculture. According to Aleksandrowicz et al. (2016), shifting to a plant-based diet could decrease GHG emissions by 70-80% and water use by 50%. Furthermore, leguminous plants have also the benefits of fixing nitrogen, and breaking weed, disease, and insect cycles (Köpke and Nemecek, 2010; Nayak et al., 2015).

Despite the well-documented potential of pulses to help meet the increasing worldwide demand for proteins while improving human nutrition and food security and fostering sustainable agriculture, the production and consumption of pulses, especially in Europe, are remarkably low. For instance, the consumption of pulses in the UK, the country with the largest consumption level of pulses in Western Europe, has gradually decreased since 1974, from 120g per person per week to 100g in 2017 (Luciane, 2018). This intake level is far below the recommended daily intake of

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

pulses that should be between 80g and 100g (NHS, 2018; Marinangeli et al., 2017). According to FAO (2019), Per capita weekly consumption has remained stagnant at about 52.5 grams in Europe. So, why pulses are not more widely consumed, especially in Europe?

Schneider (2002) reported that long cooking time of dry pulses, the problem of flatulence, the image of pulses as an old-fashioned food, the lack of convenient new pulse-based products, and the lack of promoting pulses' benefits are the major barriers to the consumption of pulses in Europe. Studies in the USA and Canada found that the lack of culinary skills and knowledge around cooking pulses was the main barrier to their consumption (Wenrich and Cason, 2004; IPSOS, 2010). In Latin America, Jallinoja et al. (2016) reported that time constraints and access to more convenient pulses and pulse-based products seem to be the main barriers to the low consumption of pulses in urban areas compared with rural areas.

There is a growing evidence that the use of pulses as (main or secondary) ingredient in ready meals or easy to cook foods can overcome the commonly cited pulses' consumption barriers such as long cooking time, lack of skills and knowledge around cooking pulses, the "old fashioned" image of pulses, and to the problem of flatulence (Niva et al., 2017; Henchion et al., 2017, Sozer et al., 2017; Lascialfari et al, 2019). This seems to be supported by the growing number of new pulse-based foods and drinks available to consumers, especially in high-income countries. In fact, we used the Mintel Global New Products Database (GNPD), which provides information about the characteristics of new products launched in the UK between 2000 and 2019. We found that the number of new pulse-based products being developed and released to supermarket shelves in the UK has increased dramatically over the past 20 years from only 10 products in 1999 to 1105 products in 2019. We also found that the most popular pulse-based products being developed are meals, soups, and snacks accounting for 68% of all products released.

Surprisingly, this considerable rise in the development of new pulse-based food products has not been accompanied by proportional research work on consumers' acceptance of this type of new food products. The literature on consumers' preferences for new pulse-based food products is still very limited (Jallinoja et al., 2016; Spencer, 2018; de Boer, 2019). Understanding consumers' preferences for pulse-based food products is crucial for the developments of new products that are tailored to the need of consumers. This, in turn, is likely to foster the consumption of pulses as well as reducing the chances of market failure of the new pulse-based products.

The research described in this report contributes to the scant literature on consumer acceptance of innovative pulse-based food products by (1) assessing consumers' preferences and willingness to pay (WTP) for pulse-based mince substitute as compared to other alternatives (i.e., beef mince, mix of beef mince and pulse-based mince, mix of vegetables); (2) assessing consumers' preferences and WTP for other desirable food attributes (i.e., "Organic", "Low Fat", "British", and "Chilled") and their role in fostering the demand for pulse-based products; and (3) investigating how the results vary across three consumer segments (i.e., regular consumers of meat, flexitarians, and vegetarian and pescatarians).

Before assessing consumers' preferences for new pulse-based products, we used secondary data of the weekly purchases of pulses in the UK between 2013 and 2016 to investigate the sensitivity of demand for pulses to variation in retail prices. In particular, we estimated the demand elasticities of pulses to assess whether decreasing the retail price of pulses can significantly foster the demand for pulses.

3.2. Methods

3.2.1. Demand for pulses in the UK

3.2.1.1. Data

To assess the demand for pulses in the UK, the Kantar Worldpanel dataset was used. The dataset includes weekly records of all foods and beverages that were taken home from supermarkets and similar stores by approximately 40,000 households during the period 2013 to 2017. The recruited households are representative of the UK population. However, not all of them were observed every year as the dataset is a rotating panel (Hsiao, 2014). For each product, the dataset contains rich information on several attributes (e.g., brand, origin, retailer, fresh/processed, nutritional content of the product, organic/not, type of promotion). For each product, the dataset also contains information the price paid, the quantity purchased by the household as well as neighbourhood information and socio-demographic characteristics for all the households.

The data were found to contain information on 1546 pulses and pulse-based products. These products were aggregated into seven groups of products: beans, peas, lentils, other pulses, mix of different pulses, and pulse-based products (i.e., pulses are used as an ingredient).

3.2.1.2. Data analysis

In empirical demand analysis that aims to measure the sensitivity of demand to changes in products' price and consumer income, economists usually use a system of demand equations to derive a key indicator of demand sensitivity to changes in price and income termed as elasticity. There are three types of elasticities: own-price, cross-price and income elasticities. The own-price elasticity is a measure of the percentage change in the quantity demanded of product J as a result of one per cent change in price of product J. The cross-price elasticity is a measure of the percentage change in the quantity demanded of product A as a result of one per cent change in the price of anther product (say product I). The income (or expenditure) elasticity is a measure of the percentage change in the quantity demanded of a product "caused" by one per cent change in consumers' income (or expenditure). These elasticities are computed based on the output obtained from the estimation of a demand system.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Almost Ideal Demand System (AIDS) is the most widely used system of demand equations (known as a demand system) to analyse consumer demand. The AIDS model was pioneered by Deaton and Muellbauer (1980). The popularity of this demand model among demand analysts is due to its flexibility to include parametric restrictions required for consistency with economic theory.

The AIDS model is generated from a cost minimization problem that defines the minimum expenditure necessary for a consumer to attain a specific level of utility at a given set of prices. The demand functions are obtained in the share of consumer's budget spent on product i, in time t (i.e. $\mathrm{w_{it}}$). The budget shares are obtained by logarithmic differentiation of the expenditure function relative to prices. These shares are given by:

$$w_{it} = a_i + \sum_{j=1}^{n} \gamma_{ij} lnp_{jt} + \beta_i ln\left(\frac{x_t}{p_t}\right) \qquad (1)$$

where the shares are a function of the price of commodity j (p_{jt}) and the total expenditure x_t. The price index p_t is used as a deflator to express the total expenditure in real terms. a_i is the constant coefficient (i.e. intercept) in the i^{th} share equation, γ_{ij} is the slope coefficient associated with the j^{th} good in the i^{th} share equation. It represents the change in the i^{th} product's budget share with respect to a change in j^{th} price with real expenditure held constant. The coefficient β_i represents the change in the i^{th} product's budget share with respect to a change in real expenditures with price held constant. The analysis consists in estimating the parameters γ_{ij} and β_i which will be then used to compute the conditional own-price elasticities (e_{ii}) and cross-price (e_{ij}) elasticities as well as the expenditure elasticity (e_i) as follows:

$$e_{ii} = \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i}\left(\alpha_j + \sum_{k=1}^{n} \gamma_{ij} lnp_k\right) - 1 \qquad (2)$$

$$e_{ij} = \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i}\left(\alpha_j + \sum_{k=1}^{n} \gamma_{ij} lnp_k\right) \qquad (3)$$

$$e_i = 1 + \frac{\beta_i}{w_i} \qquad (4)$$

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

3.2.2. Consumers' preferences and willingness to pay for a new pulse-based product

3.2.2.1. Data: choice experiment

The data were collected in the UK through a national web-based choice experiment. A choice experiment is a quantitative research technique that involves asking individuals to state their preference over hypothetical alternative scenarios, products or services. Each alternative is described by several attributes. Individuals' responses are used to determine whether their preferences are significantly influenced by the attributes of the studied product or service. The responses are also used to determine the relative importance of the attributes.

The initial design of the choice experiment was developed and revised based on input from a small sample of 100 respondents. The final version of the survey was administered by a market research company. A total of 1880 primary grocery shoppers in the UK completed the survey. All subjects gave their informed consent for inclusion before taking part in the study. The sample is representative of the UK population in terms of gender, age, employment status and geographical area of the country (i.e., Scotland, England, Wales, and Northern Ireland). The quality of the data was checked, and all the ineligible observations were discarded and replaced by eligible ones from new respondents.

Respondents were successively shown nine choice sets. Each choice set consists of two lasagna alternatives and an opt-out alternative. An example of one of the choice sets used in the study is displayed in Figure 4. Each alternative of lasagna is described in terms of five attributes: meat/meat substitute, type of production, the content of saturated fat, Origin, convenience, and price[1]. The attributes and their corresponding levels were chosen based on the literature and the outcome of a shelf audit that was carried out by the authors in major UK supermarkets. The attributes and their levels are displayed in Figure 5.

---

[1] Two vectors of prices were considered to test the effect of varying the levels of the attribute price on consumers' WTP in a choice experiment. All the prices used in the choice experiment are within the range of the current retail prices of lasagne. Two treatments were considered. In the first (second) treatment, respondents were shown choice sets with prices from the first (second) price vector. Respondents were randomly assigned to the two treatments.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Ngene Software was used to generate a Bayesian D-optimal design that allows robust estimation of all main and two-way interaction effects (ChoiceMetrics, 2018). The Bayesian D-optimal design was obtained after 25,000 iterations with 500 Halton draws per iteration, achieving a Db-error of 0.41. The final design of the choice experiment consisted of 36 choice sets of three alternatives each (i.e., two lasagna alternatives and the opt-out alternative). To make the choice task cognitively easier for respondents, the design was blocked in four blocks (i.e., nine choice sets per respondent).

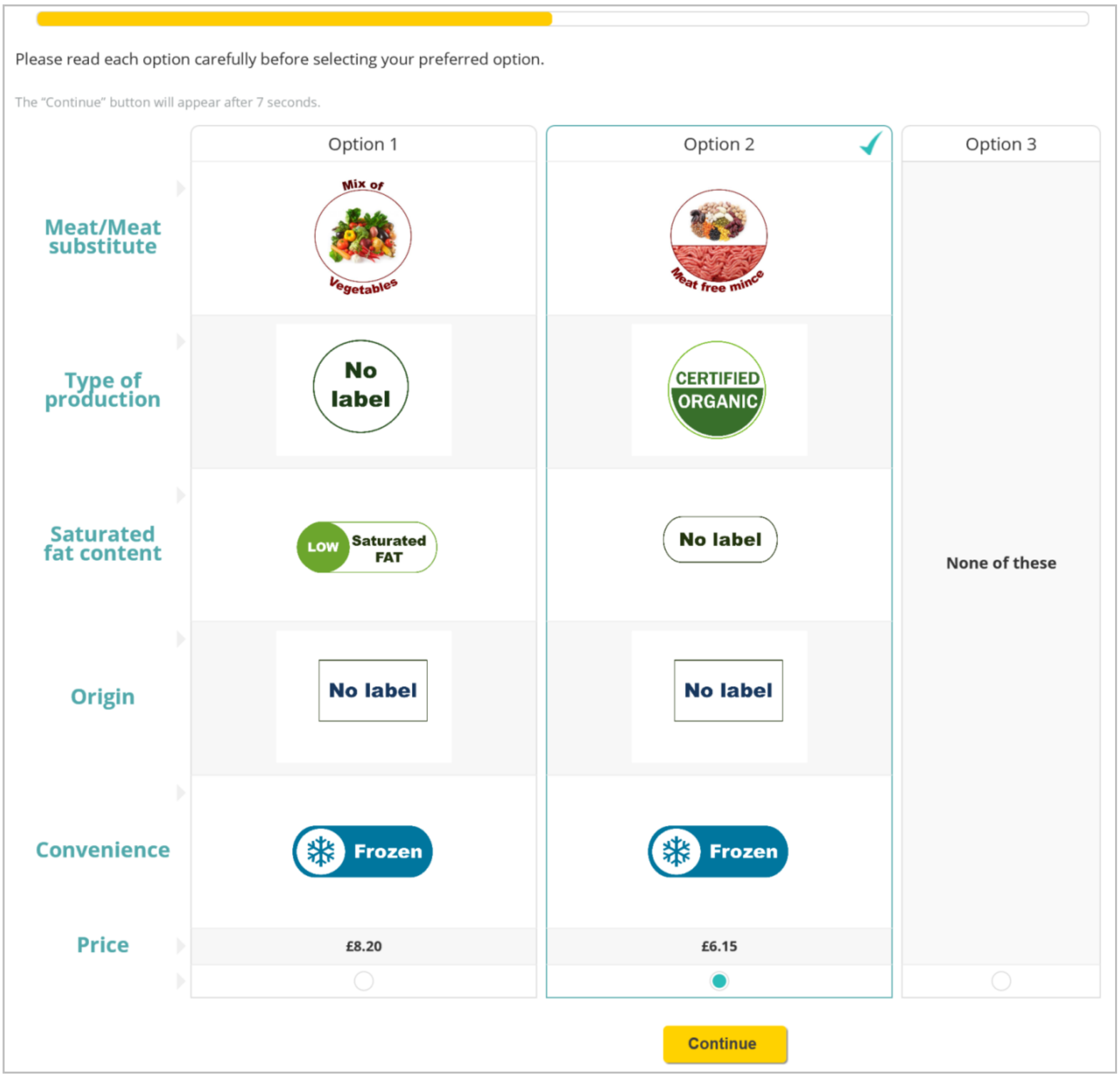
The order of showing the nine choice sets was randomised for each respondent. The choice task was followed by a questionnaire. The questionnaire was used to collect information on respondents' socio-demographic characteristics as well as their purchasing habits and attitudes toward several issues related to the consumption of pulses. The questionnaire was also used to collect information on various aspects of respondents' choice behaviour such as attribute non-attendance, certainty about choice responses, and respondents' level of altruism and free riding.

3.2.2.2. Data analysis

The data collected were analysed within a random utility framework (Lancaster, 1966). Thus, an individual *n* presented with *j* alternatives at a choice occasion *t* is expected to choose the alternative that maximises his/her utility. Following Lancaster's concept that any product is a bundle of attributes, the utility that an individual *n* derives from the consumption of a product is assumed to be equal to the sum of his/her marginal utility for each of the product's attributes. Consequently, if we assume a sample of *N* respondents who are presented with *T* choice occasions of *J* alternatives each, individual *n*'s utility (U_{njt}) from choosing the j^{th} alternative at a t^{th} choice occasion takes the form:

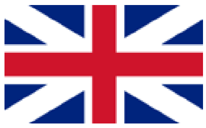
$$U_{njt} = V_{njt} + \varepsilon_{njt} \quad (5)$$

Figure 4. Example of a choice set used in this study



The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Figure 5. Attribute levels of porridge oats

Characteristic	Characteristic's levels	
Meat or meat substitute	Beef mince; Meat free mince; Mix of Beef mince & Meat free mince	Mix of Vegetables
Type of production	No label	CERTIFIED ORGANIC
Saturated fat content	No label	LOW Saturated FAT
Origin	No label	
Convenience	Chilled	Frozen
Price	£1.40 £2.10 £3.10 £4.45 £6.15 £8.20	£1.40 £2.90 £5.15 £8.15 £11.90 £16.40

where V_{njt} is the deterministic (observed) component and ε_{njt} is the random (unobserved) component. ε_{njt} is assumed to be independent and identically distributed. Assuming that the deterministic component of the utility is linear-in-parameter, equation (1) can be written as:

$$U_{njt} = \beta X_{njt} + \varepsilon_{njt} \quad (6)$$

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

where β denotes the K×1 vector of unknown utility parameters. X_{njt} represent the following level of attributes "Vegetables", "Pulse-based mince", "Mixed mince" (i.e., a mix of beef mince and pulse-based mince), "Organic", "Low Fat", "British", "Chilled", and "Price". The levels "Beef mince", "No label (for organic)", "No label (for saturated fat content), "No label (for the Britishness of the lasagne)", and "Frozen" were dropped from the estimation to avoid the problem of perfect multicolinearity. They are also used as the baseline levels when interpreting the estimated effects.
Conditional logit (CL) (McFadden,1974) is the workhorse model for analysing discrete choice data. However, its assumptions (i.e., homogeneity of respondents' preferences and the independence of the alternatives included in any choice set) do not generally hold. Revelt and Train (1998) proposed a less restrictive model (Random Parameter Logit (RPL)) that allows individuals' preferences to be heterogeneous and the assumption of the independence of alternatives to be relaxed. In the RPL, at least one parameter is specified as random. In other words, each individual is considered to have a unique set of preferences, reflected in the individual parameters β_i. Since the unconditional choice probability does not have a closed-form solution, simulation methods are used to estimate the parameters (see Revelt and Train (1998) for details).

In choice experiments, the standard approach to calculating WTP is to compute the ratio of the non-monetary attribute coefficient and the (negative of the) price coefficient. Nonetheless, using this approach can lead to heavily-skewed WTP distributions and thus result in very large WTP values. To address this problem, we estimated the RPL models in WTP space following Train and Weeks (2005). This involves estimating the distribution of respondents' willingness to pay directly by re-formulating the model in such a way that the coefficients represent the WTP measures (see Train and Weeks (2005) for more details).

Four RPL models were estimated: one using the full sample and one model for each one of the three segments of respondents (regular meat consumers, flexitarians, and vegetarian and pescatarians[2]). To test whether the differences in respondents' WTP in the different segments are statistically significant, the Complete Combinatorial Test, proposed by Poe et al. (2005), was used. The test, first,

[2] The data on vegetarians, vegans, and pescatarians were pooled due to the small sample size of these three groups.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

requires the generation of distribution of 3000 WTP estimates using the parametric bootstrapping method proposed by Krinsky and Robb (1986). Then, the complete combinatorial test is used to compare the bootstrapped WTP values in the different segments.

3.3. Results and discussion

3.3.1. Demand for pulses

The computed elasticities are displayed in Table 4. All the own-price elasticities (in the diagonal) are negative and statistically different from zero, indicating that an increase in the price of any of the food products considered in the analysis will result in a decrease in its demand.

Nonetheless, the results show that the demand for beans and peas, the most consumed pulses in the UK, is inelastic. In particular, the elasticity of -0.09 suggests that a decrease in the retail price of beans by 10% will increase the demand for beans by only 0.9%. It also suggests that to increase the demand for beans by 50%, the retail price of beans must decrease by as much as 555% (i.e., 555 = (50*10)/0.9). The results also show that the demand for peas has a low sensitivity to changes in retail prices. The own-price elasticity of -0.51 indicates that the demand for peas will increase by 5.1% if its retail price is decreased by 10%. The elasticity value also suggests an increase in the demand for peas by 50% will necessitate a retail price decrease by as much as 98%.

Therefore, the results for beans and peas suggest that a moderate decrease in retail prices of beans and peas is unlikely to result in a significant increase in its demand. Among others, this is due to (1) the considerable decrease in retail price needed to obtain a significant increase in the demand for beans and peas, (2) the retail prices of beans and peas are already low, (3) a substantial decrease in the retail prices is likely to place UK producers at a disadvantage in comparison with producers in developing countries (e.g., Egypt and India), and (4) retail prices of pulses were not found to be a barrier to the consumption of pulses as opposed to other factors such as lack convenience and cooking time and skils (Schneider, 2002; Wenrich and Cason, 2004; IPSOS, 2010; Jallinoja et al. 2016).

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

As opposed to the demand for beans and peas, the results show that demand for lentils, other pulses, mix of pulses, and pulse-based products is elastic. For instance, the own-price elasticity (-3.11) indicates that a 10% decrease in the retail price of pulse-based products will result in a 31% increase in their demand. The results also show that, e.g., a 50% increase in the demand for lentils, mix of pulses, and pulse-based products will necessitate a decrease in their retail prices, respectively, by 36%, 29%, and 16%. These results suggest that discounting the retail prices of pulse-based products could be an effective strategy to foster the demand for pulses in the UK. This conclusion is supported by the results from the estimation of cross-price elasticities (Table 4).

For instance, the results show that consumers in the UK are willing to substitute beans by pulse-based products (the cross-price elasticity (0.028) of these two products is positive and statistically significant). UK consumers were also found to perceive beans and peas as strong substitutes and peas and lentils as complements. Furthermore, the results on expenditure elasticities suggest that increasing consumers' food expenditure will lead to a slite increase in the demand for beans but a significant rise in the demand for lentils.

Overall, the results suggest that moderately discounting the retail prices of the major consumed pulses in the UK (i.e., beans and peas) is unlikely to result in a significant increase in their demand. Nonetheless, the high sensitivity of the demand for pulse-based products to price changes as well as their superiority to conventional dry pulses in terms convenience makes them a stepping-stone to foster the consumption of pulses in the UK. In the second study, we focus on investigating consumers preferences and willingness to pay for an increasingly popular pulse-based product: pulse-based mince.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Table 4. Estimated demand elasticities

	Own-price (in diagonal) and cross-price ealsticities (off diagonal)												Expenditure elasticities	P-value
	Beans	P-value	Peas	P-value	Lentils	P-value	Other pulses	P-value	Mix of pulses	P-value	Pulse-based products	P-value		
Beans	-0.0923	0.4611	0.7080	0.0000	0.0083	0.3108	0.1011	0.0000	0.0030	0.7564	0.0284	0.0051	0.1663	0.0008
Peas	1.4589	0.0000	-0.5213	0.0000	-0.0470	0.0121	-0.0834	0.1662	-0.0212	0.3546	-0.0307	0.1924	1.0363	0.0000
Lentils	2.1484	0.3160	-6.0015	0.0119	-1.4020	0.0127	0.9755	0.1490	0.0609	0.8908	0.0592	0.9133	3.2580	0.0132
Other pulses	2.3424	0.0000	-0.9337	0.1670	0.0859	0.1487	-1.9011	0.0000	-0.0718	0.3142	-0.1569	0.0398	0.4623	0.1105
Mix of pulses	0.4210	0.7460	-1.3634	0.3575	0.0307	0.8911	-0.4128	0.3146	-1.7417	0.0000	-0.3640	0.2573	-2.0524	0.0131
Pulse-based products	4.0965	0.0049	-2.1289	0.1938	0.0322	0.9134	-0.9722	0.0399	-0.3920	0.2573	-3.1163	0.0000	-1.1104	0.2177

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

3.3.2. Consumers' preferences and WTP for a pulse-based product

The RPL models were estimated using R (Apollo R package), with 1000 Halton draws to simulate the eight random parameters. All the random parameters were assumed to have a triangular distribution. The results of the estimated WTPs and their standard deviations are presented in Table 5. The results of the Poe test are displayed in Table 6. The results in Table 5 show that the estimated RPL models for panel data fit better the data when tested against constant-only conditional logit (e.g., $\chi 2$ =8344.36, p<0.01 in the case of Model 1).

The results from the estimation of Model 1 show that all the estimated standard deviations are statistically significant. This suggests that consumers WTP for the considered attributes' levels are heterogeneous, which, in turn, supports our decision of estimating the choice model for different consumer segments to uncover the heterogeneity of consumers' preferences and WTP.

A binary variable "None" was included in the estimation of the RPL model to capture respondents' preferences for the opt-out alternative. In Models 1, the estimated coefficient is negative and highly significant. This suggests that the majority of sampled respondents preferred the offered alternatives of lasagna as opposed to the opt-out alternative. The positive sign of the estimated coefficient for the opt-out alternative in Model 3 suggests that vegetarians and pescatarians respondents tended to select the opt-out alternative over the offered alternatives of lasagna. This was expected since 50% of the offered lasagnas were not suitable for them (i.e., contain beef mince).

Most importantly, the results from Model 1 suggest that, in average, UK consumers are willing to pay £3.42, £5.03, and £5.38 less for lasagna that contains a mix of beef and pulse-based mince, vegetables, and pulse-based mince, respectively, than for a lasagna that contains beef mince. In other words, the majority of sampled respondents value more beef mince than its substitutes. As expected, the results from Model 2 show that regular meat-eaters value beef mince significantly more than its substitutes. In particular, they are willing to pay £4.14, £6.21, and £6.78 less respectively for a lasagna that contains a mix of beef mince and pulse-based mince, vegetables, and pulse-based mince than for a lasagna that contains beef mince.

The results from Model 3 and 4 are remarkably different. The results show that flexitarians are willing to pay a price premium of £1.63 for a lasagna that is made of a mix of vegetables instead of beef mince. Flexitarians' price premiums for pulse-based mince and mix of beef mince and pulse-based mince relative to beef mince are equal to zero. This suggests that flexitarians are indifferent between lasagnas that contain beef mince, pulse-based mince or a mix of the two.

The results from Model 3 and 4 are remarkably different. The results show that flexitarians are willing to pay a price premium of £1.63 for a lasagna that is made of a mix of vegetables instead of beef mince. Flexitarians' price premiums for pulse-based mince and mix of beef mince and pulse-based mince relative to beef mince are equal to zero. This suggests that flexitarians are indifferent between lasagnas that contain beef mince, pulse-based mince or a mix of the two.

The results from Model 4 show that vegetarians and pescatarians are willing to pay up to £12.26 more for a vegetable lasagna than for a lasagna that contains beef mice. Interestingly, they are also willing to pay a price premium of £9.62 for the use of pulse-based mince instead of beef mince. For obvious reasons, they are indifferent between beef mince and a mix of beef mince and pulse-based mince. The results in Table 5 show that the WTP that flexitarians, vegetarians and pescatarians are willing to pay for pulse-based mince is significantly higher than what regular consumers of meat are willing to pay for this meat substitute.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Table 5. Estimated willingness to pay for the full sample (Model 1) and the three segments (Model 2: meat-eaters (MEAT), Model 3: flexitarians (FLEX), Model4: Pescatarian, vegetarians and vegans (VEG))

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	Full Sample		MEAT		FLEX		VEG	
Mean								
None	-5.06	***	-5.65	***	-4.90	***	4.39	***
Vegetables	-5.03	***	-6.21	***	1.63	***	12.26	***
Pulse-based mice	-5.38	***	-6.78	***	0.00		9.62	***
Mixed mince	-3.42	***	-4.14	***	0.00		0.00	
Organic	1.24	***	1.32	***	2.31	***	0.00	
Low fat	1.16	***	1.24	***	1.74	***	1.12	***
British	1.84	***	2.21	***	2.06	***	0.00	
Chilled	0.84	***	0.98	***	1.02	***	0.00	
Standard deviations								
None	-4.558	***	-4.808	***	-7.074	***	-4.217	***
Vegetables	-4.239	***	-3.223	***	-3.006	***	-3.099	***
Pulse-based mice	-3.535	***	-3.448	***	2.096	***	2.140	***
Mixed mince	2.756	***	2.806	***	-0.865		-3.053	***
Organic	1.642	***	1.641	***	-2.076	***	-1.606	***
Low fat	-0.603	***	-0.629	***	-1.045	***	-0.344	
British	-2.174	***	-2.381	***	-2.407	***	-1.669	
Chilled	-1.152	***	-1.417	***	1.209	***	-0.118	
Number of individuals	1880		1554		210		116	
Number of observations	16920		13986		1890		1044	
Log-likelihood (constant only)	-18588.5		-15365.2		-2076.4		-1146.9	
Log-likelihood (final)	-14416.34		-11611		1644.91		-737.7302	
Log-likelihood ratio test (X^2 value)	8344.36		7508.40		7442.62		818.34	
P-value	<0.01		<0.01		<0.01		<0.01	

Note that (***) and (**) indicate that the corresponding value is statistically significant at (1%) and (5%), respectively.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Table 6. Heterogeneity of consumers' WTP

	Average WTP			Poe test (p-value)		
	MEAT	FLEX	VEG	MEAT Vs. FLEX	MEAT vs. VEG	FLEX vs. VEG
Mean						
None	-5.65	-4.90	4.39	0.221	<0.001	<0.001
Vegetables	-6.21	1.63	12.26	<0.001	<0.001	<0.001
Pulse-based mice	-6.78	0.00	9.62	<0.001	<0.001	<0.001
Mixed mince	-4.14	0.00	0.00	<0.001	<0.001	0.185
Organic	1.32	2.31	0.00	0.009	0.078	0.003
Low fat	1.24	1.74	1.12	0.074	0.383	0.123
British	2.21	2.06	0.00	0.373	<0.001	0.009
Chilled	0.98	1.02	0.00	0.461	0.002	0.005

On average, UK consumers are willing to pay £1.24 more for a lasagna labelled as organic than for a lasagna that does not carry the label "Organic". The results also show that regular meat consumers and flexitarians are willing to pay a substantial price premium for organic lasagna, being considerably higher in the case of flexitarian consumers (£2.31 vs £1.32). Interestingly, vegetarian and pescatarian consumers were found to be indifferent between organic and non-organic lasagna.

The results displayed in Table 5 show that UK consumers also positively value low-fat lasagna. In average, consumers are willing to pay £1.16 more for a lasagna labelled as "Low Saturated Fat" relative to a lasagna that does not carry this label. Consumers in the three segments were also found to positively value lasagnas with low content of saturated fat, being the highest in the case of flexitarians (£1.74) and the lowest in the case of vegetarian and pescatarian consumers (£1.12). Notice, however, that vegetarians and pescatarians' WTP for the label "Low Saturated Fat" is significantly higher than their WTP for the label organic. As opposed to the labels "Organic", "British", and "Chilled", the label "Low Saturated Fat" is the only label that vegetarian and pescatarian consumers are willing to pay a price premium for.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

As regard respondents' preferences for the Britishness of the product, the results show that, in average, UK consumers are willing to pay £1.84 more for lasagna labelled as "British" than for a lasagna that does not carry this label. Furthermore, among the labels "Organic", "Low Saturated Fat", "British", and "Chilled", the label "British" stands out by being the most valued label. This is the case for regular meat-eaters. Flexitarians are also willing to pay a considerable price premium for the label "British" (£2.06), however, their price premium for the label "Organic" is 12% higher. Interestingly, the results show that vegetarian and pescatarians consumers are not willing to pay a price premium for British lasagna.

Finally, the results show that the majority of UK consumers prefer lasagna to be chilled. They are willing to pay £0.84 more for chilled lasagna than for frozen lasagna. However, this label "Chilled" is the least positively valued label in comparison with the labels "Organic" (£1.24), "Low Saturated Fat" (£1.16), and "British" (£1.84). Similar to their preferences for the labels "Organic" and "British", vegetarian and pescatarian consumers were found to be indifferent between chilled and frozen lasagnas. Furthermore, the results displayed in Table 6 show that vegetarians and pescatarians' "price premium" (£0.00) for the labels "Organic", "British", and "Chilled" is significantly lower than the price premium that flexitarians and regular meat-eaters are willing to pay for the same labels.

3.3.2.1. Discussion and conclusion

The results that the value that regular consumers of meat, who represent the majority of UK consumers, place on pulse-based mince is significantly lower than their value for beef mince. This suggests that at a retail price difference of less than £6.78, it is unlikely that regular meat-eaters would choose lasagna with pulse-based mince over a lasagna that contain beef mince instead. Nonetheless, there is an opportunity to increase the consumption of pulse-based meat substitutes by regular consumers of meat. In fact, the results show that regular meat-eaters are willing to pay a price premium of £2.05 for a lasagna that contains a mix of beef and pulsed-based mince than a lasagna that only contain pulse-based mince. Therefore, a way to foster the demand for pulse-based products is to use pulses as a partial substitute of meat (e.g., a mix of the two).

Promoting the benefits of consuming pulse-based products as well as addressing the barriers that are hindering their intake could also foster their consumption. In the questionnaire that respondents completed after finishing the choice task, we asked them about their motivations/deterrents of consuming pulse-based products. We found that 75% of regular meat-eaters revealed to mainly eat pulse-based products because they are a good source of proteins. This is signalling the importance of promoting the well-documented richness of pulses in proteins and fibres. In other words, pulse-based products should be clearly labelled as high in proteins and fibres.

In line with previous studies (e.g., Wenrich and Cason, 2004; IPSOS, 2010), we found that the majority of regular meat consumers revealed that the lack of knowledge on how to cook pulses is the main barrier to the purchase and consumption of pulses. This result is suggesting that regular meat consumers are more likely to buy and consume pulses and pulse-based products if they are cooked (e.g., baked beans, ready-to-eat soups) or are available in forms that do not require specific cooking knowledge and skills (e.g., ingredients in an easy-to-cook meal such as lasagna). This result is also supported by finding from the questionnaire that showed that 75% and 47% of respondents, who identified themselves as regular meat consumers, revealed to eat pulses when they are baked or used as an ingredient in a ready meal, respectively.

In addition to promoting the high protein and fibre content of pulses and pulse-based products as well as making them available in a convenient form (e.g., as an ingredient in a cooked meal), the results show that the acceptance of pulse-based products can be fostered if they are also labelled as "Organic", "Low Saturated Fat", and/or "British". In line with the findings from a growing body of literature (e.g., Akaichi et al., 2020) on consumers' preferences for desirables food attributes (e.g., organic, local, healthy), we found that regular consumers of meat are willing to pay a considerable price premium for the use of the labels "Organic", "Low Saturated Fat", and "British". Labelling pulse-based meat substitutes as "Organic", "Low Saturated Fat", and/or "British" could increase their desirability as well as reduce the preference gap between them and meat. For instance, the results in Table 5 show that regular meat consumers are willing to pay £4.14 less for lasagna whose main ingredient is a mix of beef and pulse-based mince than beef lasagna. If the lasagna with a mix of beef pulse-based mince is labelled as "Organic", "Low Saturated Fat", and "British" and the beef

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

lasagna does not carry these labels, the difference in price premium between the two products passes from -£4.14 to £1.61 (i.e.,-4.14+1.32+1.24+2.21+0.98 = 1.61), in favour of the lasagna made of a mix of beef and pulse-based mince. Nonetheless, it is noteworthy that since desirable food attributes (e.g., organic, low fat, local) are not exclusive to meat substitutes, they can be used by meat producers and marketers to increase the desirability of meat vis-à-vis meat substitutes (e.g., organic and British beef mince versus British pulse-based mince).

The results also showed that regular meat consumers prefer the lasagna to be chilled as opposed to frozen lasagna, independently of whether it is made of meat or meat substitutes. However, this result cannot be generalized to most of the pulse-based food products, especially to those products that are not destined to be consumed over a short period of time (e.g., a bag of ten pulse-based burgers). Fortunately, nowadays, many of the marketed chilled food products are also freezable.

In line with previous studies (e.g., Jallinoja et al., 2016; Spencer, 2018; de Boer, 2019), flexitarians, vegetarians, and pescatarians were found to be more likely to buy pulse-based meat substitutes in comparison with regular meat consumers. In particular, flexitarians were found to be indifferent between the use of beef mince, pulse-based mince and a mix of beef and pulse-based mince in lasagna. This suggests that marketing strategies that increase the value of the lasagna with pulse-based lasagna in the eyes of flexitarians could foster its consumption. These strategies include selling the pulse-based lasagna at a retail price lower than the retail price of beef lasagna, promoting the high protein and fibre content of the pulse-based meat substitutes[3], labelling pulse-based lasagna as "Organic", "Low Saturated Fat", and/or "British". Similar to regular consumers of meat, flexitarians prefer the lasagna to be chilled.

The results also showed that vegetarians and pescatarians are potential buyers of pulse-based lasagna. In fact, they are the only sampled consumers who are willing to pay a price premium for the use of pulse-based mince as a beef mince substitute in lasagna. We also found that their demand for pulse-based lasagna can be fostered if the lasagna is labelled as having low saturated fat. Analysing

[3] This is because we found that 80% of flexitarians consume pulses and pulse-based products mainly because of their high content of proteins and fibres.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

the questionnaire data, we found that vegetarians and pescatarians mainly consume pulses and pulse-based products because they are suitable for vegetarians and they are high in proteins and fibres. This suggests that promoting the high protein and fibre content of pulse-based lasagna as well as clearly labelling it as suitable for vegetarians can increase its consumption by vegetarians and pescatarians. Interestingly, we found that vegetarians and pescatarians are not willing to a price premium for a lasagna that carries the labels "Organic" and "British". They are also indifferent between chilled and frozen lasagnas. Further research is needed to uncover the reasons behind their indifference vis-à-vis the use of the labels "Organic" and "British".

Finally, it is noteworthy that the use of vegetables (other than pulses) as a meat substitute is a potential competitor of pulse-based meat substitutes. In fact, we found that regular meat-eaters, flexitarians, vegetarians, and pescatarians value more the use of vegetables to substitute beef mince in lasagna than the use of pulse-based mince. Therefore, when valuing the use of pulses as a meat substitute, it is recommended to take into account not only how consumers trade off meat and pulse-based meat substitutes but also how this later is traded off with other meat substitutes such vegetables.

Acknowledgement

This research is supported by the EU Horizon2020 Research and Innovation Programme project 'TRansition paths to sUstainable legume-based systems in Europe' (TRUE, www.true-project.eu) funded under Grant Agreement number 727973. Scotland's Rural College (SRUC) is supported by the Scottish Government's Rural and Environmental Science and Analytical Services (RESAS), a Division of the Scottish Government. Farmer survey data was funded under RESAS SRP Work Package 2.4 'Rural Industries' (2016-2021) and WP4.1 'Adaptation to change in land-based and other rural industries' (2011-2016). We are grateful to the respondents to both farmer and consumer surveys.

References

Adrian, A.M., Norwood, S.H., & Mask, P.L. (2005). Producers' perceptions and attitudes toward precision agriculture technologies. Computers and Electronics in Agriculture 48, 256–271

Akaichi, F. (2019). British consumers' demand for legumes. Presentation at the 'Transition paths to sustainable legume-based systems in Europe' TRUE annual meeting, Porto, July 2019

Akaichi, F., Revoredo Giha, C., Glenk, K., & Gil, J. M. (2020). How Consumers in the UK and Spain value the coexistence of the claims low fat, local, organic and low greenhouse gas emissions. Nutrients 12(1), 120.

Areal, F.J., Riesgo, L., &Rodriguez-Cerezo, E. (2011). Attitudes of European farmers towards GM crop adoption. Plant Biotechnology Journal 9, 945–957

Bollen KA. Structural equations with latent variables. New York: John Wiley and Sons, 1989

ChoiceMetrics. (2018). Ngene User Manual. Available at: http://www.choice-metrics.com/NgeneManual120.pdf

Cowen, R., & Gunby, P. (1996). Sprayed to death: path dependence, lock-in and pest control strategies. The Economic Journal 5(106), 521–542

de Boer, J., & Aiking, H. (2019). Strategies towards healthy and sustainable protein consumption: A transition framework at the levels of diets, dishes, and dish ingredients. Food quality and preference, 73, 171-181.

Deaton, A., & Muellbauer, J. (1980). An almost ideal demand system, The American economic review, Vol 70 No 3, pp 312-326.

Dobbs, R., Sawers, C., Thompson, F., Manyika, J., Woetzel, J., Child, P., & Spatharou, A. (2014). How the world could better fight obesity| McKinsey & Company. https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/how-the-world-could-better-fight-obesity

Dorfman, J.H. (1996). Modeling Multiple Adoption Decisions in a Joint Framework. American Journal of Agricultural Economics 78, 547-557

European Parliament's Committee on Agriculture and Rural Development. (2013). Environmental role of protein crops in the new common agriculture policy. Brussels: European Parliament. Retrieved from:

http://www.legumefutures.de/images/The_environmental_role_of_protein_crops_in_the_new_Common_Agricultural_Policy.pdf

FAO. (2016). The Global Economy of Pulses. Available at: http://www.fao.org/3/i7108en/i7108en.pdf [Accessed 20 February 2020].

FAO. (2019). The International Year of Pulses. [Online]. Available at: http://www.fao.org/es/faodef/ [Accessed 6 August 2018].

Finney, S.J., & DiStefano, C. (2006). Non-normal and Categorical data in structural equation modeling. In G.R.

Ghadim, A.K.A., Pannell, D.J. (1999). A conceptual framework of adoption of an agricultural innovation. Agricultural Economics 21, 145-154

Hägerstrand, T. (1952). The propagation of innovation waves. Lund studies in geography. Series B, Human geography no. 4. Lund: Royal University of Lund, Department of Geography

Hair, J. F., Black, W., Babin, B., Anderson, R.E., & Tatham, R.L. (2006). Multivariate data analysis. 6th edition, Upper Saddle River, NJ: Pearson Prentice Hall

Henchion, M., Hayes, M., Mullen, A. M., Fenelon, M., & Tiwari, B. (2017). Future protein supply and demand: strategies and factors influencing a sustainable equilibrium. Foods, 6(7), 53.

Hsiao, C. (2014), Analysis of panel data (Vol. 54). Cambridge university press.

IPSOS. (2010). Factors influencing pulse consumption in Canada. Available at: https://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/sis13117/$FILE/v4_factors_influencing_pulse_consumption_summary_feb24_2010.pdf [Accessed 20 February 2020]

Jallinoja, P., Niva, M., & Latvala, T. (2016). Future of sustainable eating? Examining the potential for expanding bean eating in a meat-eating culture. Futures 83, 4-14.

Jöreskog, K. G., & Sörbom, D. (2007). LISREL8.80: structural equation modeling with the SIMPLIS command language. Chicago, USA: IL Scientific Software International

Khanna, M. (2001). Sequential adoption of site-specific technologies and its implications for nitrogen productivity: a double selectivity model. American Journal of Agricultural Economics 83, 35–51

Köpke, U., & Nemecek, T. (2010). Ecological services of faba bean. Field Crops Research 115(3), 217-233.

Krinsky, I., & Robb, A. L. (1986). On approximating the statistical properties of elasticities. The Review of Economics and Statistics, 715-719.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Lancaster, K. J. (1966). A new approach to consumer theory. Journal of political economy, 74(2), 132-157

Läpple, D., Renwick, A., & Thorne, F. (2015). Measuring and understanding the drivers of agricultural innovation: Evidence from Ireland. Food Policy 51, 1–8

Larson, J. A., Roberts, R. K., English, B. C., Larkin, S. L., Marra, M. C., Martin, S. W., et al. (2008). Factors affecting farmer adoption of remotely sensed imagery for precision management in cotton production. Precision Agriculture 9(4), 195–208

Lascialfari, M., Magrini, M. B., & Triboulet, P. (2019). The drivers of product innovations in pulse-based foods: Insights from case studies in France, Italy and USA. Journal of Innovation Economics Management (1), 111-143.

Luciane, W. (2018). Moving past meat consumption: is there room for pulses on the British plate? MSc dissertation. University of Edinburgh

Marinangeli, C. P. F., Julianne Curran, Barr S. I., Slavin, J., Puri, S., Swaminathan, S., Tapsell, L., & Patterson, C. A.. (2017). Enhancing nutrition with pulses: defining a recommended serving size for adults. Nutrition Reviews 75(12), 990-1006

McFadden. (1974). Conditional logit analysis of qualitative choice behaviour. University of California at Berkeley. https://eml.berkeley.edu/reprints/mcfadden/zarembka.pdf

Mills, J., Ingram, J., Dibari, C., Merante, P., Karaczun, Z., Molnar, A., Sánchez, B., Iglesias, A., Ghaley, B.B. (2019). Barriers to and opportunities for the uptake of soil carbon management practices in European sustainable agricultural production. Agroecology and Sustainable Food Systems, DOI: 10.1080/21683565.2019.1680476

Mudryj, A. N., Yu, N., & Aukema, H. M. (2014). Nutritional and health benefits of pulses. Applied Physiology, Nutrition, and Metabolism 39(11), 1197-1204.

Muthén B. (1984) A general structural equation model with dichotomous, ordered categorical, and continuous latent variable indicators. Psychometrika 49, 115–132

National Health Service (2018). Beans and pulses in your diet. https://www.nhs.uk/live-well/eat-well/beans-and-pulses-nutrition. Accessed February 04, 2020.

Nayak, G. K., Roberts, S. P, M., Garratt, M., Breeze, T. D., Tscheulin, T., Harrison-Cripps, J., Vogiatzakis, I.N., Stirpe, M. T., & Potts, S. G. (2015). Interactive effect of floral abundance and semi-natural habitats on pollinators in field beans (Vicia faba). Agriculture, Ecosystems & Environment 199, 58-66.

Niva, M., Vainio, A., & Jallinoja, P. (2017). Barriers to increasing plant protein consumption in Western populations. In Vegetarian and plant-based diets in health and disease prevention (pp. 157-171). Academic Press.

Oré Barrios, C., Mäurer, E., & C. Lippert (2020): Factors determining the spatial distribution of grain legume cultivation in the EU. In: Schriften der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V. 55, In Press.

Poe, G. L., Giraud, K. L., & Loomis, J. B. (2005). Computational methods for measuring the difference of empirical distributions. American Journal of Agricultural Economics 87(2), 353-365.

Rauniyar, G.P. and Goode, F.M. (1992). Technology adoption on small farms. World Development 20, 275-282

Revelt, D., & Train, K. (1998). Mixed logit with repeated choices: households' choices of appliance efficiency level. Review of Economics and Statistics 80(4), 647-657.

Rogers, E. M., & Shoemaker, F. (1971). Communication of innovation: a cross cultural approach. Free Press, New York.

Sanyang, S.E., Kao, T-C., & Haung, W-C. (2009). Comparative study of sustainable and non-sustainable interventions in technology development and transfer to the women's vegetable gardens in the Gambia. Journal of Technology Transfer 34, 59–75.

Shapiro, B.I., B.W. Brursen, & Doster, D.H. (1992). Adoption of double-cropping soybeans and wheat. Southern Journal of Agricultural Economics 24, 33-40.

Soule, M., Tegene, A. & Wiebe, K. (2000). Land Tenure and the adoption of conservation practices. American Journal of Agricultural Economics 86, 993-1005.

Sozer, N., Holopainen ‐ Mantila, U., & Poutanen, K. (2017). Traditional and new food uses of pulses. Cereal Chemistry, 94(1), 66-73.

Spencer, M., Cienfuegos, C., & Guinard, J. X. (2018). The Flexitarian Flip™ in university dining venues: Student and adult consumer acceptance of mixed dishes in which animal protein has been partially replaced with plant protein. Food Quality and Preference, 68, 50-63.

Stagnari, F., Maggio, A., Galieni, A., & Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: an overview. Chemical and Biological Technologies in Agriculture 4(1), 2.

sustainable agricultural production, Agroecology and Sustainable Food Systems, DOI:10.1080/21683565.2019.1680476

Teklewold, H., Kassie, M., Shiferaw, B., & Köhlin, G. (2013). Cropping system diversification, conservation tillage and modern seed adoption in Ethiopia: Impacts on household income, agrochemical use and demand for labor. Ecological Economics 93, 85–93

Toma, L., Barnes, A., Sutherland, L-A, Thomson, S., Burnett, F., & Mathews, K. (2018). Impact of information transfer on farmers' uptake of innovative crop technologies. A structural equation model applied to survey data. Journal of Technology Transfer 43, 864–881

Train, K., & Weeks, M. (2005). Discrete choice models in preference space and willingness-to-pay space (pp. 1-16). Springer Netherlands.

Wenrich, T. R., & Cason, K. L. (2004). Consumption and perceptions of soy among low-income adults. Journal of Nutrition Education and Behavior 36 (3), pp.140–145.

Wheeler, S.A. (2009). Exploring the influences on Australian agricultural professionals' genetic engineering beliefs: an empirical analysis. Journal of Technology Transfer 34, 422–439

Wu, J.J., & Babcock, B.A. (1998). The choice of tillage, rotation, and soil testing practices: economic and environmental. American Journal of Agricultural Economics 80, 494–511

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Disclaimer

The information presented here has been thoroughly researched and is believed to be accurate and correct. However, the authors cannot be held legally responsible for any errors. There are no warranties, expressed or implied, made with respect to the information provided. The authors will not be liable for any direct, indirect, special, incidental or consequential damages arising out of the use or inability to use the content of this publication.

Copyright

Citation

Please cite this report as follows:

Toma, T., Akaichi, F., Shrestha, S., Barnes, A., Zimmermann, B., Oré Barrios, C., Krimly, T., Angenendt, E., Lippert, C., Bienkowski, D., Iannetta, P.P.M. (2020). Behavioural analysis of farmers' and consumers' choice for legume uptake. Deliverable (D) 6.2 (D37) for the EU-H2020 funded project, '*TRansition paths to sUstainable legume-based systems in Europe*' (*TRUE)* - Grant Agreement Number 727973. 10.5281/zenodo.3719183.

Also available online at: www.true-project.eu.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Appendix I: Background to the TRUE-Project

TRUE Project Executive Summary

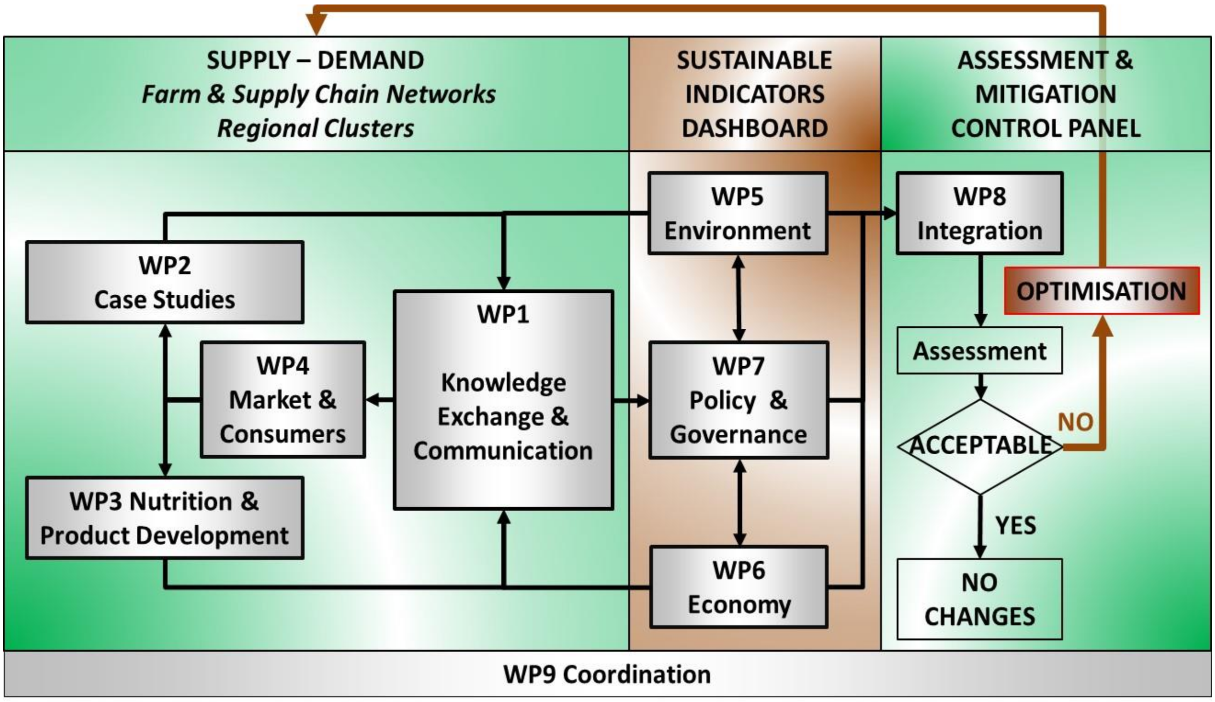
TRUE's perspective is that the scientific knowledge, capacities and societal desire for legume supported systems exist, but that practical co-innovation to realise transition paths have yet to be achieved. TRUE presents 9 Work Packages (WPs), supported by a *Intercontinental Scientific Advisory Board*. Collectively, these elements present a strategic and gender balanced work-plan through which the role of legumes in determining '*three pillars of sustainabilit*y' – '*environment*', '*economics'* and '*society'* - may be best resolved.

TRUE realises a genuine multi-actor approach, the basis for which are three *Regional Clusters* managed by WP1 ('*Knowledge Exchange and Communication',* University of Hohenheim, Germany), that span the main pedo-climatic regions of Europe, designated here as: *Continental*, *Mediterranean* and *Atlantic,* and facilitate the alignment of stakeholders' knowledge across a suite of 24 Case Studies. The Case Studies are managed by partners within WPs 2-4 comprising '*Case Studies'* (incorporating the project database and *Data Management Plan*), '*Nutrition and Product Development'*, and '*Markets and Consumers'.* These are led by the Agricultural University of Athens (Greece), Universidade Catolica Portuguesa (Portugal) and the Institute for Food Studies & Agro Industrial Development (Denmark), respectively. This combination of reflective dialogue (WP1), and novel legume-based approaches (WP2-4) will supplies hitherto unparalleled datasets for the '*sustainability WPs*', WPs 5-7 for '*Environment'*, '*Economics'* and '*Policy and Governance'.* These are led by greenhouse gas specialists at Trinity College Dublin (Ireland; in close partnership with Life Cycle Analysis specialists at Bangor University, UK), Scotland's Rural College (in close partnership with University of Hohenheim), and the Environmental and Social Science Research Group (Hungary), in association with Coventry University, UK), respectively. These *Pillar WPs* use progressive statistical, mathematical and policy modelling approaches to characterise current legume supported systems and identify those management strategies which may achieve sustainable states. *A key feature* is that TRUE will identify key *Sustainable Development Indicators* (SDIs) for legume-supported systems, and thresholds (or goals) to which each SDI should aim. Data from the *foundation WPs* (1-4), to and between the *Pillar WPs* (5-7), will be resolved by WP8, '*Transition Design',* using machine-learning approaches (*e.g. Knowledge Discovery in Databases*), allied with *DEX* (*Decision Expert*) methodology to enable the mapping of existing knowledge and experiences. Co-ordination is managed by a team of highly experienced senior staff and project managers based in The Agroecology Group, a Sub-group of Ecological Sciences within The James Hutton Institute.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Work Package Structure

Flow of information and knowledge in TRUE, from definition of the 24 case studies (left), quantification of sustainability (centre) and synthesis and decision support (right).



The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

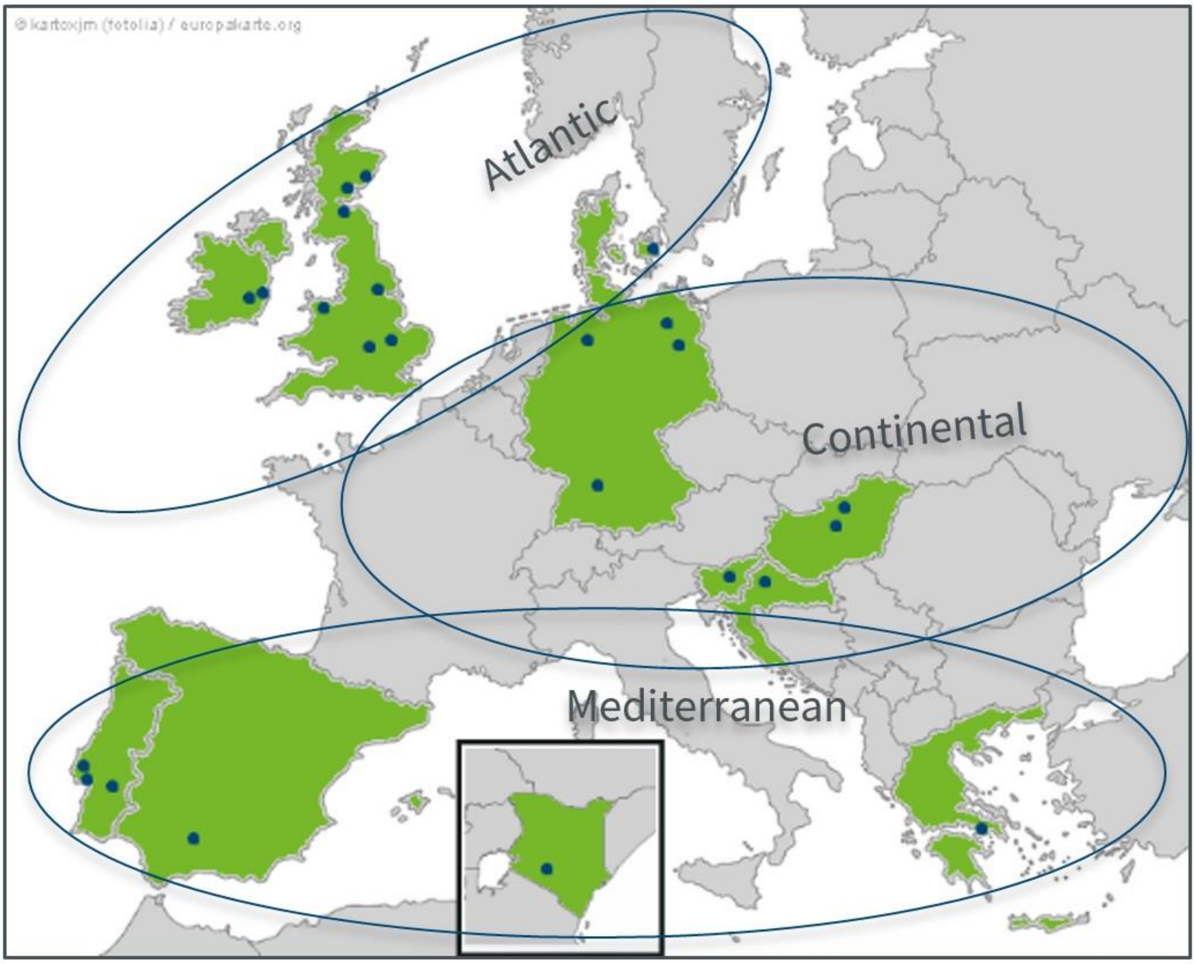
Project Partners

Nº.	Participant organisation name (and acronym)	Country	Organisation Type
1 (C*)	The James Hutton Institute (JHI)	UK	RTO
2	Coventry University (CU)	UK	University
3	Stockbridge Technology Centre (STC)	UK	SME
4	Scotland's Rural College (SRUC)	UK	HEI
5	Kenya Forestry Research Institute (KEFRI)	Kenya	RTO
6	Universidade Catolica Portuguesa (UCP)	Portugal	University
7	Universität Hohenheim (UHOH)	Germany	University
8	Agricultural University of Athens (AUA)	Greece	University
9	IFAU APS (IFAU)	Denmark	SME
10	Regionalna Razvojna Agencija Medimurje (REDEA)	Croatia	Development Agency
11	Bangor University (BU)	UK	University
12	Trinity College Dublin (TCD)	Ireland	University
13	Processors and Growers Research Organisation (PGRO)	UK	SME
14	Institut Jozef Stefan (JSI)	Slovenia	HEI
15	IGV Institut Für Getreideverarbeitung Gmbh (IGV)	Germany	Commercial SME
16	ESSRG Kft (ESSRG)	Hungary	SME
17	Agri Kulti Kft (AK)	Hungary	SME
18	Alfred-Wegener-Institut (AWI)	Germany	RTO
19	Slow Food Deutschland e.V. (SF)	Germany	Social Enterprise
20	Arbikie Distilling Ltd (ADL)	UK	SME
21	Agriculture And Food Development Authority (TEAG)	Ireland	RTO
22	Sociedade Agrícola do Freixo do Meio, Lda (FDM)	Portugal	SME
23	Eurest -Sociedade Europeia De Restaurantes Lda (EUR)	Portugal	Commercial Enterprise
24	Solintagro SL (SOL)	Spain	SME
25	Public Institution for Development of Međimurje REDEA (PIRED)	Croatia	Development Agency

*Coordinating institution

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.

Legume Innovation Networks



Knowledge Exchange and Communication (WP1) events include three TRUE European Legume Innovation Networks (ELINs) and these engage multi-stakeholders in a series of focused workshops. The ELINs span three major biogeographical regions of Europe, illustrated above within the ellipsoids for Continental, Mediterranean and Atlantic zones.

The TRUE-Project has received funding from the European Commission *via* the Horizon 2020 Research and Innovation Action Programme under Grant Agreement Number 727973.