Brexit: How might UK Agriculture Thrive or Survive?

Final report

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Short Executive Summary

1. The UK agri-food sector will be one of the most seriously affected by Brexit. Not only is it dependent on trade relations both with the European Union and with the Rest of the World, but it is also a sector dependent on migrant labour, and the most heavily subsidised and regulated under the present Common Agricultural Policy (CAP).

2. The research shows that under selected trade scenarios the impact of Brexit on UK agriculture will be far from uniform.

3. The trade scenario effects depend on the net trade position, and/or world prices. Under a Free Trade Agreement (*FTA*) with the EU, agricultural impacts are relatively modest. By contrast, unilateral removal of import tariffs (*UTL*) has significant negative impacts on prices, production and incomes. Adoption of the current EU's *WTO* tariff schedule for all imports (including those from the EU) favours net importer sectors (e.g., dairy) and harms net exporter sectors (e.g., sheep).

4. These trade effects, however, might be overshadowed by the foreign exchange rate and possible labour market changes and other non-tariff barriers.

5. Given the dependence of many UK farms on CAP direct payments, their removal, predictably, worsens the negative impacts of new trade arrangements and offsets positive impacts. Indeed, the elimination of direct payments will affect most farm businesses, but the magnitude varies significantly by enterprise and devolved administration.

6. The research shows differences in effects at farm and sector level, implying that although the agricultural industry can survive and adapt there is likely to be considerable hardship for individuals, families and businesses.

7. Changes in the agricultural industry could have more far reaching effects in other sectors, such as food processing.

8. Changes in land use may relieve environmental pressures, for example in areas experiencing over grazing, but could increase risks of pollution in others. Consideration will be needed for policies to manage any transition.

9. The Westminster and devolved governments may need to consider the implications of such changes for people, the food supply, land use and the countryside, and their responses and policy approaches to managing this may vary.

10. However, uncertainty during negotiations regarding the Withdrawal Agreement has been (and continues to be at the time of writing) a major problem, making it extremely difficult for farmers and the agri-food industry to plan for the future.

Executive Summary

Research Objectives, Scenarios and Models

- The UK agri-food sector will be one of the most seriously affected by Brexit. Not only is it dependent on trade relations both with the European Union and with the Rest of the World, but it is also a sector dependent on migrant labour, and the most heavily subsidised and regulated under the present Common Agricultural Policy (CAP). UK farmers are guaranteed to receive the same level of subsidy as under the CAP until the end of 2022. Despite these efforts, the lack of concrete policy decisions and the uncertainty that surrounds the terms of negotiations with the EU make this period difficult for farm business planning.

- This report assesses the economic impacts of a selected number of UK trade and domestic agricultural policy scenarios following Brexit by integrating state of the art economic modelling approaches at macro, sector and farm levels. It provides the UK Government, its devolved administrations and other stakeholders (e.g. levy boards, farmers and farmers' organisations) with a cohesive and robust analytic capacity to support future policy decision making.

- The project harnesses existing model frameworks and expertise to integrate trade and macroeconomic relationships with the structure and performance of the UK agricultural sector and to disaggregate macro and sector projections to the farm level.

- The possible effects of selected trade and domestic policy alternatives are estimated using both an agriculture specific variant of the well-known Global Trade Analysis Project (GTAP) multi-region computable general equilibrium (CGE) model and the UK-FAPRI partial equilibrium (PE) model. Both approaches are employed to provide sector-wide economic estimates of the possible consequences of Brexit (e.g. supply, demand, prices, exports, imports and welfare). Macro-economic projections provided by Global Insight, supplemented by data sources from the World Bank as necessary were used in both CGE and FAPRI models.

- Sectoral projections were disaggregated using farm-level models to assess impacts of Brexit scenarios on production decisions and farm household incomes. Two modelling frameworks (i.e., a farm level dynamic linear programming model, ScotFarm, and a static budgetary simulation using UK Farm Business Survey data for 2013/14 -2105/16 for 2,803 farms) were employed to estimate potential effects (e.g. financial performance) of Brexit scenarios on commercial farms across the UK as a whole, the devolved administrations and farm types.

- By individually modelling all farm businesses in the combined FBS samples for England, Wales, Scotland and Northern Ireland we consider the inherent heterogeneity within the UK farm population and, using FBS weights, simulated scenario impacts for the individual farm businesses could be 'raised' to provide a robust assessment of those impacts across the farm population as a whole.

- The FBS sample was weighted using calibrated inverse sampling fractions to provide statistically representative data for a population of approximately 100,000 commercial farming businesses with output of at least €25,000 per annum and at least 0.5 Standard Labour Requirement (SLR). These businesses represent about half (47%) of UK holdings in 2015/16 but they account for more than 90 percent of total agricultural output.

- Further analysis at the farm level decomposes the estimated impacts to ascertain characteristics of more vulnerable segments of the farm population. Sensitivity analysis to investigate mitigating factors such as farm productivity improvements, reduction in land rents and the Sterling devaluation was also carried out. It also estimates the impact of the selected Brexit policy scenarios on the viability, sustainability and vulnerability of UK farm households by devolved administration, farm type and farmer's age.

- The report also explores how to reconcile and interpret the macro, sector and farm level results, and their implications for UK agricultural policy development post Brexit.

- A literature review and the opening workshop with the project's Advisory Panel (May 2017) led to the selection of a limited number of trade and domestic policy scenarios. The scenarios were chosen to represent a broad range of feasible options for: i) *trade relations* with the EU and the Rest of World; ii) *domestic UK policy* for direct payments to farmers (currently the Basic Payments Scheme).

- To distinguish between the trade and domestic policy effects, the report estimates the potential effects of different trade agreements by modelling three scenarios with (+) and without Direct Payments (-) (i.e. Basic Payment Scheme) as follows:

Free Trade Agreement (FTA)	**Unilateral Trade Liberalisation (UTL)**	**World Trade Organisation (WTO)**
• comprehensive UK/EU Free Trade Agreement with UK-EU tariffs at zero • UK adopts the EU common tariff schedule on Rest of World imports • UK maintains share of EU Tariff Rate Quotas applying to Rest of World imports • additional trade costs of 5 per cent (livestock) and 2 per cent (crops) for UK↔EU trade flows	• an extreme free-trade scenario • elimination of all UK import tariffs for Rest of World including imports from the EU • UK-EU exports subject to EU Common Custom Tariffs (CCT) • TRQs on UK-EU exports • additional trade costs of 10 per cent (livestock) and 5 per cent (crops) for UK↔EU trade flows	• no agreement by March 2019, hence a fall back to WTO rules and current EU tariff schedules • UK trading with EU and Rest of World under WTO Most Favoured Nation tariffs • requires a UK allocation of a share of the current EU tariff rate quotas with Rest of the World • additional trade costs of 8 per cent (livestock) and 4 per cent (crops) for UK↔EU trade flows

- These six scenarios were compared with a Baseline which assumes continued membership of an unchanged EU Single Market and CAP as envisaged in 2019/20, but with no projected changes to the CAP or EU or UK trade relations beyond 2019. Each scenario is run over a modelling period from 2017 to 2026, with Brexit scenarios beginning in 2019. A phased-out of direct payments over a 5-year period (2020-2025) involving a straight-line reduction of current payment levels to zero in 2025, was considered as appropriate. The outcomes in the final year (2026) represent the longer-run projections of the consequences of the scenarios.

- There are two major conditioning factors for the economic effects of Brexit policy scenarios on UK agriculture: i) the increased restrictions on migrant labour; and ii) the sterling exchange rate, both with the Euro and with the US dollar. Given the resources available for this project, and of the major aim of providing clear and understandable policy analysis for public debate and policy decision-making, the report treats both these major considerations through some limited sensitivity analysis.

Estimated impacts on the wider economy and at the sector level: CGE results

- The UK is a net importer of agricultural and food products. The impact of the scenarios is heterogeneous across individual UK agricultural and food activities. It is conditioned by the degree of relative trade competitiveness (i.e., relative tariffs) and trade openness in each UK sector. A decomposition of the results compared with the Baseline by the underlying trade shocks drivers, reveals that each policy tool (e.g., EU/UK trade costs, UK/ROW import tariffs) can have conflicting impacts on production and prices.

- All three trade scenarios are unfavourable for UK macro growth. WTO reduces UK macro growth the most (0.42% per annum average), UTL the least (0.22% per annum average). The detrimental impact to the EU27 is relatively minor – 0.04% of GDP in all three scenarios. As expected, in macroeconomic terms, the removal of Pillar 1 CAP support is beneficial to UK macro growth, although negligible.

- Under FTA scenario, the rising protection afforded to domestic UK industries (increased UK trade costs on EU imports) benefits domestic primary agriculture and food processing production. Given the assumptions regarding trade costs, livestock sectors benefit more than the crops sector, particularly the white meat supply chain.

- Under UTL scenario, the effect of opening up the UK's agri-food sectors to the non-EU regions has a detrimental impact on the vertical supply chains of red meat, white meat and sugar, as well as wheat production. On the other hand, the 'large' sectors of horticulture, dairy and 'other food' benefit, whilst 'vegetable oils and fats' production (small sector) almost doubles in size, with concomitant increases in upstream oilseeds. Overall, primary agricultural output falls slightly compared with the Baseline (due to livestock output contractions), whilst food processing output rises by 2%.

- In the WTO scenario, the driver of rising UK protectionism on UK agri-food activities is very strong for the UK red and white meat vertical supply chains. On the other hand, in the UK's primary and processed sugar activities, the loss of tariff-free access to the EU market has a detrimental effect on production. In this scenario, agricultural and processed food output rises compared with the Baseline are driven by the production rises in the livestock and meat sectors.

- Based on estimates from the literature, a proportion of the single farm payment is coupled to production. As a result, the removal of direct payments in each of the scenarios has an additional detrimental impact on primary agricultural and processed food production – a further production decline of approximately 3% and 1%, respectively.

- The market price effect under FTA is slightly inflationary for the UK. Most notably, dairy and white meat prices rise 1.2% and 1.5%, respectively. In general, however, mutual UK/EU trade cost shocks broadly cancel one another.

- In UTL, there are important relative market price falls in red meat, sugar and rice. Similar, although moderate, price falls also occur in cereals. The dairy price rise recorded under FTA is stronger (2.5%) given the assumption of stronger trade costs under this scenario.

- In Brexit-WTO, there are clear inflationary price effects resulting from the adjustment to WTO MFN tariffs. In meat sectors and dairy, the UK market price rises are between 7-8% compared with the Baseline, whilst for primary agriculture and processed food, the corresponding price indices rise 2% and 3.7%, respectively.

- The removal of direct payments support increases the unit cost of agricultural production and, by vertical price transmission, the food sector. There is a concomitant impact on agricultural and food prices of approximately 3% and 0.5% in each scenario.

- Agricultural employment and land usage shadow agricultural output trends, although in both cases the responsiveness is limited. The biggest relative agricultural employment increase of 1.7% occurs under the WTO scenario. Moreover, with a highly inelastic land supply curve in the UK, average land yields must rise to meet the agricultural output in this scenario. Comparing with the Baseline, average UK land rents rise by as much as 5% under WTO and fall by 2.8% in UTL.

- Comparing with each scenario when the CAP is present, the removal of the direct payments depresses average land rents by between 15-16% in each of the scenarios. Similarly, corresponding results for agricultural wages show that the removal of first pillar agricultural support has a depressing impact of between 3.5% to 4% in each of the scenarios.

- Under FTA, UK-EU trade costs lead to a small relative improvement in the UK trade balance with the EU as relative UK imports from the EU drop off quicker than relative UK exports to the EU. The biggest relative trade balance improvements are for UK white meat and dairy. There is, however, an additional price substitution effect as more imports now come from the non-EU region, which implies a worsening UK trade balance with the non-EU region. Overall, the effect is a slight deterioration in the UK's total trade balances with the exception of white meat and dairy sectors.

- Under UTL, the stronger trade cost assumptions (vs FTA) generate stronger relative UK trade balance improvements compared with Brexit-Lite. On the other hand, eliminating tariffs on trade between the UK and the non-EU region worsens the UK's trade balances with the non-EU region, particularly in red and white meat sectors. With the notable exception of cattle and sheep, dairy,

vegetable oils and fats and other food processing, in general, the UK's trade balances worsen (particularly in meat) compared with the Baseline (and FTA).

- A return to WTO MFN tariffs on the UK's trade arrangements generates strong relative improvements in the UK's trade balances with the EU in meat and dairy due to the stifling effect on imports (and increasing domestic production). The shortfall between domestic production rises on the one hand, and the loss of UK imports from the EU on the other hand, must be met by imports from the non-EU region. This trade displacement effect slows the fall in UK imports from the non-EU region (due to rising UK tariffs), such that there are further trade balance deteriorations with the non-EU region in a number of sectors.

- In comparison with each corresponding scenario where first pillar CAP support is in place, the loss of direct payments reduces self-sufficiency in the UK, thereby leading to a relative worsening in the trade balance.

- Reducing the UK agricultural unskilled labour force in the post-Brexit period by 10% and 30% reduces UK agricultural output by an additional 3% and 11-12%, respectively. As a more unskilled labour-intensive activity, crop sector output falls by slightly more than the agricultural sector average.

- In each of the scenarios, primary agricultural and food market prices increase by an additional 11-12% and 1%. Unskilled agricultural sector wages rise by an additional 5% and 17% under 10% and 30% reductions in the unskilled agricultural labour force. The macroeconomic impact is very limited since agriculture is a 'small' sector, whilst non-agricultural sectors mitigate the contraction in primary agriculture.

- In the medium term, domestic market prices rise strongly as inflation is imported and primary factor prices are bid up when reducing the price of UK exports (i.e., price of sterling) on world markets. Per capita real incomes fall as the rising nominal incomes from increasing returns to primary factors do not offset the inflationary impact on domestic market prices. As a result, real macro growth shrinks in the UK by 0.3% and 0.8% in each corresponding scenario. Primary agricultural output falls by -1.2% and -1.8% in each corresponding scenario. Processed food output falls by -0.4% and -0.7% in each corresponding scenario.

Estimated impacts at the sector level: UK-FAPRI results

- The results from the partial equilibrium model demonstrate the extent to which the type of trade agreement could result in different price and production impacts in the UK depending on the disruption to trade patterns. The UK-FAPRI model offers finer disaggregation of the effects at the sector level as compared to the CGE model, however, it doesn't cover economy-wide adjustments.

- In general, a free trade agreement (FTA) results in the least disruption to trade flows, hence the estimated market impacts are relatively small. The projected impacts are larger under the two other simulated trade arrangements. All sectors experience producer price and production declines under UTL. The impacts are particularly marked in the beef and sheep sectors where international competition is very strong. In contrast, the direction of the market impact varies across sectors under the WTO scenario, depending on whether the UK is a net importer or a net exporter of the relevant commodity.

- The projected changes under FTA in conjunction with the retaining of direct payments are relatively small since this entails limited disruption in trade. UK producer prices increase slightly for commodities in which the UK is a net importer, *e.g.* beef, and the opposite for commodities in which the UK is a net exporter, *e.g.* barley, as the trade facilitation costs feed through to higher costs for the buyer. Given the modest price impacts, changes in production and value of output are marginal. Elimination of direct payments results in a modest fall in suckler cow, dairy cow and ewe numbers (-4%, -0.3% and -2% compared to the Baseline).

- A unilateral trade liberalisation (UTL) decision to remove agricultural import tariffs from the RoW and from the EU, would see domestic producer prices fall markedly for all products, particularly for beef and sheep. Specifically, under *UTL+*, the model estimates a large increase in imports from RoW for the UK beef sector. This reflects the highly competitive nature of overseas suppliers (e.g. Brazil and Australia), and results in the domestic producer beef price falling close to world levels, (e.g. by 42 per cent). The projected inflow of beef imports from the rest of the world displaces EU imports, which collapse to zero.

- The projected decline in beef production under this scenario (UTL+) is more marked in Scotland (-20%) compared to elsewhere in the UK (-10 to -13%). This is attributable to differences in the proportion of beef sourced from the dairy herd across the UK, with a higher proportion of beef animals coming from the progeny of the dairy herd in England, Wales and Northern Ireland compared to Scotland.

- The sheep sector is also exposed to strong international competition, with unilateral trade liberalisation leading to the inflow of more imports from the rest of the world and a significant fall in the domestic producer price (-19%). The decline in price leads to a fall in sheepmeat production and a rise in consumption. More imports from the rest of the world are required (+59%) to meet UK consumption since UK exports to the EU are largely maintained through the TRQ.

- The projected falls in producer prices in the pig and poultry sectors are less pronounced under UTL (-4% and -3% respectively), reflecting the more competitive nature of UK prices in these sectors. Projected input costs also exhibit a moderate decline and hence the projected declines in production and values of output are relatively modest.

- In the dairy sector, cheese and butter prices also exhibit price declines under UTL+ (-7% and -20% respectively). These price impacts are sensitive to the underlying Baseline projections, including a high projected EU butter price relative to its respective world price and the positive influence of population growth on UK demand. The projected changes in dairy commodity prices have a depressing impact on producer milk prices, e.g. falling by around 8% in England and 6% in Northern Ireland. The declines in producer milk prices have a slight depressing impact on milk production.

- In the crop sector, the changes in producer prices are also modest. For example, the price reductions are -2% and -8% for wheat and barley, respectively) since UK prices are fairly close to world levels. The price decline is greater for barley compared to wheat since under the Baseline there is a significant surplus of the former. In addition, feed demand is a greater component of domestic use for barley and this component falls in response to the decline in livestock numbers. Within the rapeseed sector, the impacts of changes in tariffs under the different scenarios are expected to be minimal as there is no import tariff on this crop.

- Removing direct payments under UTL hardly affects prices, since the reductions in domestic quantities produced are offset by changes in trade flows. The gradual elimination of direct payments in conjunction with the unilateral elimination of import tariffs has a further downward impact on suckler cow, dairy cow and ewe numbers. Nevertheless, the difference between *with* and *without* direct payments is more marked under UTL as compared to the UK-EU FTA.

- Adoption of the WTO MNF tariff schedule has significant changes on producer prices, production volume, output and trade flows. The impacts mainly depend on the status of the sub-sector concerned (e.g., beef, sheep, dairy, pigs, poultry, wheat and barley) and whether the UK is a net importer or net exporter of specific commodities. The default bound MFN tariffs are in general very high, therefore the imposition of these tariffs leads to significant adjustments in trade between the UK and EU.

- In the beef sector, the imposition of high tariffs leads to a collapse in trade between the UK and EU. Available beef supplies within the UK domestic market fall significantly since the UK is a large net importer. As a result, the UK beef price increases markedly (e.g. 17% higher than in Baseline). The rise in beef price is sufficient for non-EU countries to export beef to the UK paying the full high tariff. Production responds positively to the price rise. The projected increases in producer price and production, results in a 30% increase in the value of UK beef output.

- Similarly, the UK is a net importer of pig and poultry, hence producer prices increase in response to the imposition of high tariffs, which greatly reduce the competitiveness of EU imports. Price increase stimulates rises in production. Projected butter and cheese prices within the dairy sector also rise due to the displacement of imports from the EU-27, which are historically high. The wheat price also increases as the reduction in imports from the EU cannot be easily replaced from elsewhere due to the application of high tariffs. The projected increase in wheat production is small due to the observed inelastic relationship between returns and crop production.

- In contrast, under this scenario, lower producer prices are projected in the sheep and barley sectors (the UK is a net exporter). The introduction of WTO MFN tariffs diminishes the competitiveness and thus the volumes of UK exports to the EU, which leads to increases in available supplies within the domestic market.

- The negative price impact is particularly marked in the sheep sector due to the large quantity of sheepmeat currently exported to the EU from the UK. Despite the rechannelling of this produce onto the domestic market, the UK continues to import significant volumes of sheepmeat from the rest of the world through TRQs. Although the UK price falls sharply, TRQ imports from the rest of the world remain competitive and hence the projected change is limited. The projected fall in the

producer price has a depressing impact on UK sheepmeat production and thus on the value of output.

- The gradual elimination of direct payments under WTO has a downward impact on livestock numbers and production in the beef, dairy and sheep sectors. However, in the beef sector the differential in livestock numbers/production between *with* and *without* direct payments is less marked under WTO as opposed to UTL and FTA. This partly reflects the significant increase in value of output in this sector when the WTO tariffs are imposed, which diminishes the relative importance of direct payments.

- A sensitivity analysis with a 10% and 20% depreciation of the pound has a significant upward impact on output prices under the UTL and WTO scenarios. The transmission of the depreciation in the exchange rate and the projected price change is high. Despite the increase in output prices, it is estimated that the increases in production within the livestock sectors are small as input costs also increase.

Estimated impacts at the farm level: ScotFarm and Budget-Simulation Results

- The ScotFarm model estimates the impacts (e.g. under the assumption of profit maximisation) of the selected trade and domestic agricultural policies on different farm types and sizes across the devolved administrations. The estimates show that certain farm types are more vulnerable to farmgate price reductions than others. For example, producer price reduction under UTL, when direct payments remained unaltered, would affect most famers but particularly the profitability of beef and sheep farms. In contrast some farms would experience increased profitability through higher milk, beef and wheat prices under the WTO scenario. The FTA+ scenario has the least impact.

- However, there are differences between and within farm types, and across countries, reflecting a combination of factors. Between-type differences largely reflect differential exposure to price changes and/or current dependence on direct payments. For example, cereal prices vary by less than livestock prices across the scenarios and dairy farms are generally relatively less reliant upon direct payments.

- There is also some variation between countries in terms of current support payments and cost structures. For example, BPS rates differ across the UK and, reflecting variation in land quality and remoteness, farm areas and input prices are not uniform. However, some reported variation also arises as an artefact of the farm type classification. Although some farms are genuinely single-enterprise specialists, many have two or more different activities. For example, livestock and cereal enterprises may co-exist, as can dairy and beef enterprises. Consequently, many farms' output comprises a combination of activities.

- The elimination of direct payments will potentially have significant effects on farm profitability. This is true for all farm types and the magnitude of projected reductions in farm income are such that the viability of many farms, particularly beef and sheep, is questionable under any trade scenario if direct payments are removed.

- Within the aggregate results, there is some variation across different farm sizes and between countries. The latter reflects differences in farming systems arising from geographical (e.g. climate, soil) and structural characteristics (e.g. enterprise mix). For example, Scottish dairy farms more commonly have beef enterprises than English dairy farms. Variation in impacts across farm sizes probably reflect economies of scale and scope. Farm income gains and losses are essentially proportional to farm size.

- In terms of production patterns, ScotFarm allows for adjustments within the current farming system and the results reveal varying degrees of responsiveness. In general, significant adjustments only occur under the more extreme scenarios, where prices move beyond their observed range and/or direct payments are removed. For example, reductions in sheep numbers by up to 100% under WTO and UTL scenarios, particularly without support payments, on some Less Favoured Areas and lowland grazing farms of all sizes in all countries.

- A farm-level budgetary simulation model was used for comparative static analysis of the distribution of scenario impacts across a representative sample of 2,718 commercial farms businesses drawn from the UK Farm Business Surveys. The financial results of the simulations included the projected distributions for Farm Business Income (FBI) and Cash Income under each scenario by UK nation and main farm enterprise.

- Under the FTA+ scenario, when direct payments were maintained, estimated mean incomes were virtually identical to their baseline levels. The WTO+ scenario increased mean FBI by between 32% (Wales) and 85% (Northern Ireland) due to the elevating effects of tariffs on most domestic farm prices. In contrast the UTL+ scenario reduced mean FBI by between 52% (England) and 130% (Scotland) as liberalised trade exposed UK agriculture to greater international competition and reduced commodity prices.

- Given the important contribution of direct payments to baseline farm income their removal resulted in sharp declines in farm income. Under FTA- the average FBI declined by between 58% (England) and 135% (Scotland), with an average reduction of 69% for the UK as a whole. Under WTO-, increases in output prices almost fully offset the loss of direct support on average farm income for England and Northern Ireland. This contrasted with a less favourable potential outcome in Wales and Scotland where incomes remained well below baseline levels.

- The results highlighted the potential variation in scenario impacts across the UK. Notably, impacts were less negative, on average, for England compared to the UK as a whole. Scotland stood out as most vulnerable to the Brexit scenarios and, even on a Cash Income basis, average Scottish farm incomes became substantially negative under UTL-.

- Analysis by farm type shows that under FTA+, average FBI and Cash Income per farm remained very similar to their baseline levels, reflecting the modest price changes under this scenario. The WTO scenarios resulted in a more than doubling of average incomes for dairy and pig farms due mainly to projected increases in milk and pig meat prices. For other farm types, income remained at or slightly above the baseline when direct payments were maintained (WTO+) but declined sharply below the baseline when these were removed (WTO-).

- UTL was identified as the most challenging scenario across all farm types, especially for those involved in beef and sheep production. The impact was particularly severe where UTL was combined with removal of direct support (UTL-), particularly for grazing livestock farms, which on average, had negative margins even when defined on a Cash Income basis. This highlights the specific vulnerability of beef and sheep enterprises to international competition and the significant dependence of their farm income on Pillar 1 direct payments.

- Across the UK around 15% of businesses were loss making in the baseline FBI distribution. The FTA+ scenario resulted in income distributions that were virtually unchanged relative to the baseline. FTA-, UTL+ and WTO- increased the proportion of loss-making businesses based on FBI to between about 40% (England) and 60% (Scotland). On a Cash Income basis the proportion of loss-making businesses under these scenarios ranged from 20% (England) to 30% (Scotland).

- WTO scenario had greatest impact on the shape of the income distribution curves as price increases under this trade scenario were relatively more advantageous to larger or more profitable farming businesses at the upper end of income distribution.

- UTL- (extreme trade liberalisation coupled with Pillar 1 removal) was the most challenging scenario for farm businesses. In FBI terms the proportion of loss-making businesses under UTL- ranged from 62% (England) to 90% (Scotland). Even on a Cash Income basis the proportion of loss making businesses was about 50% for the UK as a whole.

- The financial variables showed that farms in the worst affected quintile (e.g. beef and sheep) tended to have lower financial performance in the baseline with much lower average performance ratio, FBI and Cash income. Importantly, they tended to have substantially lower levels of diversification relative to farms in the least affected quintile.

- There was little variation in the proportion of rented land across the quintiles and likewise average age of farmers was very similar across the quintiles. Farms in the least affected quintile (e.g. cropping, pigs, poultry and horticulture) tended to have a higher proportion of hired labour (relative to family labour) which reflected their larger average business size.

- The results also identified a greater concentration of English farms in the least affected quintile while Scottish farm were more heavily represented in the worst affected quintile.

- We also estimated the potential effects of the selected UK trade and domestic agricultural policy scenarios on the welfare of farm households, at regional (devolved administrations) and national level by employing a farm household viability model (Viability-Sustainability-Vulnerability or Via-Sus-Vul).

- Results show that depending on the scenario, and particularly the retention or elimination of direct payments as currently provided, the impact varies significantly across farm types and the devolved administrations.

- For example, under the Baseline Scenario, only 29% of the farms in England are viable, as oposed to 22 in Northern Ireland, 21% in Wales and 14% in Scotland. However, the viability ratings of farms increase (under WTO+), particularly farms in NI, due to the effect of tariffs on most domestic farm prices.

- The vulnerability of many farms is more pronounced when the removal of direct payments takes place. Notably, our findings by country, show farms in Scotland as the most vulnerable to Brexit scenarios. The negative impacts are lower, on average, in England when compared to the other UK countries.

- The viability assessment by farmer's age also shows that farms with income support managed/owned by relatively young farmers (35-44 years) have higher viability ratings under WTO+ scenario across all devolved administrations. This contrasts with households where farmers are 64 years and above, for which the estimates of viability ratings are lower.

- Given the substantial contribution of direct payments to farm income, their removal amplifies farm vulnerability. Hence, off-farm income is critical in safe-guarding the economic welfare of most UK farm households.

Concluding remarks

- There are notable divergences between the projections of the macro (CGE) and sector (PE- FAPRI) models and the farm level analysis. Both the CGE and PE estimates imply that UK Agriculture and its sectors can certainly survive, and in some cases may prosper, even under the harshest (UTL) conditions following Brexit. However, we note that they do not model any short-run adjustment and adaptation costs; rather they reflect the effects of these changes on an on-going and more or less fully adjusted basis. Their production responses (structural adjustment) are based on equations derived from historical data and/or assumptions about the degree to which direct payments are decoupled from production. This limitation must be noted when evaluating projections for scenarios that represent such significant divergence from past experience.

- The farm level analysis clearly demonstrates that Brexit, especially the removal of direct payments would affect severely many farms, especially beef and sheep. The principal explanation of this critical difference is that the macro and sector level models reflect the major elements of structural adjustment within the industry (PE) and between the industry and the rest of the economy (CGE). Farm-level analysis confirms the likely pressures for structural adjustments, but does not model their manifestation.

- Their production responses (structural adjustment) are Moreover, the equations used to derive production responses in these models are necessarily estimated from historical data; this limitation must be noted when evaluating projections for scenarios that represent such dramatic divergence from past experience."

- Brexit would have significant implications for UK agriculture, a sector with strong trade links to the EU and reliance on CAP income support. Moreover, the impact will be far from uniform, with large variation across the sectors and the devolved administrations. The consequences of Brexit for UK agriculture will depend upon (at least) two major factors: trade agreements or lack of them and changes in domestic agricultural policy, i.e. retaining or maintaining of direct payments.

- Trade negotiations with the EU and the RoW will be paramount, and the impact of trade agreements on the sector is conditioned by the degree of trade competitiveness (i.e. relative tariffs) and trade openness. It also depends on the status of the sub-sector concerned (e.g., beef, sheep, dairy, pigs, poultry, wheat and barley) and whether the UK is a net importer or net exporter of specific commodities.

- These trade effects, however, might be overshadowed by the exchange rate and possible labour market changes and other non-tariff barriers (beyond the remit of this project, hence not considered in this report).

- In macroeconomic terms the impacts that arise from the scenarios are relatively small. This is because average tariffs in the wider economy between the UK and EU, as well as the assumed trade cost increases, are only moderate for the majority of UK economic activities. In those scenarios where larger tariffs and/or trade cost shocks occur, these effects are typically restricted to agrifood industries, which constitute only a small share of the UK GDP.

- At the sector level, different sectors will be affected in various ways according to the different trade scenarios. Even a relatively 'soft' Brexit, a free trade agreement with the EU close to current arrangements (i.e. *FTA+*), would create some disruption to trade flows, albeit with estimated market impacts that are relatively small.

- In the case of products where the UK is a net importer (e.g. beef) the imposition of tariffs reduces the competitiveness of the imported product resulting in higher domestic producer prices in the UK. The converse applies for products where the UK is a net exporter (e.g. sheep and barley) to the EU.

- Given the dependence of many UK farms on direct payments, their removal, predictably, worsens the negative impacts of new trade arrangements and off-sets positive impacts. The elimination of direct payments will affect most farm businesses but the magnitude varies by farm type and devolved administration.

- The negative impact on farm business income is reflected across all trade scenarios, especially UTL *with or without* direct payments. Average farm income varies significantly across the devolved administrations and by farm type, with most farms worse off (relative to the baseline) under all scenarios but one, *WTO+*. Noticeably, under this scenario dairy farms will particularly benefit as their average farm income could almost triple as compared to the baseline scenario. Beef and sheep farms will be the most affected under *UTL-*.

- Our extreme free trade scenario (UTL) leads to some striking results regarding farm income distribution. Whereas 15-20 percent of the farms were not making any money at all (even in the baseline scenario), this rises to 45 percent under the UTL scenario with direct payments still in place (*UTL+*). The elimination of direct payments further increases this figure to 70 percent.

- Raising agricultural productivity closer to the all-economy average will require reallocating less productive resources (e.g., poor quality land, unskilled labour) to other uses including provision of public goods) and utilising remaining resources more effectively.

- Our sensitivity analysis at the farm level shows that, for example, by increasing productivity by 10 per cent across beef and sheep will indeed lead to a sizeable increase to in farm business income under all trade scenarios. However, this improvement in productivity would not be sufficient to offset the removal of direct payments nor the projected price decline under UTL.

- Price projections, direct payments and off-farm income, largely influence variability in the levels of viability, sustainability and vulnerability across farm types and between the devolved administrations. Especially, given the substantial contribution of CAP direct payments to farm income, their removal amplifies farm vulnerability. Furthermore, the combination of trade liberalisation and removal of direct payments increases the proportion of vulnerable farms. Hence, the presence of off-farm income is critical in safe-guarding the economic welfare of most UK farm households.

- Our models do not address the economic impacts of Brexit on the supply chain *per se*. Thus, it is difficult to predict exactly how these trade and domestic policy scenarios will affect the entire UK food supply chain, particularly consumers. However, UK food prices will depend not only on the tariff schedule put in place in the UK, but also the value of the pound in foreign exchange markets. A fall back to WTO terms would increase significantly domestic food prices which would particularly affect those with least disposable income. Lower (or no) tariffs (under FTA and UTL scenarios) could leave food prices unchanged or lower, so benefiting consumers, at least in the short term.

- Irrespective of the international or domestic constraints on their adoption, our modelling results suggest that different policy options raise a number of issues. In particular, our farm-level analysis implies significant pressure for structural adjustment as and when direct payments are eliminated. The immediate impacts on farm income are such that farm businesses and households would be expected to react by seeking to improve on-farm efficiency and/or search for alternative income sources, in some cases by leaving farming.

- Although our models do not provide any explicit outcomes about the likely nature of structural change, the national (CGE) and sectoral (UK-FAPRI) models imply that structural adjustment will continue to occur, leading to resource reallocations and changes in the level and composition of output. Such structural adjustment has implications in terms of the availability of raw materials for food manufacturing, levels of local economic activity and environmental impacts, all of which may lead to demands for further policy responses.

1. Introduction[1]

1.1. An overview of the project

Despite representing less than 1% of the UK economy, agriculture is firmly woven into the social fabric of our countryside. It supplies 60% of domestic food demand and supports downstream and upstream industries which contribute over £100 billion to the economy. The industry also shapes landscapes, habitats and biodiversity, and has considerable political importance. There is little doubt that the UK agri-food sector will be one of those most seriously affected by Brexit. Not only is it dependent on trade relations both with the European Union (EU) and with the Rest of the World (RoW) (both by tariff status, and non-tariff barriers relating to health and safety and product provenance), but it is also a sector heavily dependent on (permanent and seasonal) migrant labour, and the most heavily subsidised and regulated under the present Common Agricultural Policy (CAP). The current Westminster government is, through its Department for Environment, Food and Rural Affairs (Defra) and the UK Treasury, trying to reassure British farmers and the larger public that Brexit is a once in a life-time opportunity to replace the 'fundamentally flawed' CAP with 'our own national food policy, our own agriculture policy, …, shaped by our own collective interests' (Secretary of State Michael Gove, 2018). Since Mr. Gove outlined his vision for a 'UK Agriculture Policy' in January 2018, at the Oxford Farming Conference, the government has produced its Agriculture Bill[2], which currently is under Parliamentary scrutiny. This aims to mark a radical departure from how agricultural policy has operated for the last 45 years since the country joined the European Economic Community in 1973. Specifically, support for agricultural production and farm income (i.e. direct payments) will be progressively phased out and replaced with a more targeted support for efficiency improvements, productivity growth and rewards for public goods. To allow businesses to adjust to the new policy framework, farmers are guaranteed a "seven-year agricultural transition (beyond the 2021-month transition period set out in the EU Withdrawal Agreement)", and to receive the same level of subsidy (as under the CAP) until the end of 2022 (Michael Gove, 2019). In Defra's words the "*Government wants to transform agriculture policy through the Agriculture Bill by paying farmers and land managers to deliver environmental public goods"*[3]. To allow farm businesses to adjust to the new policy framework, UK farmers are guaranteed a "seven-year agricultural transition (beyond the 2021-month transition period set out in the EU Withdrawal Agreement)", and to receive the same level of subsidy (as under the CAP) until the end of 2022 (Michael Gove, 2019).

Despite these efforts, the lack of concrete policy decisions and the uncertainty that surrounds the terms of negotiations (both in terms of the Withdrawal Agreement and future trade relationships) with the EU make UK farmers and rural communities very anxious indeed. Thus, how future UK Agricultural Policy (UKAP) will look after the country leaves the EU and what the economic and social implications of Brexit will be, remain open to debate and academic research.

[1] The chapter was written extensively by Carmen Hubbard.

[2] https://www.gov.uk/government/news/landmark-agriculture-bill-to-deliver-a-green-brexit

[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/740670/agri-bill-evidence-paper.pdf, last accessed 03 December 2018.

Research synthesis, user engagement and research are needed to support and inform negotiations and policy development for the sector following Brexit. A few notable studies (Boulanger and Philippidis, 2015; Van Berkum *et al.*, 2016; Davis *et al.*, 2017 and Bradley and Hill, 2017) have assessed the potential effects of exit on the UK agricultural sector using different scenarios and assumptions. However, there remains an absence of more comprehensive research including analysis of variation in the effects of different trade and domestic policy options across heterogeneous farm populations and, regionally, among the UK devolved administrations. Moreover, with the exception of the UK Food and Agricultural Policy Research Institute (FAPRI) team (Moss *et al.,* 2009), there is no significant quantitative policy assessment tool kit in the UK which can be called on to develop this necessary capacity, and there is limited 'joining up' of policy expertise to provide cohesive analysis of Brexit scenarios for UK agriculture. These gaps are addressed in this priority grant project, *Brexit: How might UK Agriculture Thrive or Survive?,* funded by the UK Economic and Social Research Council (ESRC). Specifically, the project assesses the economic impacts of a selected number of UK agricultural policy scenarios following Brexit by integrating state of the art economic modelling approaches at macro, sector and farm levels. It also aims to provide the UK Government, its devolved administrations and other stakeholders (e.g. levy boards, farmers and farmers' organisations) with a cohesive and robust analytic capacity to support future policy decision making.

The project harnesses existing model frameworks and expertise to integrate trade and macroeconomic relationships with the structure and performance of the UK agricultural sector and to disaggregate macro and sector projections to the farm level. Hence, the possible effects of new trade and domestic policy alternatives are estimated using both an agriculture specific variant of the well-known Global Trade Analysis Project (GTAP) multi-region computable general equilibrium (CGE) model (Philippidis *et al*., 2007 and Philippidis and Kitou, 2012), and the UK-FAPRI partial equilibrium model (Moss *et al.*, 2009; Feng *et al.*, 2017).

We employ both approaches for a limited range of potential policy scenarios, to provide sector-wide economic estimates of the possible consequences of Brexit (e.g. supply, demand, prices, exports, imports and welfare). However, in practice, the effects of Brexit will materialise as farmers adjust and adapt their businesses to the new policy environment and its effects. These ground level adaptations drive the sector consequences and mediate the feedbacks through their interactions in the local and national output, labour, capital and land markets. While both the partial and general equilibrium models seek to reflect these complex interactions through their specification of the behaviour of these markets, they cannot identify specific ground level effects. Consequently, we disaggregate sectoral projections using farm-level models to assess impacts of Brexit scenarios on production decisions and farm household incomes. At the farm level, we employ two modelling frameworks to estimate effects among farm households across UK countries and within major farm types. We also explore how to reconcile and interpret the macro, sector and farm level results, and their implications for UK agricultural policy development post Brexit. The research took place between April 2017 and September 2018.

1.2. Specific research objectives and questions

As stipulated in the ESRC research proposal, the study is structured around six major objectives:

1. To develop UK Agricultural Policy (UKAP) scenarios following Brexit through consultation and engagement with relevant stakeholders;
2. To apply and compare general and partial equilibrium models in providing aggregate projections of the impacts of these scenarios on UK agriculture at the sector level.
3. To assess the impacts of UKAP scenarios on farm production decisions and financial performance across the distribution of holdings within major farm types in the UK.
4. To explore the effects of UKAP scenarios on the economic welfare of farm households in 'sensitive' segments of the farming population.
5. To reconcile and interpret the macro, sector and farm level results, and their implications for UKAP development post Brexit.
6. To disseminate the research outcomes to policy makers and those most affected: industry, farmers and farmers' organisations, and also the general public.

These were further organised around five sequential but overlapping phases and disaggregated into the following specific research questions:

Phase 1 ***(Objective 1):*** *Developing UKAP scenarios following Brexit through consultation and engagement with relevant stakeholders*

- What limited number of policy scenarios most clearly and realistically depicts future agricultural and trade policy options following Brexit?
- What are the critical issues raised by these options for UK agriculture and its stakeholders?

Phase 2 ***(Objective 2)***: *Applying and comparing general and partial equilibrium models and providing aggregate projections of the impacts of these scenarios on UK agriculture at the sector level.*

- What are the aggregate projections of the impacts of these scenarios on UK agriculture at the sector and regional levels?
- How do the general and partial equilibrium models' projections differ?
- How can any differences be reconciled?

Phase 3 ***(Objective 3):*** *Assessing the impacts of UKAP scenarios on farm production decisions and financial performance across the distribution of holdings within major farm types in the UK.*

- What are the impacts on farm production decisions?
- What are the effects on commercial performance across major farm types in the UK?
- How will these impacts vary within and across England, Scotland, Wales and Northern Ireland?

Phase 4 ***(Objective 4)*****:** *Exploring the effects of Brexit scenarios on the welfare of farm households in 'vulnerable' segments of the farming population*

- What are the effects of UKAP scenarios on the economic welfare of farm households?
- Who are the most 'vulnerable' segments within the farming population?

Phase 5 *(Objective 5)*: *Reconciliation and interpretation of the macro, sector and farm level results, and their implications for UKAP post Brexit.*

- How do sector and farm level projections of policy scenario consequences compare?
- How might farm level adjustments be reconciled with sector level projections?

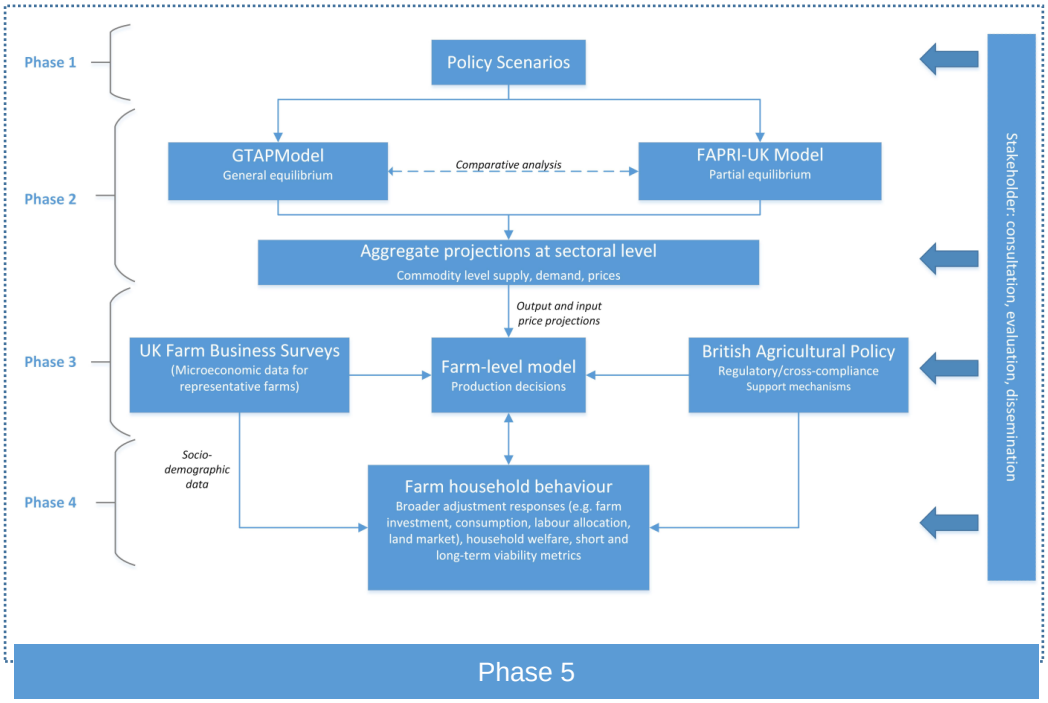
1.3. Project team and Research methods: A brief description

The project comprises a strong team with unique expertise in modelling and policy analysis of agricultural and trade policies, and research on the EU CAP. Our expertise spans agricultural economics, international trade, econometrics and policy analysis. Carmen Hubbard (Newcastle University), the project leader, was supported by : Michael Wallace (Newcastle University and University College Dublin); David Harvey (Newcastle University); Mercy Ojo (Newcastle University); Andrew Moxey (Newcastle University); Charles Scott (Farm Business Survey Northern England, Newcastle University); Shailesh Shrestha (Scotland's Rural College); Siyi Feng (Agri-Food and Biosciences Institute, Northern Ireland); Myles Patton (Agri-Food and Biosciences Institute, Northern Ireland); John Davis (Agri-Food and Biosciences Institute, Northern Ireland) and George Philippidis (independent consultant). The team had also benefited from the expertise of Anne Liddon, Science Communications Manager at Newcastle University. One of the major strengths of this study was the academic engagement with a highly focused Advisory Panel of policy experts who guided the whole project: Ian Bailey (Savills Ltd); Sarah Baker (AHDB); Jonathan Baker (CLA); Graeme Beale (Scottish Government); Michael Bourne (Defra); Paul Caskie (DAERA Northern Ireland); Richard Haw (Scottish Government); Tom Keen (NFU); Rebecca Hesketh (NFU); Peter Midmore (University of Aberystwyth); Neil Paull (Welsh Government). Graham Redman (Andersons Consultants); and Ken Thomson (University of Aberdeen)[4].

The figure below captures the project design across its major objectives. This is followed by a brief description of the research methods by phase.

[4] Not every member on the panel was able to attend all project meetings.

Figure 1.1.1. The project general framework



Phase 1: Developing UKAP scenarios following Brexit through consultation and engagement with relevant stakeholders (Leaders: C Hubbard and D Harvey)

A brief literature review and the opening workshop with our Advisory Panel (May 2017) led to the selection of a limited number of trade and domestic policy scenarios (**Chapter 2**). The scenarios were chosen to represent a broad range of feasible options for: i) *trade relations* with the EU and the Rest of World; ii) *domestic UK policy* for direct payments to farmers (currently the Basic Payments Scheme). The UKAP scenarios are very similar (but not identical) to those used by van Berkum *et al.,* 2016. We modelled three selected trade policy scenarios (Table 1) with (+) and without (-) direct payments, in order to distinguish between the trade and domestic policy effects: (i) UK-EU Free Trade Agreement (**FTA**); (ii) Unilateral Trade Liberalisation (**UTL**); and (iii) a fall back to World Trade Organisation tariffs (EU Tariffs Schedule - **WTO).** These are modelled against a Baseline scenario which assumes that the UK remains fully integrated in the Single Market and the Customs Union, with direct payments in place. In addition to the main analysis, sensitivity analysis has been undertaken with regards to two other *major conditioning factors* for the economic effects of Brexit policy on UK Agriculture: i) restrictions on migrant labour; and ii) the sterling exchange rate, both with the Euro and with the US dollar.

Table 1.1. Selected UKAP Trade Scenarios

FTA	UTL	WTO
• Comprehensive UK/EU FTA with UK-EU tariffs at zero • UK adopts the EU common tariff schedule on RoW imports • UK maintains share of EU Tariff Rate Quotas (TRQs) applying to RoW imports • Additional trade costs of 5% (livestock) and 2% (crops) for UK↔EU trade flows	• Elimination of all UK import tariffs for RoW including imports from the EU • UK-EU exports subject to EU Common Custom Tariffs (CCT) • TRQs on UK-EU exports • additional trade costs of 10% (livestock) and 5% (crops) for UK↔EU trade flows	• no agreement by March 2019, hence a fall back to WTO terms and current EU tariff schedules • UK trading with EU and RoW under WTO Most Favoured Nation (MNF) tariffs • requires a UK allocation of a share of the current EU tariff rate quotas (TRQs) with the RoW • additional trade costs of 8% and 4% for livestock & crop products for UK↔EU trade flows

Phase 2: *Applying and comparing general and partial equilibrium models and providing aggregate projections of the impacts of these scenarios on UK agriculture at the sector level.* (Leaders: D Harvey and C Hubbard)

Two existing, independent and internationally recognised models, i.e. GTAP (*Task Leader: G Philippidis*) and FAPRI-UK (*Task Leader: M Patton*) were used to generate projections of the aggregate and sector level consequences of the Brexit scenarios established in Phase 1 (**Chapter 3 and Chapter 4**). The CGE model is calibrated to release nine of the GTAP database (Narayanan *et al.*, 2015) with information on cost and demand structures, gross bilateral trade data, transport costs, and trade protection for 57 activities in 140 regions, for the year 2011. In explicitly representing the input-output relationships among various sectors, the model assesses the knock-on impacts on the wider economy given a policy change in a particular sector. Applying common scenario assumptions, disaggregated commodity-level projections for prices, production and trade flows are then estimated with the UK-FAPRI partial equilibrium model. To ensure some degree of comparison between the two models, a softlink was developed between them, in the sense that the CGE Baseline was calibrated based on the projections (i.e. production results trends) from the FAPRI model. Additionally, an Advisory Board meeting was held in December 2017 to discuss and interpret the results of these two models on the prospects for UK agriculture under different Brexit scenarios.

Phase 3*: Assessing the impacts of UKAP scenarios on farm production decisions and financial performance across the distribution of holdings within major farm types in the UK* (Leader S Shrestha)

The CGE and UK-FAPRI models (Phase 2) are linked to a series of representative farm-level models to assess the effects of Brexit scenarios on production decisions and profitability of UK farms. Results from the aggregate models underpin key assumptions in the farm models, the values of which are

treated as exogenous. These include factor price projections (e.g. land rents and wages) from the CGE model and output and direct-input price projections from the UK-FAPRI model. The most extensive farm-level policy modelling system within the UK (ScotFarm) has been developed at Scotland's Rural College (SRUC). The model employs a linear programming framework developed to assess the impacts of agricultural policy changes on Scottish farms. Specifically, using data from the Scottish Farm Accountancy Survey it estimates production and financial metrics for a large sample of representative farms. This project extended the geographic coverage of the SRUC model to include Northern Ireland, England and Wales, hence to reflect the regional variations in production systems as well as enhancement to model scenarios concerning future UKAP (**Chapter 5 and Chapter 6**).

Phase 4: *Exploring the effects of Brexit scenarios on the welfare of farm households in 'sensitive' segments of the farming population* (Leader: M Wallace)

This phase complements and augments the modelling, in Phase 3, by providing a more holistic economic welfare analysis of Brexit impacts within a farm household context. Specifically, using UK Farm Business Survey (FBS) data for three consecutive years (2013/14 - 2015/16), it models (at an individual level) all farm businesses and estimates the potential effects of the Brexit scenarios on the distribution of farm income across UK and the devolved administrations and by main farm enterprise (**Chapter 6**). It also decomposes the estimated impacts for the projected changes in farm business income under each scenario using a series of regression equations. Furthermore, by employing a viability typology (O'Donoghue *et al.*, 2015) it recognises the viability, sustainability and vulnerability associated with the pluri-active nature of many farm households, where farming production and income are usually combined with other non-farm income sources (**Chapter 7**). In addition, some sensitivity analysis is carried out to explore indirect impacts of scenarios on factor markets, particularly land and labour.

Phase 5 *Reconciliation and interpretation of the macro, sector and farm level results, and their implications for UKAP post Brexit* (Leader: D Harvey and C Hubbard)

This phase integrates and reconciles the projections of the consequences of the Brexit scenarios (Phase 1) from the two aggregate and sector models (Phase 2), and also between these implications and the farm and household effects (Phase 3 and 4). An Advisory Board workshop took place in June 2018 to consider and develop the reconciliations and interpretations. The overall results were presented and discussed at a workshop organised by AHDB and Newcastle University (September 2018) that brought together over 40 participants of high calibre across the industry, policy-makers and academia (**Chapter 8**). However, we do acknowledge that this phase (as the project as a whole) has caveats. At least two major reasons support the differences and acknowledge some of the caveats of our study. First, the representation of supply and demand responses, and hence trade flows and resulting prices, differs substantially between the models. FAPRI represents these responses through specific product (sector) supply and demand equations, and associated trade equations, based on econometric examination of past histories of supply and demand responses to prices (and other major determinants). Whereas, the CGE model represents these same market forces through constructed consumer demand (utility) functions and production possibility functions, albeit calibrated to correspond to actual production and consumption levels. Since Brexit might generate rather different

responses in both production and consumption than have been observed in the past, neither model can be regarded, *a priori*, as more 'correct' than the other, but each generates somewhat different results as a consequence of their internal specification and calibration. Second, and more important, differences in model outcomes reflect the partial *versus* general specification of the models. FAPRI largely ignores the second-round effects of changes in primary production levels on factor, input and more or less related product markets, other than as reflected in historical (econometric) product supply and demand relationships. In contrast, CGE, explicitly includes these second (and subsequent) round effects. In general, it is expected that these second-round effects will tend to dissipate the first-round effects somewhat, though in specific (though *a priori* unspecified) instances, these second-round effects may compound the primary effects. Although it is possible, in principle, to design 'hard linkages' between partial and general equilibrium effects, to ensure that supply and demand responses reflected in the two models are similar, there was little point in doing so for this project, on two major grounds. First, there is no logical or empirical reason to suppose that any one reflection of the underlying market forces is inherently superior to another. Second, and pragmatically important, a hard linkage is technically much more demanding in extra time and resources, and was outside the scope of the present project.

2. Selected Trade and Domestic Policy Scenarios[5]

This Chapter addresses Phase 1 of the project, i.e. developing UKAP scenarios following Brexit through consultation and engagement with relevant stakeholders. It focuses on the identification of a limited number of policy scenarios that most realistically may depict the future agricultural and trade policy options following Brexit, and the critical issues raised by these options for UK agriculture and its stakeholders.

2.1. Rationale

This section describes the rationale and justification for, and choice of, the limited range of Brexit scenarios for this project. The direct consultation and engagement with relevant stakeholders for our scenario development took place in Newcastle on 23 May 2017, during the opening meeting of the project team with our Advisory Panel. Additionally, we considered a number of public expressions of the major dimensions of Brexit possibilities and issues, especially as comprehensively documented and discussed in the House of Lords (HoL) European Union Committee's *Brexit: Agriculture* report (HoL paper 169, May 2017). The selection of scenarios is limited by the extent to which the macro and sector models can reflect the implications of possible changes, as well as by the project resources and time-frame. The scenarios are chosen to represent the range of feasible options for: i) *trade relations* with the EU and the Rest of the World; ii) *domestic UK policy* for direct payments to farmers (currently the Basic Payments Scheme); iii) *labour availability and costs* (mainly relevant to the macro CGE model).

We recognize that restricting attention to these three major dimensions ignores Brexit implications and options for both *environmental policies* and also for *market, product and process regulations*. We justify our restricted focus on two major grounds. First, neither of our sector or macro models is able to reflect either environmental policies or the extent and effects of changes in market, product and process regulations in sufficient detail to warrant specific attention to these dimensions of Brexit options at the sector and macro levels. Second, exploration, dissemination and explanation of the possible options and their potential consequences over these dimensions in addition to the major trade and support policy dimensions would be both over-ambitious and largely impractical within the scope of this project. In addition, we consider that the implications of potential changes in both of these dimensions to be largely additive rather than strongly inter-active with changes in the trade, support and labour dimensions, at least in the first instance.

2.2. Conception and Specification of Brexit Scenarios

Three important features of the sector level analysis need to be emphasized at the outset. First, unlike most economic policy analysis, the *status quo* option, which normally forms a sensible Baseline, is not a realistic option in this case – the UK is to leave the EU (at the time of writing). Nevertheless, present circumstances, and hence model reflections of these circumstances, are conditioned on UK membership of the EU, the Single Market and the CAP. Hence, the only feasible Baseline available to analysts is that of continued membership of the EU.

[5] This chapter was extensively written by David Harvey.

Second, our scenarios are not intended to represent alternative forecasts or predictions of the actual outcomes of the UK/EU negotiations for either Article 50 or future trade relations and transition arrangements. The purpose of our scenarios is to represent the major characteristics of a range of possible negotiation outcomes specifically with reference to agriculture. Our model results of the scenarios relative either to the Baseline or to each other are not predictions of Brexit consequences. Rather, they are highly conditional projections of the effects of specific scenario variations, assuming that nothing else changes. In reality, many things will change, either as a consequence of or coincidentally with Brexit in March 2019. Specifically, with respect to agriculture, national and personal incomes, employment rates, exchange rates and interest rates will all change after 2019. Forecasts of the condition of UK agriculture after Brexit would require prediction of all these coincidental and consequential changes in macro-economic conditions, which is outside the scope of the present project.

Third, our modelling frameworks are inherently and explicitly 'equilibrium' in nature. We do not pretend to be able to represent the dynamic evolution, adjustment paths and processes of even the highly complex and multifaceted agri-food systems in Europe and the rest of the world, let alone the macro-economic and trade systems within which the agri-food systems are embedded. The models we use are *analytical simplifications*. They are intended to illustrate the principles on which we believe markets behave – essentially to balance supply with demand given current production possibilities, consumer preferences, market structures, transaction costs and trade possibilities. Although both models (CGE and FAPRI) include some dynamical adjustment – lagged responses and feedbacks – and hence are typically run over a number of periods (years), specific annual outcomes can only be interpreted as the model representations of the consistent effects of the market-equilibrating processes given the precise (but necessarily) general policy conditions specified in the scenarios. Thus, the model outcomes are best considered as the logical consequences of the specific features of the chosen scenarios, and not as coherent forecasts of the future.

2.2.1. Baseline

Our Baseline assumes continued membership of an unchanged EU Single Market and CAP as envisaged in 2019/20, but with no projected changes to the CAP or EU or UK trade relations beyond 2019. Each of the models is based on Global Insight macro-economic projections, supplemented by data sources from the World Bank as necessary. Each is run over a modelling period from 2017 to 2026, with Brexit scenarios beginning in 2019, where the outcomes in the final year represent the longer-run projections of the consequences of the scenarios. The Brexit scenarios are developed for, first, the UK's trade relations, and second for the UK (and implicitly for devolved administration) domestic agricultural support policy.

2.2.2. Trade Relations Scenarios

Against this Baseline, we consider three general trade relation scenarios which are designed to cover the range of possibilities which appear (Summer 2017) to embrace the possible outcomes of the UK/EU negotiations. In practice, as even a casual reading of trade agreements and associated disputes will testify, any trade agreement is highly complex. Our scenarios do not attempt to replicate this complexity and associated specificity and are intended only as a highly simplified and stylised

representation of the general frameworks of such potential agreements. Otherwise, both specification and modelling of these new and as yet unspecified relations is impossible.

2.2.2.1. UK-EU Free Trade Agreement (FTA)

This trade scenario represents a comprehensive UK/EU Free Trade Agreement, with UK-EU tariffs at zero. For relations with the rest of the world (RoW), this scenario assumes that the UK also adopts the EU Common Custom Tariff schedule (CCT) on RoW imports, and that the UK has a share of existing EU Tariff Rate Quotas (TRQs) applying to these RoW imports. However, since only the poultry TRQ has been close to being fully utilized, these quotas are not expected to be significant for this scenario. This scenario can be considered as a possible transition agreement, pending the development of further trade agreements between the UK and the rest of the world, as well as the UK's adoption of existing EU/RoW trade agreements. It does envisage the UK's departure from the Single Market, and hence raises the probability that there would be some additional trade facilitation costs affecting UK-EU trade. The 2017 HoL report (Brexit: Agriculture) outlines these considerations (p.30ff) related to the harmonization, mutual recognition or agreed equivalence of product and process standards, which are particularly relevant to agricultural and food trade, and to many of the inputs to the food system. While this scenario (FTA) implies that most of these standards and protocols would continue largely as at present, it is reasonable to assume that the UK-EU agreement could not exactly replicate the present complete Single Market harmonization without additional costs and thus (in effect) impediments to UK/EU trade. Since these impediments are generally likely to be more onerous in the livestock than the crop sectors, this scenario applies an admittedly arbitrary 5% and 2% additional trade facilitation cost respectively to EU/UK trade flows for these products, implying somewhat lower prices in the UK than the EU.[6]

2.2.2.2. Unilateral Trade Liberalisation (UTL)

To reflect comprehensive trade agreements between the UK and the RoW after Brexit, this scenario adds elimination of all tariffs between the UK and the RoW (an obviously extreme free-trade scenario), including imports from the EU. Such a scenario would necessarily involve extensive controls on the UK/EU trade flows to avoid displacement effects – the UK's tariff-free imports, at a lower price, from the rest of the world flowing straight to the EU market, either directly or indirectly (through substitution of products in the UK market), and hence undermining the EU's common customs tariffs. The most likely method of applying such controls would be through an extensive set of TRQs on UK/EU exports, effectively limiting export flows to be no greater than the Baseline flows (and thus generating some quota rents for UK producers from higher EU prices). Any additional UK/EU exports would then be subject to the EU's CCT, which would dilute UK prices. The monitoring and regulation of these TRQs and the associated rules of origin would add to the costs of UK/EU exports, which are likely to be more onerous for livestock than for crop products.

[6]There are some technical issues about the appropriate method of applying such trade costs within each of the models. In particular, the CGE model uses the Armington approach to reflect trading preferences and product differentiation between country pairs, which can be shifted to reflect additional non-tariff-measure (NTM) costs of trade. The alternative is to include these costs with border tariffs.

To reflect the essence of these complex considerations, we impose additional trade costs of 10% and 5% respectively for these products flowing from the UK to the EU under this scenario.

2.2.2.3. World Trade Organisation (WTO)

Our third trade scenario reflects the potential for no agreement being in place by March 2019, and a fall back to WTO terms (e.g. tariffs) thereafter. However, the establishment of the UK's commitments and obligations under the WTO would not be straightforward (HoL, 2017, p 15ff). For our purposes, this scenario is specified as the UK trading with both the EU and the RoW under WTO most favoured nation (MFN) tariffs, effectively removing the UK from all existing trade agreements, and requiring an allocation to the UK of a share of the current EU TRQs with the rest of the world. Again, there is an issue about the trade costs under such a scenario, where UK exports (both to the RoW and the EU) would be required to meet the product standards of the importing country, while it is also likely that there would be considerable pressure from UK consumers and citizens for the application of British standards to imports from elsewhere (e.g. hormone-free beef from the US). To reflect these considerations, we apply additional trade costs of an arbitrary but illustrative 8% and 4% for livestock and crop products, respectively, to UK trade flows in both directions with the EU.

2.2.3. UK Agricultural Policy (UKAP)

Brexit clearly implies that the UK, and the devolved administrations, will need to reconsider the framework of agricultural policy, currently determined by the EU via the Common Agricultural Policy (CAP), and heavily complicated by both environmental and rural development measures (largely under Pillar 2 of the CAP). In particular, Brexit (under any future trade scenario) implies no further UK contributions to or receipts from the EU budget. Currently, UK farmers receive a number of direct payments, under both "entitlement" and "voluntary" schemes. These schemes were introduced in a series of reforms of the CAP, and have their origin in compensating farmers for reductions in price support. They have a range of justifications, including income support (national or regional), nature and landscape conservation, payments for improved animal welfare, and vary by both CAP Pillar (1 or 2) and country (England, Wales, Scotland, Northern Ireland). Rather than trying to disentangle these different monetary streams and re-quantifying each under alternative scenarios, the project approach taken to post-Brexit payments to UK farmers is to consider all Pillar 2 payments (i.e. Less Favoured Areas and more explicit Agri-environmental payments) as continuing after Brexit at current real levels (in total), while Pillar 1 direct payments (which include the "greening" element of Basic Payments) would be replaced by "UK direct payments" (see below). Secretary of State, Michael Gove has promised a "green Brexit", to include payments to farmers being based on their supply of "public goods", such as the environment and "rural life" (or "human ecology"). Given the large range and complexity of these public goods, how this might be done remains unclear, as does the likelihood of further restrictions on individual direct payments in terms of their total value per farm business, farmer "activity" or other qualifying criteria. In view of this unresolved complexity, this project did not attempt to model the potentially different "green" effects of such a UK domestic policy (or more likely policies, in the four devolved administrations). Inclusion of environmental policy options would have very substantially complicated our analysis, and make dissemination of the results very much more difficult. Furthermore, and importantly, neither our partial nor our general equilibrium model currently deals with the environmental consequences of farming activities (and *vice versa*) in any

specific detail, so that the analytical gain from including environmental policies would have been rather limited. On these grounds, we excluded environmental policies (i.e. Pillar 2 payments) from consideration in this project and treated these policies and their payments as ongoing at current levels in the UK after Brexit. In particular, consideration of the potential options for the UK and devolved administrations for agricultural policy needs to take account of the trade relations, and any associated harmonization of product standards, which the UK adopts after Brexit.

It is likely that (in practice) the trade scenarios will be linked with the UK agricultural policy options (e.g., freer trade being linked, perhaps, with higher and more persistent farm support). We considered making this link explicit in our scenario definition, but have rejected this option. This is principally because to do so confuses the causes of model outcomes, making it difficult to distinguish between the effects of changing support and those resulting from changes in trade relations. We consider that this distinction is critical in providing coherent and robust analytical support to the policy decision-making process – the principal aim of this project.

As a result, our key agricultural policy focus concerns the Basic Payments (Pillar 1). Since these payments have been in existence for some time, both the CGE and FAPRI models already include them. There is, however, still considerable debate about the extent to which these payments actually affect the supplies of farm products (based on the commercial profitability of farms). It is possible to consider that farmers treat these payments as additional payments for their production. In the trade policy jargon, they are treated as being fully coupled, and directly affect (increase) production from what it would otherwise have been. Under the present WTO conventions, however, these payments are not considered to be significantly production-distorting in this sense, and designated so they are included in the "green box", hence they are not subject to any spending limits under current WTO rules. But, the actual effect of the EU basic payment scheme on agricultural production levels remains unclear, and hence the reflection of the effects in our present models is also somewhat arbitrary.

As a consequence, we are obliged to rely on the logic of existing economic principles, informed by the relevant research where available, to reflect the effect of these fixed annual payments. These principles assert that the effects of fixed annual payments on the agricultural industry are to increase the rents earned by the fixed factors employed in the industry (land, labour, capital and management), while perhaps allowing imperfectly competitive input, plant and equipment suppliers to charge the industry higher prices than otherwise. The consequence, in an effectively competitive agricultural sector, is that these annual payments to farmers are dissipated in higher land rents, possibly higher input and capital equipment prices, and greater returns to labour (both own and hired) than would otherwise be the case. With more labour, and perhaps more capital and land, employed in the sector than otherwise, production may be somewhat greater with these payments than without, depending on the productivity of the induced labour, capital and land.

At present, the CGE model uses a set of 'coupling rates' for these payments, related to the extent to which they are capitalised in the agricultural value of the land (based on estimates of the capitalisation rates found in the current literature in Summer 2017). We use these same rates in both models (CGE and FAPRI) to reflect the effects of the BPS on production. We also consider the likelihood of continued support payments to UK farmers following Brexit. There is very likely to be considerable pressure from farming groups (particularly in Scotland) for continued support in some form, and indeed the present payments have been guaranteed until 2020 (HoL, 2017, p. 57, para. 210), and promised to

2022 in the Conservative Party's 2017 election manifesto[7]. However, there will also be considerable pressure from both the Treasury and other spending Ministers to reduce and eventually eliminate these payments, releasing the funds for other purposes, including perhaps ecosystem services and rural development schemes. To reflect this broad consensus, we concluded that a phased-out of direct payments over a 5-year period (2020-2025) involving a straight-line reduction of current payment levels to zero in 2025, was considered as appropriate. Hence, we assume two domestic policy scenarios: (i) direct payments retained as currently under the CAP, and (ii) a gradual elimination of direct payments over a five-year period (2020-2025). Since the eventual production effects of these domestic policy options should be rather similar as far as our macro and sector models are concerned, we present results for the three trade scenarios, each with (+) and without (-) direct payments, in order to distinguish between the trade and domestic policy effects. Additionally, the potential differential effects between the phased elimination were explored in the farm-level analysis phase of the project.

2.3. Sensitivity Analysis Considerations

There are two major conditioning factors for the economic effects of Brexit policy scenarios on UK agriculture: i) the increased restrictions on migrant labour; and ii) the sterling exchange rate, both with the Euro and with the US dollar. While we could include these considerations in the specification of our scenarios, we have been very conscious of both the resources available for this project, and of the major aim of providing clear and understandable policy analysis for public debate and policy decision-making. We have therefore decided to treat both these major considerations through some limited sensitivity analysis of our major results.

2.3.1. UK migrant labour policies

As the HoL 2017 report makes clear (Chapter 6, p.68ff), the UK's agri-food sector is presently heavily dependent on (both seasonal and permanent) migrant labour, much of which comes from the EU. If, after Brexit, UK immigration policies tighten the regulation of these migrant flows, then labour supplies will be restricted, especially affecting the horticultural, intensive livestock (pigs and poultry), food processing and packaging, and retailing (restaurant) sectors. However, our sector model (FAPRI) does not include either horticulture, or the processing and retail sectors. The CGE model, on the other hand, includes both 14 primary (agriculture, fishing and forestry) sectors, and 8 food processing sectors, as well as 5 different labour supplies (by skill level), and so is able to reflect restricted labour supplies to this extent.

According to evidence submitted to the HoL committee (HoL, 2017, p. 68, para. 253) between 10 and 60% of labour used in the most affected sectors is presently provided by migrant labour. Estimates show that 27,000 EU nationals are directly employed in agriculture and some 116,000 in the food processing sector (Byrne, 2018)[8]. It is highly unlikely that all of this labour will be prevented from coming to the UK after Brexit, or fail to be replaced to some extent by domestic labour or increased

[77] The 2018 Agriculture Bill (currently under the scrutiny of UK Parliament) proposes a seven-year transition period starting 2021. Hence, from 2021 direct payments for English farmers would be subject to a progressive phase-out, with 2027 the last year of payments.

[8] http://blogs.lse.ac.uk/brexit/2018/01/05/the-migrant-labour-shortage-is-already-here-and-agri-tech-cant-yet-fill-the-gap, last accessed 10 December 2018.

mechanisation. Hence, we tested the sensitivity of our main results to potentially restricted labour supplies, to the extent that resources allow, by examining the effects of restricting low (though specific) skilled labour supplies by between 10 and 30%.

2.3.2. Sterling Exchange Rates

The base exchange-rate projections used for our modelling exercises already included some allowances for the Brexit decision. The post-Referendum depreciation of sterling, by up to 20%, albeit with a recent recovery, indicates that the foreign exchange markets might be particularly sensitive to post-Brexit trade and economic policies in the UK, and consequential changes elsewhere, especially in the European Union. The CGE model database is specified in US dollars, whilst the model framework does not include any money markets, with the implicit exchange rates being embedded in the main drivers of economic activity (macro-economic projections), which are also used for the FAPRI model.

In both cases, it seems sensible to test the sensitivity of the main model results to a shift in the underlying real exchange rate between sterling and other currencies, not least because maintaining a real sterling depreciation is one major economic lever available to the UK government and the Bank of England to offset any potential decline in UK competitiveness in world markets as the UK economy adjusts to a post-Brexit world. For illustrative purposes, we tested the sensitivity of our main results to a depreciation in the real sterling exchange rate of between 10 percent and 20 percent, to the extent that the model structures (particularly the CGE) allow.

3. The Computable General Equilibrium (CGE) Model[9]

As a component of Phase 2, this Chapter focuses on the provision of aggregate projections of the impacts of the selected trade and domestic policy scenarios (as described in Chapter 2) on the UK agriculture, using an agriculture specific variant of the Global Trade Analysis Project (GTAP) multi-region computable general equilibrium (CGE) model. Specifically, it estimates the impacts of the Brexit scenarios focusing on the wider economy, on the sector *per se* (in terms of production volumes, market prices and factor markets) and trade balances between UK and EU, and UK and the rest of the world (non-EU regions). Furthermore, using sensitivity analysis, it assesses potential impacts following the reduction of unskilled migrant labour and the devaluation of the pound with respect to other currencies (e.g. euro).

3.1. CGE Methodology and Database

In the current experiment, version 9 of the well-known GTAP database is employed, benchmarked to the year 2011. The database is complete with a series of input-output tables for 140 regions, 57 activities and 5 primary factors of production (i.e., land, skilled labour, unskilled labour, capital and natural resources). This data is supplemented by gross bilateral trade flows, international transport margins and tariff protection data. To this database, is calibrated a multi-region neoclassical computable general equilibrium (CGE) market model known as 'Defra-Tap' (Philippidis *et al*., 2007 and Philippidis and Kitou, 2012). In explicitly representing the input-output relationships among various sectors, the model assesses the knock-on impacts on the wider economy given a policy change in a particular sector, i.e. agriculture. As typical of all neoclassical CGE models, the Defra-Tap model is based on a system of three types of mathematical equations to represent economic activity. First, a series of theoretically consistent *behavioural equations* based on convenient homogeneously linear functional forms implement the tenets of neoclassical constrained optimisation theory. With zero homogeneity of prices in the underlying demand and supply equations (i.e., no money illusion), only changes in relative prices matter. Second, *market clearing equations* are required to ensure that an equilibrium price emerges in the model solution for all N markets. Third, *accounting equations* are coded to enforce long-run zero economic profits for constant returns to scale production technologies in each activity 'j', whilst these accounting conventions also ensure a closed circular flow within each economy (i.e., output equals expenditure equals income). Global savings, which in each region is a fixed share of changes in real income, drives global international investment. At the regional level, investment is allocated across regions as a function of differences in the regional rates of return on capital. Assuming all N domestic markets clear, the net balance on the current account (exports minus imports) is balanced by the capital account (investment minus savings), such that the overall balance of payments sums to zero.

To ensure a model solution for a simultaneous system of mathematical equations, the number of endogenous variables (prices and outputs) must be equal to the number of equations; this is known as 'model closure'. The exogenous variables are typically policy variables (i.e., tax rates), productivity variables (i.e., technical change assumptions) and endowment stocks of primary factors of production. Subject to available secondary data projections, these can be manipulated by the modeller (i.e.,

[9] This chapter was written by George Philippidis.

'shocked') over time periods to capture, in as much detail as possible, the evolving macroeconomic structure of the economy.

3.2. Simulation Design

Starting from a benchmark year of 2011, the simulations are projected over three periods (2011-2017, 2017-2019 and 2019-2026). The Baseline scenario captures a 'business as usual' status quo which includes projections shocks on real growth and population provided from the FAPRI Baseline, to generate greater consistency between the common macro drivers of the two models. In the Defra-Tap model, it is assumed that the capital stock changes at the same rate as real GDP (fixed capital output ratio) and that skilled and unskilled labour change at the same rate as population (i.e., the rate of unemployment is assumed at a medium to long run fixed rate). In addition to these macroeconomic projections a series of policy drivers are also modelled. A Common Agricultural Policy (CAP) Baseline to 2020 consisting of shocks to first pillar payments is implemented based on the data work of Boulanger and Philippidis (2015). From 2020 to 2026, payments are deflated by a rate of 2 percent per annum. Thus, it is assumed that the decoupled/coupled structure of CAP first pillar payments is maintained unchanged beyond 2020 to 2026. Within the model, it is further assumed that first pillar (decoupled) payments under the single area payment scheme (SAPS) embody a degree of coupling to production based on the best available estimates from the literature (with the usual associated caveats) collated by Boulanger, Philippidis and Urban (2017)[10]. In the database, the proportion of the SAPS which is capitalised into land rents by each EU member state is allocated as a uniform subsidy rate payment to the agriculture specific land factor[11]. By entering the first order conditions as a uniform payment, this component of the decoupled payment is not production distorting whilst avoiding cross commodity effects. The remaining proportion (92%) of the SAPS is allocated uniformly across land, agricultural labour (skilled and unskilled) and agricultural capital factors. To the extent that a proportion of the single payment schemes is implemented to labour and capital, which can enter/leave the agricultural sector, the SAPS payment can be considered as coupled to production. Notwithstanding, this degree of coupling is also limited by a (elasticity) transformation mobility parameter (typically very inelastic) between agricultural and non-agricultural uses, which is implemented to reflect the rent and wage differentials that exist between these two sub-sectors.

In addition to the CAP shocks, trade policy shocks in the 2011-2017 period are implemented to characterise the accession of Croatia to the EU and the elimination of all EU export refunds. Moreover, for a select group of cereals, oilseeds, meat and dairy sectors, the Baseline trends in output reported in FAPRI across each period are targeted in the Defra-Tap model (a so-called 'soft-linkage'). To meet these output targets in the CGE model, in an initial run, a Hicks neutral output productivity variable for activity 'j' is 'endogenised' (swapped with exogenous output) and calibrated to the exogenously shocked output targets fed in from FAPRI. In the final Baseline, the resulting calibrated productivity values for those activities 'j', are implemented as exogenous shifters in all periods for all simulations (i.e., Baseline plus Brexit policy simulations). In the Baseline, these shifters will generate the desired

[10] This implies that the standard GTAP benchmark database corresponding to the EU domestic support component, must be recalibrated to reflect the new allocation of the SAPS across the factors of production in the EU regions.
[11] In the UK, this capitalisation rate is estimated to be approximately 8%, compared with the EU15 average of 6-7% and the 2004 enlargement members average of 10% (Boulanger, Philippidis and Urban, 2017).

FAPRI Baseline output trends, whilst in the remaining simulations, deviations from this Baseline are due to additional policy shocks. A summary description of the Scenarios is provided in Box 3.1.

Box 3.1. Baseline and Scenario Descriptors

Baseline from 2011 to 2026: real GDP and population projections consistent with FAPRI model, agricultural output developments linked to the FAPRI model (soft-link), EU enlargement tariff shocks, CAP Baseline.

UK-EU Free Trade Agreement (FTA) (Scenarios 1 and 2):

Scenario 1 (FTA +): Baseline shocks plus for 2019-2026 for UK-EU trade flows, 2% additional trade costs on all non-agri-food goods, 2% additional trade costs on cropping activities and 5% additional trade costs on livestock.

Scenario 2 (FTA-): The same as scenario 1 plus the elimination of CAP Pillar 1 direct payments.

Unilateral Trade Liberalisation (UTL) (Scenarios 3 and 4):

Scenario 3 (UTL+): Baseline plus for 2019-2026 for UK-EU trade flows, 2% additional trade costs on all non-agri-food goods, 5% additional trade costs on cropping activities and 10% additional trade costs on livestock. Also, all import tariffs between the UK and the ROW are eliminated, whilst EU imports of goods from the UK cannot exceed the Baseline level (to avoid cheaper imports to the EU emanating from the UK).

Scenario 4 (UTL-): The same as scenario 3 plus the elimination of CAP Pillar 1 direct payments.

A fall back to World Trade Organisation (WTO) (Scenarios 5 and 6) terms:

Scenario 5 (WTO+): Baseline plus for 2019-2026 for UK-EU trade flows, 2% additional trade costs on all non-agri-food goods, 4% additional trade costs on cropping activities and 8% additional trade costs on livestock. Tariffs on trade between the EU and UK are now subject to WTO Most Favoured Nation (MFN) applied average rates, whilst tariffs on UK-ROW trade are also subject to WTO MFN.

Scenario 6 (WTO-): The same as scenario 5 plus the elimination of CAP pillar 1 direct payments.

3.3. CGE Results

The results presented in this section are comparisons with the Baseline at the end of the third period. The differences can be interpreted as an average per annum deviation from the Baseline path over the seven-year period 2019-2026. All results are in real terms (as no allowance for inflation in the model). The CGE model highlights the following key points. The UK is a net importer of agricultural and food products. The impact of the scenarios is heterogeneous across individual UK agricultural and food activities, and it is conditioned by the degree of relative trade competitiveness (i.e., relative tariffs) and trade openness in each UK sector. A decomposition of the results compared with the

Baseline by the underlying trade shocks drivers, reveals that each policy tool (e.g., EU/UK trade costs, UK/ROW import tariffs) can have conflicting impacts on production and prices.

3.3.1. Macroeconomic results

Our CGE modelling shows that in all scenarios considered, Brexit has a negative impact on UK Gross Domestic Product (GDP) and real per capita incomes (Table 3.1). Under FTA+, with the imposition of additional trade facilitation costs associated with the loss of single market access (by 2026), UK real GDP and per capita income are, on average, -0.34% and -0.44% lower per annum, respectively, than the Baseline[12]. In the absence of other trade shocks, higher assumed trade costs between the EU and the UK, under UTL+, would generate an even greater slowdown to the UK economy. This impact is, however, mitigated by the removal of UK-RoW tariff barriers which, in isolation, generates increasing UK real incomes associated with cheaper UK access to RoW imports and increased economic opportunities to UK exporters from lower cost access to RoW markets. As a result, although UK real economic growth and real incomes remain below the Baseline (-0.22% and -0.12%, respectively), this scenario produces the best outcome for the UK when comparing with FTA+ and WTO+. The macroeconomic impact resulting from WTO+ (scenario 5) is the worst outcome for the UK. Although the assumed trade costs from the loss of EU single market access are lower than in UTL+ (scenario 3), the damage inflicted on the UK economy from the loss of tariff free access to the EU and the adoption of WTO MFN applied average tariff rates (with the associated loss of preferential access to third markets) results in an average per annum reduction in UK real Gross Domestic Product and per capita real income of -0.42% and -0.59%, respectively.

As expected, when comparing with each of the pathways represented in scenarios 1, 3 and 5 (trade scenarios with direct payments), the elimination of first pillar CAP payments under FTA-, UTL- and WTO- (scenarios 2, 4 and 6) has a very slight positive impact on UK real GDP and real per capita income (Table 3.1), due to the allocative efficiency gains from the removal of subsidy distortions in the UK agricultural sectors and associated reallocations of agricultural factors to higher value uses. That these effects are negligible is due to the fact that in macroeconomic terms, UK agriculture is a 'small' sector.

Table 3.1. Impacts on UK GDP (%) and per capita income (%) (cf Baseline projections 2026)

	Scenarios					
	S1	S2	S3	S4	S5	S6
	FTA+	FTA-	UTL+	UTL-	WTO+	WTO-
UK GDP (%)	-0.34	-0.33	-0.22	-0.22	-0.42	-0.41
Per capita real income	-0.44	-0.44	-0.12	-0.12	-0.59	-0.58

[12] GDP changes differ from real per capita income changes because of the depreciation on investment. Real GDP is a quantity measure of real economic growth (including depreciation) and the utility measure is a per capita change in 'net' domestic product.

Thus, in macroeconomic terms, the impacts that arise from the scenarios are relatively small. A reversion to WTO under most favoured nation (MFN) tariff schedules reduces it the most, circa 0.4 percent per annum on average, whereas UTL reduces it the least, 0.22 percent per annum on average. This is because average tariffs in the wider economy between the UK and EU, as well as the assumed trade cost increases, are only moderate for the majority of UK economic activities. In those scenarios where larger tariffs and/or trade cost shocks occur, these effects are typically restricted to agri-food industries, which constitute only a small share of the UK GDP.

For the EU27, comparing with the Baseline, real GDP losses in scenarios 1, 3 and 5 (not shown) are -0.042%, -0.048% and -0.051% per annum on average. The asymmetry in magnitudes between the UK and the EU27 reflects the fact that the EU represents a much larger trade partner for the UK in proportional terms, whilst the percentage changes in UK macroeconomic performance are calculated from a smaller base. With very small sectoral percentage impacts in EU sectors, the remaining Chapters focus on the impacts for the UK only. Despite the small impacts at the macroeconomic level, considerable potential impacts are expected, both for the agri-food sector and food consumers in terms of retail price changes, as elaborated below.

3.3.2. CGE sectorial model drivers

In each of the scenarios, the resulting impact on different UK agri-food activities is not uniform. This observation is driven by (i) the degree of 'openness' of each UK agri-food sector 'j' with respect to foreign trade; (ii) the relative competitiveness of each UK agri-food sector 'j' compared with its trade partners, measured in terms of the applied *ad valorem* tariff barriers in place; (iii) and the degree of substitutability of trade in said sector 'j' when the vector of relative UK import prices changes in response to policy shocks.

Furthermore, the impact of different trade shocks can generate conflicting impacts for UK prices and output. To illustrate, the case of the loss of the single market access to the UK is applied. The EU imposed trade costs discourage demand for UK exports, thereby depressing UK production and market prices. By the same token, increased protection in the form of UK trade costs on imports from the EU, increase production and domestic market prices. The net market effects of these individual shocks depend on the purchase share of EU imports in the UK and the UK sales share of EU exports in each sector 'j' (first round effects), as well as the impact on primary factor reallocations between expanding and contracting sectors, resulting changes in regional incomes and real GDP growth (second-round or 'general equilibrium' effects). With these considerations in mind, this Chapter describes the structure of UK agri-food production, consumption and trade calculated by the model for the Brexit starting-period year of 2019 (Annex 3.1), whilst Annex 3.1 shows the level of average *ad valorem* tariff protection between the UK and the RoW. In the composite UK 'primary agriculture', exports account for approximately 8% of the value of sales, with 5.4% going to the EU market (Annex 3.1). On the other hand, not only does the UK exhibit a trade deficit with the world in all primary agricultural sectors totalling approximately £8 billion (Annex 3.11 - 2011 prices), 33% of the value of UK purchases of aggregate agricultural products are imports, with over 17% originating from outside the EU (Annex 3.1).

In the broad sectors of horticulture and other crops (which includes live plants, flowers, seeds, spices, fodder crops, protein crops), a majority share of UK purchases (73% and 59%, respectively) are imported and evenly split between EU and non-EU sources. In the oilseeds sector, UK imports from RoW sources accounts for over a third (34%), whilst almost all UK purchases of paddy rice (91%) originate from non-EU sources. In contrast, UK cereals production exhibits a much higher degree of self-sufficiency, with trade mainly occurring with the EU. Comparing relative trade protection between the UK and the non-EU region (Annex 3.1), the UK imposes lower tariffs in all of these aforementioned cropping sectors. In terms of live animals, both UK cattle and sheep and pigs and poultry exhibit relatively small export sales shares and import purchase shares, whilst the level of trade protection imposed by the UK and non-EU region on mutual trade is broadly similar. Interestingly, although both plant-based fibres and wool sectors are very small (with small UK trade deficits – Annex 3.11), they are extremely open to trade. In the wool (plant fibres) sector, 84% (88%) of the value of UK sales are exported whilst 91% (95%) of the value of UK purchases are imported. In both commodities, the UK's export and import trade is dominated by the non-EU region. Trade between the UK and the non-EU region in wool and plant fibres is practically tariff free, although the RoW imposes a tariff of 26% on imports of wool from the UK (Annex 3.1).

As in the case of the primary agriculture sector, the UK also runs a trade deficit in all food processing activities totalling approximately £16.5 billion (in 2011 prices; Annex 3.11). Approximately 18% of the value of UK food sales are exported, where some 11% are destined for the EU market. On the import side, approximately 30% of the value of UK food purchases is imported (Annex 3.1), with a relatively larger proportion (compared with primary agriculture), coming from the EU trade bloc. In the (aggregate) dairy sector, the value share of exports is marginally above the UK food average (20%), whilst the large majority of (tariff free) UK dairy trade is with the EU – with exports accounting for 20% of the value of UK production and 25% of the value of UK purchases of dairy products. As an EU member, the UK also benefits from TRQ preferential access to imports of butter and cheese from the non-EU region, with a weighted *ad valorem* applied tariff of 24.5% (Annex 3.1).

In the red and white meat sectors, the UK exhibits large trade deficits of £1.1 billion and £4.8 billion with the entire World (EU + RoW), respectively (Annex 3.11 - 2011 prices), whilst 29% and 40% of UK purchases are imported (Annex 3.1). Although UK white meat imports are heavily biased in favour of the EU, red meat imports are evenly split between the EU and non-EU region (e.g., New Zealand, Australia). Comparing UK and non-EU region tariffs (Annex 3.1), the UK imposes an average *ad valorem* applied import tariff of 21% on white meat (which accounts for the UK's TRQ on poultry meat), compared with only 11% by the non-EU region. On red meat trade, the UK's *ad valorem* tariff on non-EU region red meat exports is 45% (which accounts for the UK's TRQ on sheepmeat), whilst the non-EU region imposes an average *ad valorem* applied tariff of 27% on UK exports of red meat.

The UK also runs trade deficits in processed sugar and processed rice of £329 million and £188 million, respectively (Annex 3.11), with greater import dependency in both cases from the non-EU region[13]. In both cases, comparing with the non-EU region, the UK is considerably more protective of its imports, 18% and 17% on sugar and rice, respectively, compared with corresponding tariffs of 6% and 8% imposed by the non-EU region on UK exports (Annex 3.1). The UK is also heavily dependent on

[13] In the case of raw sugar, non-EU region sourced imports to the UK come from Brazil, Central America, Jamaica and Oceania. In terms of rice trade, non-EU import sources to the UK include Thailand, India, Pakistan and the USA.

vegetable oils and fats imports, with almost 40% coming from the non-EU region[14]. With its comparative disadvantage, these imports enter the UK market almost tariff free (2%), whilst the average RoW tariff on the UK's exports is a highly prohibitive 55%.

A considerable proportion of remaining food processing production and trade is captured in the residual composite 'other food' processing sector (including fish products, and all remaining processed food products not elsewhere classified). This sector accounts for half of the UK's food processing trade deficit (£7.7 billion in 2011 prices, Annex 3.11). The export sales share (19%) is almost evenly split between EU and non-EU trade routes (Annex 3.1), whilst the value share of UK purchases attributed to imports is 27%, with 20% coming from the EU. The average *ad valorem* tariff imposed by the UK on RoW exports is half (7%) of that imposed by the non-EU region on UK exports.

3.3.3. Output results vs Baseline Scenario

In the following Chapters, the results are presented in two formats. On the one hand, the incremental impact of each of the policy scenarios is measured *in comparison with the Baseline*. Furthermore, an approximate decomposition of this incremental impact can also be performed for each scenario by linking to the corresponding additional exogenous trade (and CAP) policy drivers which define each policy scenario. In other words, employing a technique by Harrison *et al.*, (2000), we show the approximate contribution ('part-worth') of each additional trade and CAP policy driver, to the change in output volumes compared with the Baseline.

3.3.3.1. FTA+ (Scenario 1)

Comparing with the Baseline, the net production impacts resulting from the introduction of assumed UK and EU trade costs (to capture the loss of UK single market access) are relatively small. This results from the opposing domestic production impacts arising from UK imposed trade costs on EU imports (Annex 3.2, column 2) which protect domestic production, and the EU imposed trade cost on UK exports (Annex 3.2, column 3), which discourages UK production.

Examining the part-worth of EU imposed trade costs on UK production (Annex 3.2), in the food processing sectors the effect is negative, with the strongest impact in the export-oriented UK dairy and processed sugar sectors (-2.8% and -1.0%, respectively). As a result, in the corresponding upstream sectors of raw milk and raw sugar, production also contracts as a result of this shock. In the upstream agricultural sectors, with higher EU trade costs assumed for UK livestock produce, the impact is also negative on UK livestock sectors, although this has the second-round impact of freeing up agricultural resources (i.e., capital and labour) into a number of cropping activities.

Rising UK trade costs on EU imports act as a form of protectionism for UK producers, which encourages production. This observation is particularly prevalent in the UK livestock, dairy and meat sectors. In white meat, 34% of UK purchases are from the EU, such that the UK trade cost increases provides UK produces with a significant opportunity to increase production, resulting in an output rise of 4.0% (Annex 3.2, column 3).

[14] Principally from Argentina and to a lesser extent, Brazil, the USA, India and the Ukraine.

In remaining agricultural and food sectors, the effect of this specific shock is more ambiguous. Despite the protectionism that this trade policy affords to UK producers, primary resources are also reallocated (particularly in primary agriculture) in favour of livestock and away from cropping activities whilst the UK trade cost shock also reduces real growth due to the deflating impact on primary factor returns, regional income and domestic demand.

Comparing with the Baseline, the net impact of these two opposing trade shocks on UK primary agricultural production and food processing production is approximately +0.4% in both sectors (Annex 3.2, column 3), suggesting that the UK trade protection effect is slightly stronger, whilst there is relatively greater relative production gain in UK meat production (+2.0%) and livestock (+0.5%) (vis-a-vis cropping, +0.2%).

3.3.3.2. UTL+ (Scenario 3)

Under *UTL*, one assumes greater trade cost increases on crops and livestock products, which produces stronger positive and negative production effects. For example, in red meat, dairy and processed sugar sectors, the negative production impacts compared with the Baseline reported under *FTA*, are larger. Similarly, the positive production impact for white meat under the *FTA* scenario is also stronger (6.2%, Annex 3.3, column 3).

In addition to the trade cost shocks, the *UTL* scenario also contemplates tariff elimination shocks between the UK and the non-EU region. In isolation, UK import tariff elimination encourages greater import competition from the non-EU region, whilst non-EU region tariff elimination offers export opportunities to UK producers. In Annex 3.3 (columns 4 and 5) are presented the net impacts on production and the part-worths associated with these tariff shocks.

From the discussion of the model drivers above, in a number of primary agricultural activities (paddy rice, horticulture, oilseeds, other crops, plant-based fibres, wool) and food processing activities (red meat, vegetable oils and fats, processed rice, processed sugar) the non-EU sourced import share of UK purchases is relatively high. Furthermore, there are high UK tariffs on wheat, red meat, white meat, dairy, processed rice and processed sugar. Thus, the isolated impact on UK production arising from the removal of UK protection on imports of red meat, white meat, processed sugar and processed rice, is negative (Annex 3.3, column 5). A similar negative effect is also observed for UK wheat production (-1.6%), which implies sectoral trapped land is substituted into other cropping activities (particularly cereals and oilseeds). With reduced downstream demand by sugar and meat sectors from the elimination of UK tariffs, upstream raw sugar and livestock production also contracts under this shock, also reinforcing the reallocation of agricultural factors into other agricultural activities.

Although UK dependency on horticulture and oilseeds imports from the ROW is relatively high, the elimination of UK tariffs does not contract output in these sectors, partly due to the resource reallocation effect and also owing to the fact that UK tariff protection in both sectors is very low (3% and zero, respectively). In the dairy sector (and by extension, the upstream raw milk sector), the production effect arising from removing UK TRQs (on butter and cheese) is only minor given the small non-EU region UK purchase share of dairy products (approximately 1%; Annex 3.1, column 7).

Turning to the effect of the non-EU region tariff eliminations, the highest average applied *ad valorem* tariffs imposed are on UK exports of wheat, wool, red and white meat, vegetable oils and fats and the 'large' sectors of dairy and 'other food processing' (see Table 3). Notwithstanding, the UK sales share corresponding to the non-EU is minor in all these activities except for wool, vegetable oil and fats, other food processing and to a lesser extent, dairy. As a result, these latter UK activities benefit the most from the removal of the non-EU region import tariff (46.4%, 103.9%, 4.4% and 3.1%, respectively – Annex 3.3, column 4). With dairy and other food processing sectors accounting for over 70% of UK food processing output, the removal of non-EU region tariffs results in the contraction in the remaining food sectors (rice, sugar, white meat) as primary resources are diverted away from these activities.

Due to the isolated impact of non-EU tariff removal, production trends recorded in downstream sugar (negative), dairy, vegetable oils and red meat (all positive) are also in evidence in the corresponding upstream sectors of raw sugar (negative production effect), raw milk, oilseeds and cattle and sheep (both with positive production effects). In remaining agricultural activities, there are low non-EU import tariffs on UK exports (Annex 3.1) and/or small UK export sales shares to the non-EU region (see Annex 3.1). Thus, with the exception of wool, the part-worth production impact resulting from the non-EU region tariff removal (Annex 3.3, column 4) is more related to second-round general equilibrium primary resource reallocation effects.

Combining all the trade shocks, under *UTL*, UK meat (particularly red meat), processed rice and sugar sectors perform worse than under *FTA* and *WTO* (see below). On the other hand, the large sectors of dairy and other food processing, as well the vegetable oils and fats sector, perform better, owing to unfettered UK access to non-EU export markets. As a result, UK food processing output rises almost 2% compared with the Baseline (Annex 3.3, column 6), which is the highest production increase across all three policy storylines. Despite a significant improvement in UK oilseeds and wool (small sector) production, UK primary agricultural output under *UTL* performs the worst compared with *FTA* and *WTO* (see later) due to the output contraction in UK 'cattle and sheep' and wheat sectors, as well as the smaller sectors of sugar beet, paddy rice and plant-based fibres. Importantly, UK agricultural production shifts in favour of cropping activities and away from livestock.

3.3.3.3. WTO+ (Scenario 5)

In this scenario, the UK now faces WTO Most Favoured Nation (MFN) tariffs on its trade with both the EU and the UK. The UK is a net importer of all agricultural and food products and has very strong trade relationship with the EU trade bloc. Not surprisingly, the part-worth impact of the rising EU tariffs on UK exports is very damaging to the food sector, particularly in red meat, dairy and processed sugar sectors (Annex 3.5, column 4), which leads to contractions in corresponding upstream agricultural sectors (cattle and sheep, pigs and poultry, raw milk, raw sugar). In the large 'other food' sector, the negative production impact is rather muted given the relatively smaller assumed increase in the average EU tariff. In primary agricultural activities, UK paddy rice (very small sector) and wheat are losers from rising EU import tariffs due to a large EU export sales share (paddy rice) or the EU tariff increase (wheat) (Annex 3.5). In the remaining, principally crop based, agricultural sectors (other grains, horticulture, oilseeds, other crops, plant fibres, wool), the assumed EU tariff increases are relatively small, so under this shock, these sectors increase in size as they attract more agricultural-

specific primary factors from those UK agricultural sectors which are contracting (e.g., wheat, sugar beet, paddy rice, cattle and sheep, pigs and poultry, raw milk).

In many UK agri-food sectors, the negative production affect from reduced market access to the EU is, in broad terms equally offset by MFN tariff protection imposed by the UK on its imports from the EU Annex 3.5, column 5). In some (small) sectors (e.g., paddy rice; sugar processing and sugar beet), however, the negative production impact in the UK from the EU imposition of MFN tariffs is markedly stronger as the value share of UK sales destined to the EU is high. On the other hand, for UK white meat activity, the positive production effect from UK tariffs dominates given the significant competitive edge given to UK producers to partially fill the significant white meat market share previously occupied by EU imports (34%; Annex 3.1).

Comparing with the part-worth production impacts arising from UK-EU tariff increases, those part-worths corresponding to UK-non-EU region tariff increases are of a lesser magnitude, since the non-EU trade shares (both on UK export sales and UK import purchases) are generally smaller. In general, the MFN tariff levels imposed by the UK and RoW offset one another in terms of UK production impacts. On the other hand, the UK tariff raising impact is strongly positive for UK production in the case of processed sugar, processed rice, red and white meat (plus corresponding upstream activities sugar beet, livestock). In the UK, each of these sectors exhibits a high UK purchase shares corresponding to imports from the non-EU region, whilst tariff increases corresponding to WTO MFN rates are significant. In the case of 'wool' and 'vegetable oils and fats' activities, the rise in the RoW tariff rate has a strong negative impact on UK production.

Examining the net impact resulting from all these trade policy shocks, aggregate agricultural output rises by 1.9% compared with the Baseline - more than in any other scenario. The fall in cropping activity output (-0.8%) is more than compensated by the relative rise in UK livestock output (3.5%), largely motivated by stronger meat processing demand for upstream 'cattle and sheep' and 'pigs and poultry' output. Indeed, UK meat production witnesses a significant production increase of 14.8% compared with the Baseline. UK dairy production rises very slightly (0.4%) compared with the Baseline, whilst UK food processing output expands 0.8% (Annex 3.5) compared with the Baseline.

3.3.3.4. Removal of direct payments (FTA-, UTL-, WTO-)

For each of the three pathways explored above (Scenarios 2, 4 and 6), a variant is modelled which eliminates all first pillar Common Agricultural Policy (CAP) payments (Annexes 3.3, 3.4, 3.5). The isolated impact of the trade costs is very close to that observed in the three scenarios above (results not shown). On the other hand, the production effect from the removal of first pillar CAP payments is negative in the UK's agricultural sectors, and as a result, the UK's downstream food processing sectors. As noted in Chapter 2 above, only a proportion of the first pillar single area payment is decoupled (allocated to the agriculture specific land factor as a uniform subsidy rate), whilst the proportion of the payment allocated to labour and capital factors which are not specific to agriculture (although highly immobile), is the proportion of the payment which is coupled. As a result, comparing with the 'standard' *FTA+* (scenario 1), *UTL+* (scenario 3) and *WTO+* (scenario 5), the policy shock to remove direct payments depresses UK agricultural output by -3.3% (Annex 3.2), -3.3% (Annex 3.3) and -3.1% (Annex 3.5), respectively, with a concomitant reduction in UK food processing output of approximately one percent in all three scenarios.

3.3.4. Price results vs Baseline

The trade policy shocks impose conflicting price effects, which implies that the net market price effect of any given policy scenario in comparison with the Baseline is not, *a priori*, immediately clear. A decomposition of the price effect by trade policy shock decomposes each of these effects into more intuitive part-worths. For example, as expected, the market price change in the UK resulting from the imposition of UK tariffs on imports from the EU is positive, since there is a resulting increase in the price of intermediate imported inputs (cost push) and final import demands in the UK. Similarly, EU trade cots imposed on UK exports, depress EU export demand for UK produce, with the result that relative UK market prices fall. As alluded to above, that the price effect across different UK activities is differentiated (although uniform in sign), is a function of the relative degree of trade openness of each sector, the size of the tariff or trade cost shock, and the elasticity of substitution of imports in the importing region.

3.3.4.1. FTA + (Scenario 1)

The isolated market price impact arising from the imposition of EU and UK trade costs is presented in Annex 3.6 (columns 2 and 3). On the one hand, the imposition of the UK trade costs on EU produce has a positive impact on UK market prices (column 3). Typically, the largest price rises occur in the animal related sectors (higher assumed trade cost). Indeed, in the UK white meat market, which exhibits a significant EU import purchase share, the price transmission effect resulting from the UK trade cost increase has a stronger repercussion on UK market prices (2%).

On the other hand, the introduction of EU import trade costs on UK exports has a depressing effect on UK market prices (Annex 3.6, column 2). In most cases, the UK trade cost shock on imports from the EU has the stronger effect resulting in a net increase in market prices compared with the Baseline. This reflects the net importer position that the UK maintains with the EU in all agricultural and food products (see also Chapter 3.6). In primary agriculture, prices rise a very moderate 0.1% compared with the Baseline, whilst in food processing the corresponding price rise is 0.4%.

3.3.4.2. UTL+ (Scenario 3)

In this scenario, the magnitude of the price effects is now stronger (Annex 3.7) given the assumption of higher trade costs both in animal (10%) and crop (5%) activities. As under *FTA* scenario, the UK trade cost shock has the stronger effect (vis-a-vis the EU trade cost effect). Additional trade shocks in the form of applied average *ad valorem* tariff removals between the UK and the non-EU region also present consistent price effects. Thus, the removal of RoW tariffs on UK exports increases UK agri-food market prices, whilst the opening of UK markets through the elimination of UK tariffs on non-EU exports, depresses UK market prices.

Examining the net price impacts compared with the Baseline resulting from the tariff shocks Table 8 (column 6), there is no clear price trend, although in processed rice, processed sugar and meat sectors, the UK tariff shock on non-EU exports has a larger impact leading to UK market price falls. More specifically, red meat exhibits a market fall of 11% compared with the Baseline, whilst notable market price falls are also recorded in processed rice (-5%) and processed sugar (-7%). Compared with the Baseline, there are overall market price falls in paddy rice (-2%), sugar beet (-3%) and cattle and sheep (-2%) reflecting falling demand in the corresponding downstream sectors. On the other hand, the

relative UK price rise in oilseeds (2%) reflects the expansion of the vegetable oils and fats sector in this scenario, whilst there are also price rises in the large dairy, and 'other food' processing sectors. With positive and negative net price effects across individual agri-food sectors, in the aggregate crop and livestock sectors, as well as total food processing, the UK market price impact compared with the Baseline is negligible

3.3.4.3. WTO+ (Scenario 5)

As under *FTA and UTL* scenarios above, the net impact from the imposition of UK and EU trade costs (4% cropping activities, 8% livestock activities) is relatively price inflationary in the UK (Annex 3.8) under *WTO*. Furthermore, rising protectionism reflecting the adoption of WTO MFN rates, generates a notable inflationary impact on agri-food prices in the UK (Annex 3.8). Once again, this net price inflationary effect reflects the import trade dependency exhibited by the UK for agricultural and food products. Examining the overall impacts (Annex 3.8, column 8), compared with the Baseline there are market price rises of approximately 7%-8% in red meat, white meat, dairy and processed sugar, whilst aggregate food processing prices rise 3.7%. The index of agricultural prices rises 2% compared with the Baseline, with the largest price rises in cattle and sheep (3.5%), pigs and poultry (2.6%) and horticultural sectors (3%).

3.4.4. Removal of direct payments: FTA- (Scenario 2), UTL- (Scenario 4), WTO- (Scenario 6)

Examining the relative market price effects within each of the Brexit scenarios due to the additional removal of first pillar CAP payments, the clear trend that emerges is that agricultural prices rise further (Annexes 3.6, 3.7, 3.8). This result is driven by cost considerations as the SAPS is removed from the agricultural factors of production, resulting in an increase in the unit cost of primary agricultural factors to the farmer. As a result, the increase in UK aggregate primary agricultural market prices attributed to the loss of first pillar payments is approximately 3.2%-3.4% across the three scenarios, with a concomitant price rise of approximately 0.3%-0.4% in the downstream food processing sectors.

3.5. Agricultural factor markets

Annex 3.9 shows the impacts on the UK's agricultural land and agricultural labour markets under each of the Brexit scenarios. In each of scenarios 1, 3 and 5, the changes in UK agricultural labour employment and land supply shadow the trends for agricultural output. Agricultural labour supply changes are limited since total UK labour supply in each policy scenario is assumed unchanged, whilst the transfer of labour between agricultural and non-agricultural subsectors is highly sluggish. Similarly, relative changes in UK land supply are small since it is modelled as supply inelastic.

Thus, under *WTO*, UK agricultural output rises compared with the Baseline (driven by downstream processed meat demand for upstream animal livestock – Section 3.3.3) drive up relative UK agricultural employment and land use by 1.7% and 0.1%, respectively. A similar relative effect is observed for the *FTA* scenario, although the magnitudes are considerably smaller since agricultural output only expands by 0.4% compared with the Baseline. Under *UTL*, the relative fall in UK agricultural production of 0.9% leads to agricultural land leaving the sector and land abandonment, although in both cases the impacts are very small.

With a highly inelastic UK land supply curve, land rent changes are larger in magnitude than the accompanying land supply changes. Moreover, with only a muted relative rise in UK land supply in the *FTA* and *WTO* scenarios (inelastic land supply function), land yields need to rise to bridge the increases in agricultural output. Under the *UTL* scenario where agricultural output falls relative to the Baseline, land yields also fall as output falls more than land abandonment. The marginal impact on agricultural wages is relatively limited under *FTA+* (S1), *UTL+* (S3) and *WTO+* (S5), conditioned by relative rates of growth between competing agricultural and non-agricultural using sectors.

With the additional removal of the Common Agricultural Policy first pillar payments in the UK in each of the three scenarios, both employment and wages are depressed in UK agriculture. For example, the agricultural employment reduction compared with the corresponding Brexit scenario where first pillar CAP payments are maintained, is between -2.4% and -2.7%. As a result, the wage depressing effect compared with the corresponding Brexit scenario where first pillar CAP payments are maintained, is approximately 3.5%-4%. Similar negative trends for land use and land rents are also observed (due to the lost capitalisation of first pillar CAP payments into land rents). In addition, land yields in the UK also fall with removal of first pillar payments (as agricultural output drops more rapidly than land abandonment).

3.6. Trade Balances

Annex 3.10 presents the impacts on the UK trade balance for each of the agriculture and food sectors compared with the Baseline by 2026 (2011 world prices, million pounds). Examining the UK trade balance with the EU27 in the Baseline, by 2026, there is a UK trade deficit in all primary agricultural and food markets. Of the total in primary agriculture (-£3,310 million), the vast majority is in the aggregate sectors of horticultural products (-£2,239 million) and 'other crops' (-£1,099 million). Similarly, from the trade deficit for food processing (-£14,993 million), most is attributed to meat (-£4,462m million), dairy (-£2,075 million) and the large residual 'other food processing' (-£8,194 million) sector.

The UK also exhibits a trade deficit with the non-EU region in both of primary agriculture (-£4,730 million) and food processing (-£1,499 million). Once again, the structure of the food processing deficit is largely attributed to the meat sector (-£1,487 million). In primary agriculture, the cropping sector trade balance (-£4,834 million) dominates, corresponding to the broad sectors of horticulture (-£2,763 million) and other crops (-£1,215 million). In the following Sections, all results are presented in comparison with the Baseline.

3.6.1. FTA+ (Scenario 1)

In general, by 2026 agricultural and food trade balances with the EU27 improve compared with the Baseline by £26 million and £693 million, respectively. On the one hand, this result is due to the fact that the UK is a net importer with the EU. Thus, applying the same trade cost rises in both partners the expectation is that the monetary impact from reduced UK imports from the EU will be larger than the monetary impact from reduced UK exports to the EU.

The net UK trade balance impacts with the non-EU region reflect a price substitution effect as the UK imports more from the RoW to partially substitute the loss of EU imports, and a trade displacement of UK exports to the RoW. In all primary agricultural sectors, the import substitution effect is stronger, resulting in worsening UK agricultural and food trade balances with the RoW (-£193 million and £430 million, respectively).

Summing over the UK's trade balances with the EU27 and the non-EU region, in primary agriculture, the situation worsens slightly compared with the Baseline in 2026 (-£167 million), whilst for processed food, there is a corresponding improvement (£262 million).

3.6.2 UTL+ (Scenario 3)

With the imposition of higher trade cost assumptions between the UK and the EU, the relative UK trade balance improvements with the EU27 reported in the FTA scenario are now even stronger under the UTL scenario (£291 million and £3,622 million in primary agriculture and food processing, respectively – Annex 3.10). In terms of the UK's relative trade balance changes with the non-EU region, in addition to the effects of the UK's displaced trade with the EU, as reported for FTA, these balance changes are also driven by simultaneous tariff elimination shocks on gross bilateral trade flows between the UK and the non-EU region. Examining Annex 3.1, non-EU tariff protection is higher for many agri-food activities, with the notable exceptions of pigs and poultry, meat activities, dairy, rice and sugar. Furthermore, the UK has trade deficits with the non-EU region in almost all commodities, which implies that non-EU tariff eliminations (vs. UK tariff eliminations) on gross bilateral trade flows would have to be considerably larger in order to generate relative trade balance improvements for the UK. Examining the results for primary agriculture and food processing, the relative UK trade balances with the non-EU region, in general, worsen compared with the Baseline (and under FTA). In some sectors (other food, vegetable oils), relative production improvements reported in Section 3.3.2, generate export increases to the non-EU region and, consequently, UK trade balance improvements compared with the Baseline.

Examining the overall trade balance impact with the world (Annex 3.10), the UK primary agricultural and food trade balances worsen £435 million and £468 million, respectively, due to the UK's stronger trade balance deterioration with the non-EU region.

3.6.3. WTO+ (Scenario 5)

With significant increases in trade protection imposed on gross trade flows between the UK on the one hand, and the EU and non-EU regions, both UK export and import volumes are reduced significantly. In the case of the meat and dairy sectors, relative UK trade balance improvements with the EU in red meat (£380 million), white meat (£2,299 million) and dairy (£949 million), due to the loss of tariff-free import access, are the key drivers of the UK's processed food trade balance improvement with the world (£2,145 million). Indeed, as noted in Section 3.3.3, in the case of the UK's red and white meat activities, domestic production rises strongly to fill the gap created by the reduction in imports. Elsewhere, the UK's dairy trade balance with the EU improves £949 million, which drives an overall UK trade balance improvement with the entire world of £844 million.

The shortfall in UK domestic agri-food consumption between the loss of UK imports from the EU and the rise in domestic production, must be met by imports from the non-EU region. This effect mitigates the fall in UK imports from the non-EU region, such that there are further trade balance deteriorations with the non-EU region in many sectors.

3.6.4. Removal of direct payments: FTA- (Scenario 2), UTL- (Scenario 4), WTO- (Scenario 6)

Under all scenarios, the removal of direct payments, results in relative falls in production and relative rises in market prices are reported (Sections 3.3 and 3.4). As a result, there is a further deterioration in UK's agri-food trade position reflecting slight falls in UK competitiveness and exports (Annex 3.11 vs Annex 3.10). For example, Annex 3.11 reveals that without CAP Pillar 1 direct payments, the UK's primary agriculture trade balance with the world compared with the Baseline now deteriorates -£520 million, -£794 million and -£892 million under *FTA*, *UTL* and *WTO* scenarios, respectively. This is compared with the corresponding figures reported in Annex 3.10 (CAP unchanged) of -£167 million, -£435 million and -£567 million. A similar observation is apparent for the UK's processed food trade balances.

3.7. Sensitivity Analysis

3.7.1. Unskilled labour migration controls

Further simulation experiments examine the impacts of an immigration policy limiting the agricultural unskilled labour force in the UK in the post Brexit period of 2019-2026. More specifically, in the period 2019-2026, two experiments are conducted where the agricultural unskilled labour force is assumed to be reduced by 10% and 30% compared with the Baseline, under each of the six scenarios.[15]

A cursory examination of Annex 3.12 shows, as expected, that for each of the six scenarios, the volume of output in all UK agricultural and food sectors falls further. For example, compared with the Baseline, *FTA+* (scenario 1) reported a 0.4% increase in UK primary agricultural production, although with a 10% and 30% reduction in agricultural unskilled labour in the post-Brexit period, there is a further fall in UK agricultural output, *compared with simulation 1*, of -2.8% and -10.4%, respectively. The corresponding output volume fall in the UK crops sector is slightly larger than the agricultural average (-3.3% and -12.1%, respectively), confirming that this sector is more intensive in unskilled labour. In all sectors and scenarios, the magnitude of the output contraction from the reduction in agricultural unskilled labour is broadly uniform across all scenarios.

With the reduction in the labour force, unskilled labour wages and agricultural prices rise in the UK (Annex 3.12). Thus, relative to the result in each of the six policy scenarios, agricultural wages rise a further 5% and 17% with reductions in unskilled labour of 10% and 30%, respectively. As a result, corresponding rises in UK agricultural prices are approximately 3% and 11.5%, respectively, whilst in processed food, these price rises are approximately 0.3% and 1%-1.5%, respectively.

[15] According to the House of Lords Committee (HoL, 2017, p.68), between 10% and 60% of UK agricultural unskilled labour is migrant.

The UK trade balance effect with the world is also shown in Annex 3.13. With the reduction in UK agricultural output and export volumes resulting from a smaller unskilled agricultural labour force, the trade balances also deteriorate. In each scenario, a 10% unskilled labour force reduction in the 2019-2026 period generates an additional deterioration in the agricultural and food trade balances of approximately -£300 million and -£450 million across all the scenarios. Under the stronger assumption of a 30% unskilled labour reduction over the same period, the corresponding figures for each scenario are approximately -£1,000 million and -£1,600 million.

With a reduction in the unskilled agricultural labour force the real UK growth impact is consistently worse for the UK, although the additional macro costs are negligible since the contraction in UK agri-food production is offset by growth in the non-agricultural sectors. More specifically, compared with the macro results in Table 3.1 for each of the policy scenarios, the additional cost to the UK from the reduction in the unskilled agricultural labour force by 10% in the 2019-2026 period, is a further reduction in UK GDP by approximately 0.02% compared with the real GDP results shown in Table 3.1. Similarly, the 30% reduction in the UK's agricultural unskilled labour results in a 0.11% additional loss in average UK GDP per annum.

3.7.2. Exchange rates devaluation

An additional set of experiments examines the impact of a devaluation of the pound with respect to all currencies (the pound has already slipped from €1.30 at the time of the Brexit referendum in June 2016, to approximately €1.10 at the current time). In the following experiments, it is assumed that the pound devalues 10% and 20%, respectively, compared with the Baseline. In the CGE framework, this is modelled as a 10% (20%) uniform increase in the price of UK imports and an equal percentage decrease in the price of UK exports. It should be noted that this model reports the medium-term effect owing to the assumptions of market clearing and flexible factor markets within the UK's agricultural and non-agricultural subsectors. As a result, the results will not capture the short-term boost to UK exports from the fall in sterling. Thus, with rising import prices, the UK imports inflation as imported intermediate inputs and final demands face higher per unit costs/prices. On the other hand, UK export competitiveness is enhanced by the cheaper pound on the foreign currency markets. The anticipated boost to exports, *ceteris paribus*, raises UK output in all activities which, in the medium term, increases the returns to the factors of production, and as a result, increases regional incomes in the UK.

As a result, the medium-term impact is that of rising market prices (Annex 3.14) from the combined effect of imported inflation and rising UK factor prices. Thus, for UK primary agriculture, food processing and in total, the import trade balances with the world improve relatively (Annex 3.15) as imports fall compared with the Baseline (-3.5%, not shown), whilst the impact of inflation also leads to an export volume fall compared with the Baseline (-1.5%, not shown), which is mitigated by the devaluation of the pound.

In macroeconomic terms, UK real per capita incomes fall (i.e., the weighted market price rise is greater than the increase in regional incomes). Compared with the per capita income results for each scenario presented in Table 3.1, the additional reduction in real per capita incomes under 10% and 20% devaluation is 0.6% and 1.4%, respectively (not shown). Furthermore, in comparison with the relative real GDP results for the UK presented in Table 3.1, under 10% and 20% devaluations, average per annum UK real growth falls a further 0.3% and 0.8%, respectively (not shown). With slower economic

growth in the UK due to the impacts of inflation, the volume of production in agri-food markets falls in relative terms compared with each corresponding scenario. For example, under a 10% devaluation of the pound, production volumes in primary agriculture and food processing approximately fall a further -1.2% and -0.4% in each scenario. Under 20% devaluation, the corresponding approximate output volume falls are -1.8% and -0.7%.

4. FAPRI-UK Partial Equilibrium Model: The Sector Analysis[16]

4.1. Overview of the FAPRI-UK Model

The FAPRI-UK partial equilibrium model captures the dynamic interrelationships among the variables affecting supply and demand in the main agricultural sectors of England, Wales, Scotland and Northern Ireland, covering the dairy, beef, sheep, pigs, poultry, wheat, barley, oats, rapeseed and biofuel sectors. The UK model is fully incorporated within the EU grain, oilseed, livestock and dairy (GOLD) model[17]. The modelling system has been substantially updated to account for the fact that in the case of Brexit the UK and EU markets would no longer be fully integrated.

The modelling system is firstly simulated to generate Baseline projections based on the assumptions that current policies remain in place, specific macroeconomic projections hold[18] and average weather conditions apply. The Baseline used in this analysis covers the projection period 2017 to 2026, wherein it is assumed that the UK is fully integrated within the EU's Single Market and the Customs Union. In addition, post-2013 CAP reforms (including the phased introduction of flat rate payments, greening measures and the provision of coupled payments within some countries) remain in place for the duration of the entire projection period within the Baseline[19].

These Baseline projections provide a benchmark against which projections derived from policy scenarios can be compared and interpreted. Within this study, the modelling system is further simulated to incorporate changes to trade arrangements and direct payments based on alternative Brexit scenarios. The projections for the alternative Brexit scenarios are compared against the Baseline to isolate the impact of these policy changes.

Note, we do not cover certain agriculture sectors such as sugar or examine the implications of Brexit on food products. In addition, the model uses Agriculture in the UK data for imports/exports, which only covers raw meat trade; *i.e.* the data for UK imports/exports excludes processed meat. Processed trade is significant within the poultry and pig meat sectors, hence disruptions to this trade may have knock-on market impacts on the agricultural sector.

4.2. Results

4.2.1. Main analysis

A summary table containing percentage changes between each scenario and the Baseline at the end of the projection period for producer prices, production and value of output at the UK-level is provided below in Table 4.1. More detailed results on a per-sector basis at the UK-level and the country level (England, Wales, Scotland and Northern Ireland) are provided in the annexes for Chapter 4.

[1616] This chapter was written by Siyi Feng, Myles Patton and John Davis.

[17] The FAPRI-UK model is operated by staff in AFBI- Economics, while the FAPRI-EU GOLD model is run by FAPRI at the University of Missouri.

[18] Projections of macroeconomic variables (including exchange rates, GDP growth rates, inflation and the oil price) are based on projections by IHS Global Insight.

[19] Although the Basic Payment Scheme payments are decoupled from production in an administrative sense, it is assumed that these payments exert a partial influence on production (30 percent production stimulating impact compared with the old coupled payments).

The following discussion primarily focuses on UK-level results but highlights individual country level results where notable differences exist.

4.2.1.1. FTA+ (Scenario 1) and FTA- (Scenario 2)

As described above, Scenarios 1 and 2 simulate the implementation of a comprehensive Free Trade Agreement between the UK and EU-27, with tariff and quota free access for UK exports to the EU and tariff and quota free access for imports into the UK from the EU. However, additional trade facilitation costs are incorporated. These costs arise due to cross border administration paperwork (e.g. checking rules of origin), sanitary and phytosanitary inspections and delays at ports. Note, these additional trade facilitation costs exclude wider non-tariff barriers.

FTA+ (Scenario1)

The projected changes under a Free Trade Agreement with the EU in conjunction with unaltered direct payments are relatively small (Table 4.1) since this entails limited disruption in trade. UK producer prices increase slightly for commodities in which the UK is a net importer, *e.g.* beef, and the opposite for commodities in which the UK is a net exporter, *e.g.* barley, as the trade facilitation costs feed through to higher costs for the buyer (Figure 4.1). Given the modest price impacts, changes in production and value of output are marginal.

Figure 4.1. Percentage Change in UK Commodity Prices under the Six Scenarios

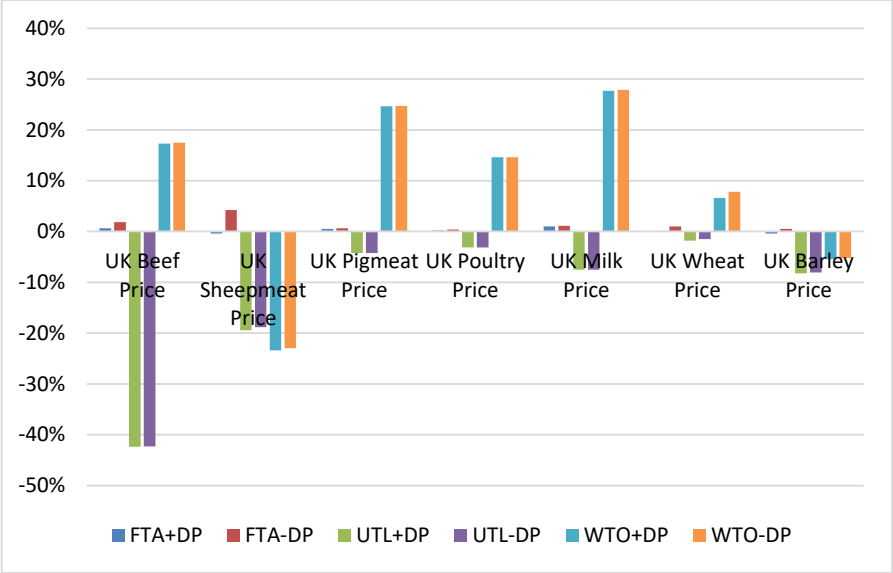


Table 4.1. Percentage Change in UK Commodity Prices, Production and Value of Output (Main Analysis)

		S1 FTA+	S2 FTA-	S3 UTL+	S4 UTL-	S5 WTO+	S6 WTO-
Commodity							
Beef:	Price	1%	2%	-42%	-42%	17%	17%
	Production	1%	0%	-12%	-13%	11%	10%
	Output value	1%	1%	-44%	-44%	30%	29%
Sheep:	Price	0%	4%	-19%	-19%	-23%	-23%
	Production	0%	-2%	-5%	-8%	-9%	-12%
	Output value	0%	2%	-18%	-19%	-31%	-32%
Pigs:	Price	1%	1%	-4%	-4%	25%	25%
	Production	1%	1%	-2%	-2%	22%	22%
	Output value	1%	1%	-6%	-6%	52%	52%
Poultry:	Price	0%	0%	-3%	-3%	15%	15%
	Production	0%	0%	-1%	-1%	8%	8%
	Output value	0%	0%	-4%	-4%	24%	24%
Milk &	Price	1%	1%	-8%	-8%	28%	28%
Dairy:	Production	0%	0%	-2%	-2%	7%	6%
	Output value	1%	1%	-9%	-10%	37%	36%
Wheat:	Price	0%	1%	-2%	-2%	7%	8%
	Production	0%	-1%	0%	-1%	1%	1%
	Output value	0%	0%	-2%	-3%	8%	9%
Barley:	Price	0%	1%	-8%	-8%	-5%	-5%
	Production	0%	-1%	-1%	-2%	-1%	-1%
	Output value	0%	0%	-10%	-10%	-6%	-6%

FTA- (Scenario 2)

The phased elimination of direct payments in conjunction with and UK-EU FTA results in a modest fall in suckler cow, dairy cow and ewe numbers (-4%, -0.3% and -2% compared to the Baseline). The limited impact partly reflects the assumption that these payments do not have the same production stimulating impact as fully coupled payments (it is assumed that the production stimulating impact of these decoupled payments is 30%)[20,21]. In addition, although Pillar 1 direct payments are completely eliminated by 2024, they are still retained within this scenario analysis.

It is projected that dairy cow numbers fall by less compared to suckler cow numbers as direct payments represent a smaller component of overall farm income for dairy farmers compared to beef farmers. The projected decline in UK beef production is lower compared to UK suckler cow numbers due to the phased nature of the elimination of payments combined with the time lag of approximately two years between the birth of a calf and finished beef production; the limited decline in dairy cow numbers; and the increased slaughtering of suckler cows and heifers as the herd size contracts.

It is projected under Scenario 2 that there are positive price responses in the beef and sheep sectors associated with the declines in production. This price responses further contributes to the limited decline in livestock numbers. Note that the elimination of Pillar 1 support has a more marked decline in suckler cow and ewe numbers in Scotland compared to elsewhere in the UK (Annex 4.5) due to the provision of coupled support within the Baseline in these sectors.

4.2.1.2. Unilateral Trade Liberalisation: UTL+ (Scenario 3) and UTL- (Scenario 4)

Tariffs on imports from the rest of the world and the EU are eliminated under Scenarios 3 and 4. In addition, exports from the UK to the EU are controlled via tariff rate quotas (TRQs) in order to avoid the possibility that the UK exports the majority of its domestic production to the EU (for higher prices) and imports from elsewhere in the world to meet domestic demand, which would significantly increase the supply on the EU market. The magnitude of these TRQs are based on recent historic levels on a per sector basis.

UTL+ (Scenario 3)

In the <u>beef sector</u> it is projected that there is a large increase in imports from the rest of the world under Scenario 3 in which import tariffs are eliminated and direct payments are unaltered (Figure 4.2a and Annex 4.1; end of chapter). This reflects the highly competitive nature of overseas' suppliers, such as Brazil and Australia, and results in the domestic producer beef price falling close to world levels (-42%; Figure 4.2b). The projected decline in the producer beef price is substantial and, hence, would result in severe knock-on impacts on farm income in the beef sector (see Chapter 6). It is important

[20] The production stimulating coefficient means that the production impact of a £1 increase in direct payment is 30% of that of a £1 increase in price.

[21] The decline in livestock numbers would be greater if it is assumed that the production stimulating impact of decoupled payments is higher than incorporated within this main analysis. For example, if it is assumed that the production stimulating impact of decoupled payments is 70%, suckler cow, dairy and ewe numbers fall by 7%, 1% and 4% respectively under the equivalent policy changes compared to the Baseline. In addition, the associated positive price impacts are greater.

to acknowledge that there is some uncertainty concerning the extent to which UK prices may drop under such an extreme liberalisation scenario. The potential impact of different factors that may impact the decline in price is discussed in Box 4.1. The projected inflow of beef imports from the rest of the world displaces EU imports, which collapse to zero. Total beef imports increase compared to the Baseline due to a concurrent increase in consumption and decline in production. The rise in beef consumption reflects the large falls in price, while the decline in production is described in more detail below.

Figure 4.2. Projected Changes in the Beef Sector under UTL+

Figure 4.2a. UK Imports and Exports (2026)

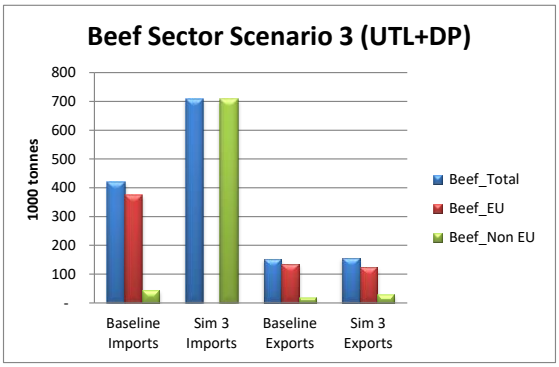
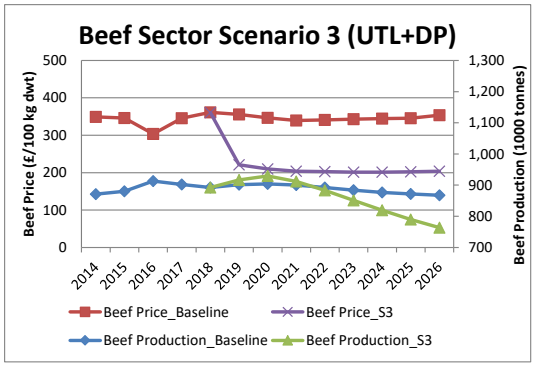


Figure 4.2b. UK Beef Price and Production



Box 4.1. Factors affecting projected price decline under UTL+ (Scenario 3)

Potential of RoW to meet expansion in imports

It is implicitly assumed that there is sufficient capacity within the rest of the world to meet the expansion in UK imports. This assumption is regarded as plausible since the increase in the level of imports to the UK under this scenario is relatively small compared to the global level of trade and imports are sourced from various countries.

Extent to which imports from RoW may displace local produce

It is also assumed within the FAPRI modelling system that consumers show equal preferences for local produce and that from the rest of the world, with the result that imports from the latter displace produce from both the EU-27 and the domestic market. Consumer preferences for local produce, supermarket sourcing policies and beef heterogeneity may dampen the increase in imports from the rest of the world. In this case, the decline in the domestic beef price would be somewhat less marked than shown here. It is difficult to gauge the extent to which these factors would result in a segmented market based on local and non-local produce. Nevertheless, the segment for higher priced, locally produced produce would need to be considerable to support beef prices.

Note that although the CGE model allows for imperfect substitution, the decline in the price of 'red meat' (beef and sheep meat) under this scenario using this alternative modelling system is still considerable. The figures are not directly comparable but the 11% fall in the retail price for 'red meat' from the CGE model implies a 22% decline in the average producer price for beef and sheep. This indicates that the projected price decline is less marked in the CGE model but not by a substantial margin (see Chapter 8 for a comparison of the CGE and PE results).
It is important to underline the extreme nature of this scenario, with tariffs on imports being completely eliminated. This scenario was specified to capture the outer boundary of possible market impacts. A less radical reduction in tariffs would affect the competitiveness of imports from the rest of the world and possibly stem the inflow of imports.

Relevant world price

The Brazilian beef price is used as the reference world price within the modelling system under this scenario analysis as tariffs are eliminated to all importing countries and hence the most competitive price is the relevant benchmark price. The differential between the UK and Brazilian beef prices within the modelling system is reasonably consistent with international datasets. As shown in Figure 4.3 and Table 4.2, the Brazilian R3 Steer Price has remained very competitive compared to the UK price over the recent historic period. The same is true for other important beef exporters from South America such as Uruguay. The competitiveness of produce from South America is underlined by cost data, with Agri-Benchmark data indicating that Brazilian costs are at least half that in the UK (Agri-Benchmark, 2016).
Australia is also an important exporter on the global beef market. While the differential between the UK and Australian price narrowed in 2015, this reflected drought conditions in the latter. Drought conditions have been less severe over the last year and consequently, the historic price gap is beginning to re-emerge.

Figure 4.3. International Comparison of R3 Steer Price

Source Price quoted in Euros from Bord Bia https://www.bordbia.ie/industry/farmers/pricetracking/cattle/pages/prices.aspx

Table 4.2. Average, Maximum and Minimum Differential between UK and Brazil, Uruguay and Australia R3 Steer Prices between May 2015 and April 2018

	Brazil	Uruguay	Australia
Avearge	-46%	-39%	-20%
Minimum	-33%	-34%	-6%
Maximum	-60%	-43%	-36%

UK Export potential

While it is projected that there is a 55% increase in UK beef exports to the rest of the world, this is from a small base; UK exports to the RoW increase from 19 to 29 thousand tonnes. The relatively small absolute expansion partly reflects the unilateral nature of the scenario in which it is assumed that existing exporting trading arrangement remain unchanged.

The potential for expanding UK beef exports may be greater under a Bilateral Trade Agreement with specific non-EU countries, particularly for lower value cuts. Targeting markets that value these cuts more highly would help to increase the whole carcass value, but would require a substantial increase in exports to support the price transmitted to the producer.

The lower projected producer price is not offset by a significant fall in input costs, partly because domestic grain prices are closer to their world equivalents, and consequently cattle numbers fall significantly. For example, UK beef cow numbers are 37% lower under Scenario 3 compared to the Baseline at the end of the projection period[22]. The projected decline in beef production is less marked (-12%) due to a lagged effect and progeny from the dairy herd supporting beef production.

The projected decline in beef production under UTL+ (Scenario 3) is more marked in Scotland (-20%) compared to elsewhere in the UK (-10 to -13%). This is attributable to differences in the proportion of beef sourced from the dairy herd across the UK, with a higher proportion of beef animals coming from the progeny of the dairy herd in England, Wales and Northern Ireland compared to Scotland. For example, in 2015, dairy cows accounted for 55% to 63% of total cows in England, Wales and Northern Ireland, compared to 30% in Scotland. This variability results in a greater fall in beef production in Scotland in this scenario since it is projected that trade liberalisation has a substantial negative impact on beef cow numbers across the UK, but a modest negative impact on dairy cow numbers.

The projected fall in the value of output in the beef sector is particularly acute. By the end of the projection period, the UK beef sector value of output is 44% lower under Scenario 3 compared to the Baseline. The value of output is partially supported by TRQ exports from the UK to the EU since EU and UK producer prices diverge under this scenario; EU prices exhibit a small decline in response to the rechannelling of produce to the EU-27 market that previously would have been exported to the UK, but this price fall is significantly below that for the UK. However, the extent to which this supports the beef value of output is relatively small due to the limited quantity of TRQs.

Similar to the beef sector, the sheep sector is exposed to strong international competition, with unilateral trade liberalisation leading to the inflow of more imports from the rest of the world and a significant fall in the domestic producer price (-19%). The decline in price leads to a fall in sheep meat production and a rise in consumption. More imports from the rest of the world are required (+59%) to meet UK consumption since UK exports to the EU are largely maintained through the TRQ[23].

The projected value of output in the sheep sector is 18% lower under this scenario compared to the Baseline. While this represents a significant fall, the impact is tempered by the large volume of produce that is exported from the UK to the EU via the TRQ. As in the beef sector, the UK sheepmeat price falls relative to the EU price, which deepens the importance of exports to the EU in supporting the sheep sector.

[22] Note within this analysis it is assumed that UK producers receive the full benefits of the TRQs; within the model beef cow numbers are a function of an average domestic/EU price, weighted according to the level of exports from the UK to the EU. This implies that UK exporters receive the full EU price, with no loss due to allocation or administration of TRQs.

[23] There is a question mark concerning the significant increase in imports from the rest of the world to the UK given the current underutilisation of TRQs by New Zealand. This is dependent on the extent to which a sheepmeat exporter such as Australia, which has consistently fully used its quota (but from a significantly lower base), can increase its export potential. It is effectively assumed that there is sufficient capacity in the rest of the world to meet UK consumption. Under this trade liberalisation scenario total imports from the rest of the world equates to 162 thousand tonnes. In order to assess the importance of this assumption, sensitivity analysis is undertaken in which imports to the UK from the rest of the world are capped at a level equal to the existing level of TRQ imports to the EU from New Zealand (139 thousand tonnes). Under this sensitivity analysis, the projected decrease in the UK sheepmeat price is 13%.

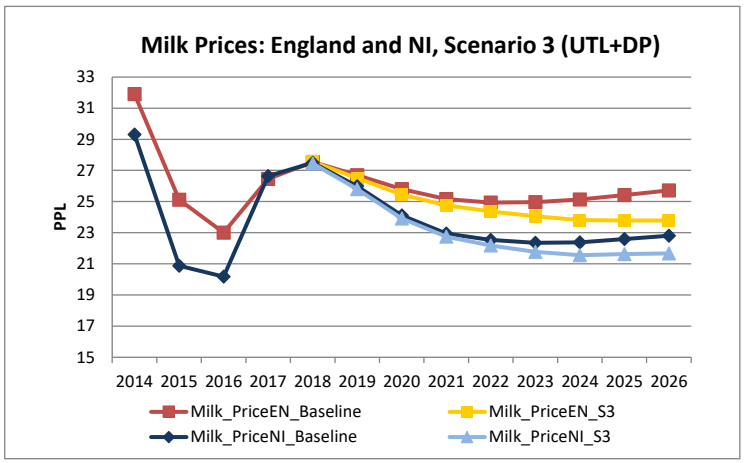
The projected falls in producer prices in the pig and poultry sectors are less pronounced (-4% and -3% respectively), reflecting the more competitive nature of UK prices in these sectors. Projected input costs also exhibit a moderate decline and hence the projected declines in production and values of output are relatively modest.

In the dairy sector, cheese and butter prices exhibit price declines under UTL+ (Scenario 3) (-7% and -20% respectively). These price impacts are sensitive to the underlying Baseline projections, including a high projected EU butter Baseline price relative to its respective world price and the positive influence of population growth on UK demand.

Due to data availability issues it has not been possible to model UK market clearing prices for SMP and WMP. Thus, changes to the trading arrangements for these commodities have not been explicitly incorporated within this scenario analysis. Nevertheless, it is expected that the price changes for these commodities under a Unilateral Trade Liberalisation scenario would be small since domestic prices are close to world levels; *i.e.* world prices would limit the extent to which UK powder prices can fall. Implicitly it is assumed within this analysis that the changes in UK SMP and WMP powder prices are negligible.

The projected changes in dairy commodity prices have a depressing impact on producer milk prices, with those in GB falling by around 8% and the NI producer milk price falling by 6% (Figure 4.4). The declines in producer milk prices have a slight depressing impact on milk production. Apart from Northern Ireland, the projected fall in milk production has a disproportionate negative impact on milk for manufacture as the quantity of milk required for liquid consumption is relatively stable. In Northern Ireland, milk for manufacture increases since raw milk that was previously exported to Republic of Ireland is retained for local processing within this scenario analysis[24].

Figure 4.4. Projected Producer Milk Prices in England and Northern Ireland under UTL+



[24] Note, it could have alternatively been assumed that there is a TRQ for raw milk exported from NI to RoI. The price impact of this alternative assumption is negligible since domestic commodity prices are effectively determined by world prices in this particular scenario.

In the crop sector, it is projected that wheat and barley prices decline under a Unilateral Trade Liberalisation scenario. However, the price reductions are relatively modest (-2% and -8% for wheat and barley respectively) since UK prices are fairly close to world levels within the Baseline. The price decline is greater for barley compared to wheat since under the Baseline there is a significant surplus of the former. In addition, feed demand is a greater component of domestic use for barley and this component falls in response to the decline in livestock numbers. In addition, feed demand is a greater component of domestic use for barley and this component falls in response to the decline in livestock numbers. Within the rapeseed sector, the impacts of changes in tariffs under the different scenarios are expected to be minimal as there is no import tariff on this crop.

The FAPRI model does not explicitly provide projections of consumer prices. However, it is clear that the significantly lower beef and sheep producer prices following trade liberalisation would have a knock-on downward impact on retail prices. Based on the assumption that existing producer-retailer price spreads remain the same, a 42% decline in the beef producer price implies a 21% decline in the aggregate retail price of beef, while a 19% decline in the producer sheepmeat price implies a 10% decline in the aggregate retail price of sheepmeat. The projected declines in production, combined with increases in consumption, result in notable shifts in UK self-sufficiency in the beef and sheep sectors (Table 4.3). At the end of the projection period, UK beef self-sufficiency is 58% under Scenario 3, compared to 76% in the Baseline. Similarly, UK sheepmeat self-sufficiency falls from 93% in the Baseline to 79% under UTL+.

Table 4.3. UK Self-Sufficiency under the Baseline and Six Selected Scenarios (2026)

	Baseline	S1	S2	S3	S4	S5	S6
		FTA+	**FTA-**	**UTL+**	**UTL-**	**WTO+**	**WTO-**
Beef	76%	77%	77%	58%	58%	88%	87%
Sheepmeat	93%	93%	92%	79%	77%	79%	77%
Pigmeat	57%	58%	58%	55%	55%	76%	76%
Poultry	79%	79%	79%	77%	77%	86%	86%
Cheese	62%	62%	62%	59%	58%	75%	75%
Butter	80%	80%	80%	68%	68%	99%	99%
Wheat	100%	99%	99%	101%	100%	97%	97%
Barley	125%	125%	124%	124%	123%	114%	114%

UTL- (Scenario 4)

The gradual elimination of direct payments in conjunction with the unilateral elimination of import tariffs has a further downward impact on suckler cow, dairy cow and ewe numbers (Annex 4.1 at the end of chapter). The projected declines in livestock numbers has a knock-on impact on beef, sheepmeat and milk production. The difference between *with* and *without* direct payments is more marked in connection with the Unilateral Trade Liberalisation agreement trade arrangements (UTL) compared to the UK-EU FTA. For example, the additional decline in suckler cow numbers under Scenario 4 (UTL-) compared to Scenario 3 (UTL+) is approximately 8%. In contrast, suckler cow numbers are 4% lower under Scenario 2 (FTA-) compared to Scenario 1 (FTA-). The more marked impact under Unilateral Trade Liberalisation is attributable to the inflow of imports from the rest of the world, which prevent prices from rising; *i.e.* producer prices are projected to fall by the same amount under UTL (Scenarios 3 and 4).[25]

4.2.1.3. WTO (EU Tariff Schedule): WTO+ (Scenario 5) and WTO- (Scenario 6)

Under scenarios 5 and 6, tariffs equivalent to the default bound EU MFN tariffs are applied on UK exports to the EU and likewise imports from the EU to the UK. Within the modelling system commodities are modelled at the aggregate level and thus it is necessary to impose a single tariff for each commodity, rather than multiple tariff lines. In the case of meats, for example, the relevant carcass MFN tariffs are used as representative of all meat products in that category. The MFN tariffs implemented in this scenario are shown in Table 4.4.

Table 4.4. Bound MFN Tariffs Implemented under UTL (Scenarios 5 and 6)

	WTO MFN Tariff
Beef Carcass	12.8% plus €176.8/100kg
Sheep Carcass	12.8% plus €171.3/100kg
Pig Carcass	€53.6/100kg
Chicken Carcass	€32.5/100kg
Cheese (Cheddar)	€167.1/100kg
Butter	€189.6/100kg
Wheat#	€95/tonne
Barley	€93/tonne

#: Refers to the tariff for low and medium quality wheat, which encompasses the categories of wheat mainly exported from the UK to the EU. Although the EU does operate a TRQ for these wheats, the UK's export volumes are likely to exceed the *erga omnes* quantities allowed, and so face the EU's full MFN tariff of €95 per tonne. This tariff does not apply to high quality wheat but the UK does not export this category of wheat.

[25] Note the above analysis is again based on the assumption that the production stimulating impact of decoupled payments is 30%. When an alternative assumption of 70% is used, the additional decline in suckler cow numbers under Scenario 4 (UTL-DP) compared to Scenario 3 (UTL+DP) is 12%.

It is further assumed under these scenarios that in terms of exports from the UK to the rest of the world the UK inherits the EU's tariff structure to third countries, while in terms of imports from the rest of the world the TRQs utilised by the UK from third countries are retained.

WTO+ (Scenario 5)

The default bound MFN tariffs are in the main very high and hence the imposition of these tariffs leads to significant adjustments in trade between the UK and EU. Under Scenario 5 in which default bound MFN tariffs are imposed and direct payments are unaltered, the projected changes in trade have significant impacts on domestic markets, with the direction of impact again depending on whether the UK is a net importer or a net exporter of the relevant commodity.

In the beef sector, the imposition of high tariffs leads to a collapse in trade between the UK and EU (Figure 4.5a). Available beef supplies within the UK domestic market fall significantly since the UK is a large net importer in the Baseline. As a result, the UK beef price increases markedly. The rise in beef price is sufficient for non-EU countries to export beef to the UK paying the full high tariff. As a result, the rise in the UK price is effectively curbed the 'World Price +MFN Tariff'. At the end of the projection period the UK producer beef price is 17% higher under Scenario 5 compared to the Baseline. Production responds positively to the price rise. The projected increases in producer price and production, results in a 30% increase in the value of UK beef output.

Assuming the existing producer-retailer price spreads remains the same, the 17% increase in producer price implies an 8.5% increase in the aggregate retail price of beef. The higher prices have a downward impact on consumption; UK beef consumption is 3% lower under Scenario 5 compared to the Baseline in 2026.

Figure 4.5. Projected Changes in the Beef Sector under WTO+

Figure 4.5a. UK Imports and Exports (2026)

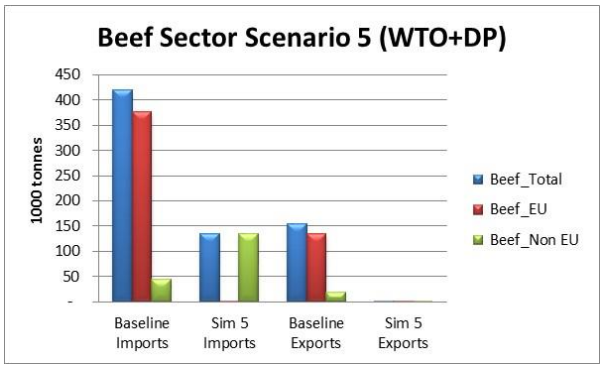
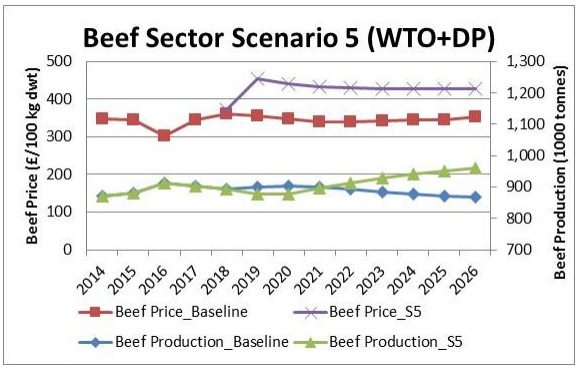


Figure 4.5b. UK Beef Price and Production



Similarly, the UK is a net importer in the pig and poultry sectors in the Baseline and hence producer prices increase is response to the imposition of high tariffs, which greatly reduce the competitiveness of EU imports. Again, the increase in prices in these sectors stimulates rises in production. Projected butter and cheese prices within the dairy sector also rise due to the displacement of imports from the EU-27, which are historically high. The wheat price also increases as the reduction in imports from the EU cannot be easily replaced from elsewhere due to the application of high tariffs. The projected

increase in wheat production is small due to the observed inelastic relationship between returns and crop production.

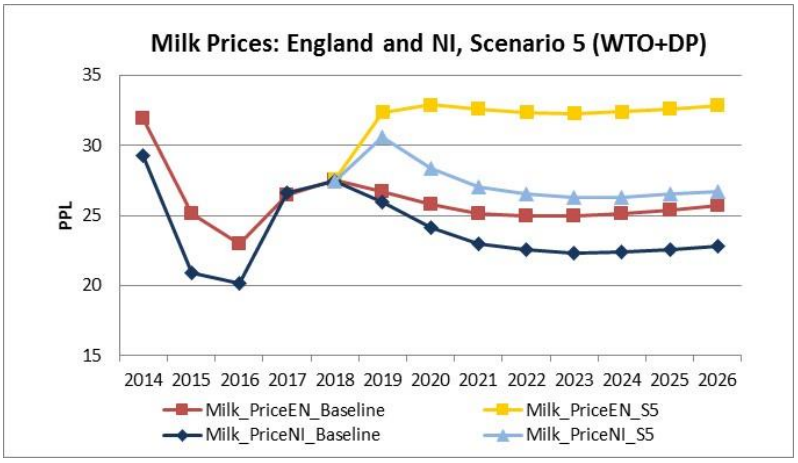
Underlying this analysis, it was necessary to make an assumption regarding exports in the poultry sector to reflect the carcass balance issue. In general, UK consumers show a preference for breast meat compared to thighs and wings. As a result, the latter cuts have a relatively low value in the UK and existing exports from the UK predominantly consist of these cuts. Within this scenario, exports from the UK to the EU collapse due to the imposition of the high tariff. Since these cuts are valued more highly elsewhere, it is assumed that the UK is able to find markets for these cuts in the rest of the world and total export levels are maintained at the Baseline level.

It is also important to note that the data for UK imports/exports excludes processed meat. Processed trade is considerable within the poultry and pigmeat sectors and thus the model results do not capture the market impacts of disruption to this trade. In particular, a significant volume of processed poultry meat is imported from third countries, while the volume of imports of raw poultry meat from third countries is small. However, processed poultry meat imports from third countries are sourced through TRQs, which are largely filled (the out of quota tariff is very high - €1,024 per 1000 kg). Thus, if the TRQ and out-of-quota tariff is retained the scope for increasing processed poultry imports to fill the supply-demand gap within this scenario is small.

In terms of pigmeat, almost all imported meat is from other EU member states. The MFN tariffs for different categories of processed pigmeat are high (e.g. €747 per 1000 kg for uncooked sausages) and hence the application of these tariffs to imports from the EU would likely reduce available supplies further. This would result in a somewhat larger UK price increase than shown in this analysis.

Within the dairy sector, the increase in producer milk prices is higher in England, Wales and Scotland (+27% to +28%) compared to Northern Ireland (+17%) where there is a much higher reliance on the milk powder market (Figure 4.6). Within Northern Ireland the increases in cheese and butter prices have a smaller impact on the producer milk price. By the end of the projection period, the price differential between the English and Northern Ireland producer milk price is 6.2 pence per litre. This differential could potentially lead to supplies of raw milk being drawn from NI to GB.

Figure 4.6. Producer milk prices



In contrast, lower producer prices are projected in the sheep and barley sectors. Within the Baseline the UK is a net exporter in these sectors. The introduction of MFN tariffs diminishes the competitiveness and thus the volumes of UK exports to the EU, which leads to increases in available supplies within the domestic market.

The negative price impact is particularly marked in the sheep sector due to the large quantity of sheepmeat currently exported to the EU from the UK. Despite the rechannelling of this produce onto the domestic market, the UK continues to import significant volumes of sheepmeat from the rest of the world through TRQs (Figure 4.7a). Although the UK price falls sharply, TRQ imports from the rest of the world remain competitive and hence the projected change is limited. If there were less imports via the TRQ the negative price impact would be smaller.

The projected fall in the producer price has a depressing impact on UK sheepmeat production (Figure 4.7b) and thus on the value of output. In addition, the fall in producer price would have a depressing impact on consumer prices. Based on the assumption that existing producer-retailer price spreads remain the same, a 23% decline in the producer sheepmeat price implies an 11.5% fall in the aggregate retail price of sheepmeat. Consumption responds positively in response to the lower price (+7%).

Figure 4.7. Projected Changes in the Sheep Sector under WTO+

Figure 4.7a. UK Imports and Exports (2026)

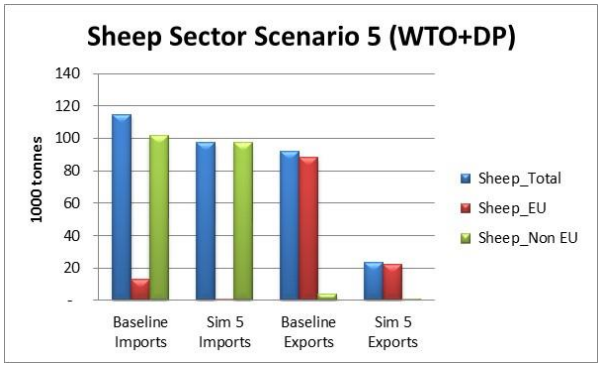
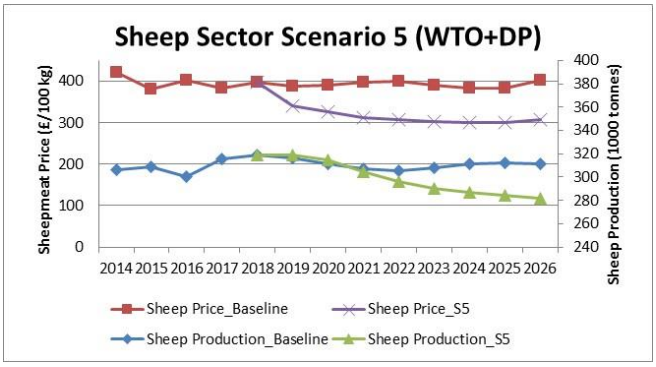


Figure 4.7b. UK Sheep Price and Production



The projected changes in production and consumption lead to shifts in self-sufficiency. Under Scenario 5, the positive production effects, combined with the falls in consumption, results in a rise in UK self-sufficiency in the beef, pigmeat, poultry and dairy sectors. In contrast, self-sufficiency declines in the sheepmeat and barley sectors in line with the falls in production and increases in consumption. The impact is particularly marked in the sheep sector. Under Scenario 5 sheepmeat self-sufficiency at the end of the projection period is 79%, compared to 93% in the Baseline.

WTO- (Scenario 6)

The phased elimination of direct payments under Scenario 6 has a downward impact on livestock numbers and production in the beef, dairy and sheep sectors. Note that in the beef sector the differential in livestock numbers/production between *with* and *without* direct payments is less marked when WTO trade arrangements apply, compared to Unilateral Trade Liberalisation or a bespoke free trade agreement with the EU. This partly reflects the significant increase in value of output in this sector when the WTO tariffs are imposed, which diminishes the relative importance of direct payments.

4.2.2 Sensitivity Analysis: 10% and 20% depreciation of the Sterling

Sensitivity analysis is undertaken with regards to the UTL+ and WTO+ (Scenarios 3 and 5) and results are reported in Table 4.5. Within this sensitivity analysis the depreciation of the pound has a marked upward impact on output prices under both the UTL and WTO scenarios. The transmission of the depreciation in the exchange rate and the projected price change is high. Despite the increase in output prices, it is projected that the increases in production within the livestock sectors are small as input costs also increase.

Table 4.5. Percentage Change in UK Commodity Prices, Production and Value of Output (Sensitivity Analysis)

		UTL+ (S3)			WTO+ (S5)		
		Main Analysis	10% Dep.	20% Dep.	Main Analysis	10% Dep.	20% Dep.
Commodity							
Beef:	Price	-42%	-37%	-31%	17%	28%	38%
	Production	-12%	-12%	-12%	11%	13%	16%
	Output value	-44%	-38%	-33%	30%	45%	60%
Sheep:	Price	-19%	-12%	-5%	-23%	-16%	-9%
	Production	-5%	-5%	-4%	-9%	-10%	-10%
	Output value	-18%	-9%	-1%	-31%	-24%	-18%
Pigs:	Price	-4%	5%	13%	25%	35%	46%
	Production	-2%	1%	3%	22%	25%	27%
	Output value	-6%	5%	16%	52%	69%	87%
Poultry:	Price	-3%	6%	15%	15%	25%	36%
	Production	-1%	2%	4%	8%	11%	13%
	Output value	-4%	8%	20%	24%	39%	53%
Milk &	Price	-8%	3%	10%	28%	40%	51%
Dairy:	Production	-2%	0%	2%	7%	10%	12%
	Output value	-9%	3%	13%	37%	53%	70%
Wheat:	Price	-2%	7%	16%	7%	15%	25%
	Production	2%	1%	-1%	-8%	-9%	-11%
	Output value	0%	8%	16%	-2%	5%	11%
Barley:	Price	-8%	1%	9%	-5%	4%	13%
	Production	-1%	0%	1%	-1%	1%	2%
	Output value	-10%	0%	10%	-6%	4%	15%

4.3. Conclusion

The results from the partial equilibrium model demonstrate the extent to which the type of trade agreement could result in different price and production impacts in the UK depending on the disruption to trade patterns. In general, a bespoke free trade agreement results in the least disruption to trade flows and hence, the estimated market impacts are relatively small. It is important to bear in mind that this analysis excludes wider non-tariff barriers. Over time further costs may be incurred due to the emergence of non- tariff barriers, e.g. due to divergence in regulations between the UK and EU-27, which would result in larger impacts than shown in this analysis.

The projected impacts are larger under the two other simulated trade arrangements. All sectors experience producer price and production declines under the Unilateral Trade Liberalisation scenario. The impacts are particularly marked in the beef and sheep sectors where international competition is very strong. In contrast, the direction of the market impact varies across sectors under the WTO scenario, depending on whether the UK is a net importer or a net exporter of the relevant commodity.

5. Farm-level analysis: the ScotFarm Linear Programming Model[26]

5.1. Brief Introduction to Phase 3

Phase 3 aims to assess the impacts of selected trade and domestic policy scenarios on farm-level production decisions and financial performance across a range of farm types and sizes. It applies price projections from the CGE and FAPRI models (Chapters 3 and 4) to a range of representative farm-level circumstances derived from Farm Business Survey (FBS) data and represented within ScotFarm(a linear programming model of farm production).

The specific Phase 3 objectives are to explore:

- What are the impacts on farm production decisions?
- What are the effects on commercial performance across major farm types in the UK?
- How will impacts vary within and across England, Northern Ireland, Scotland and Wales?

5.2. Overview of the ScotFarm Model

ScotFarm is a farm level dynamic linear programming (LP) model that optimises farm profit subject to a number of limiting farm resources (Shrestha, 2017). The current version of the model was originally developed at SRUC in 2012 to conduct impact assessments of CAP reforms on Scottish farms, with previous versions having been used for studies of English dairy farms (Shrestha, 2004) and Irish livestock and crop farms (Shrestha *et al.*, 2007; Hennessy *et al.*, 2008).

The model is based on farming system analysis and includes biophysical and management relationships to link production to resource requirements. For example, land, number of livestock, labour effort and purchased inputs required to generate a given volume of different outputs. These are combined with data on the prices of inputs and outputs to calculate farm profit as an objective function to be maximised.

Although profit can be defined in different ways, Farm Business Income (FBI) is generally now regarded as the preferred measure and is used here as an indicator of financial returns to unpaid labour and capital invested for sole-trader and partnership farms (or return on shareholder capital for corporate farms). Unlike Net Farm Income (NFI), no account is taken of imputed wages or imputed rents. To account for time-lags in farm adjustments, for example due to the length of breeding cycles, the model optimises over a time frame of multiple years rather than a single year.

It is acknowledged that profit maximisation may not be the actual objective of farmers, but as a first approximation it allows exploration of how production patterns and financial performance may evolve in response to Brexit-induced change. As such, it extends static, partial-budget type analysis (e.g. Bradley & Hill, 2017) to consider how farm-level incomes and production patterns may respond to changing market and policy signals.

[26] This chapter was written by Shailesh Shrestha and Andrew Moxey.

5.3. ScotFarm Data and Configuration

ScotFarm is configured to represent a given farm by using information on resource levels and usage patterns plus the prices of inputs and outputs. This information can be assumed (e.g. for demonstration or testing purposes) or derived from the profile of an actual farm as revealed through a case-study visit or a farm survey exercise.

The Farm Business Survey (FBS) is the most extensive and detailed survey of farm businesses conducted annually across the UK.[27] It dates back to the 1930s and is part of the Farm Accountancy Data Network (FADN) used to estimate farm incomes on a consistent basis across the European Union (EU). FBS data encompass a mix of physical and financial variables, allowing detailed profiles of farm characteristics and performance to be constructed and compared across and between different locations and years. As such, it represents the most comprehensive farm database available and was chosen as the basis for configuring ScotFarm for this project.

FBS data for England and Wales were obtained from the UK Data Archive held by the University of Essex, and directly from relevant government officials for Northern Ireland and Scotland. This process took longer than expected, partly due to unexpected differences in the formats and descriptions of individual datasets, leading to delays in actual modelling analysis.

Although data for the three years from 2013/14 to 2015/16 were obtained, only data for 2015/16 were subsequently used because inspection revealed that resource levels and usage patterns did not vary significantly and averaging across three years reduced the overall (common) sample size (and also 2015/16 is the first year where farms received Pillar 1 payments under the Basic Payment Scheme).

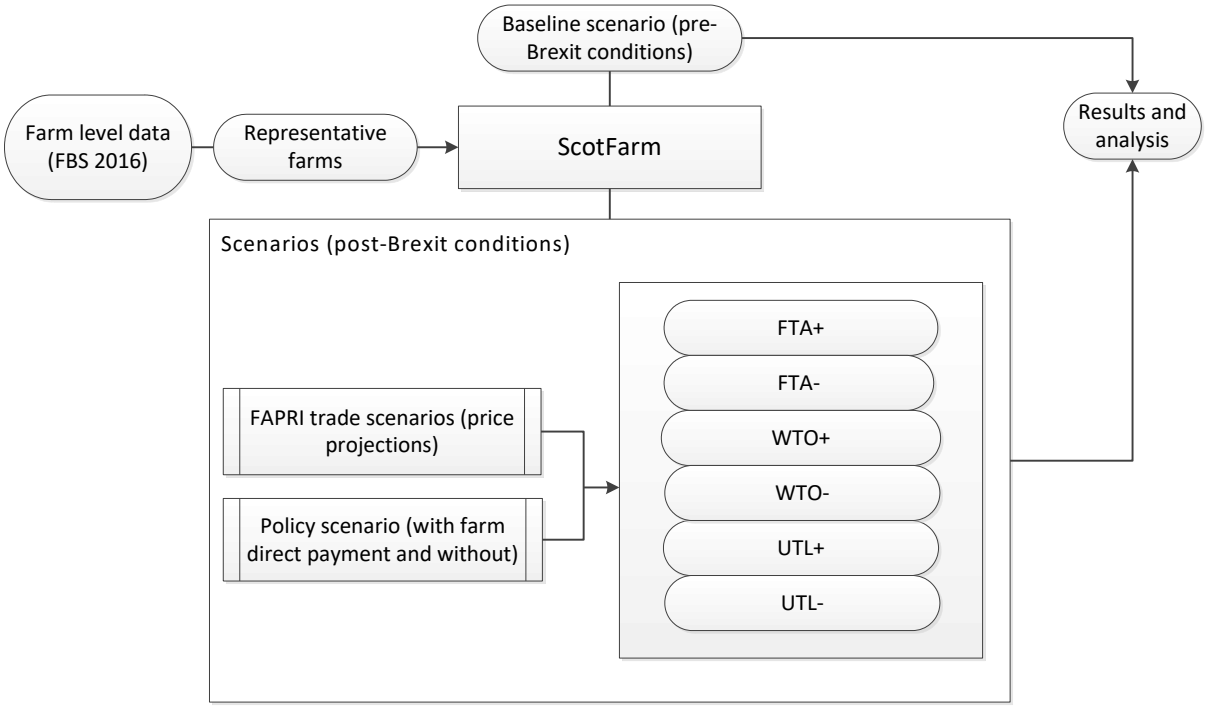
Whereas the original intention had been to use clustering analysis to generate a novel farm typology, Steering Group advice coupled with delays in obtaining the FBS data led to adoption of the pre-existing farm size and type classifications used for government reporting. This avoided further delays, but also more positively facilitates easier comparisons with routinely published FBS analysis.

Not all farm sizes and types are represented sufficiently in the FBS to support meaningful analysis. In particular, very small (essentially part-time) farms are excluded and the numbers of specialist horticultural, pig and poultry farms are low. Consequently, attention was restricted to small, medium, large and very large sized farms and to cereal, general cropping, dairy, LFA grazing (i.e. beef and sheep), lowland grazing (i.e. beef and sheep) and mixed farm types. The FBS sample in each part of the UK for each farm size and type in 2015/16 is shown in Annex 5.1.

For each farm size and type combination, a representative farm was constructed by averaging across the relevant FBS sub-sample. ScotFarm was then configured to each of these representative farms and run under each of the selected six Brexit scenarios as compared to the Baseline scenario. This modelling approach is outlined in Figure 5.1

[27] For example, see www.farmbusinesssurvey.co.uk/about/Default.aspx for England and Wales coverage.

Figure 5.1. Outline of ScotFarm usage



In terms of production responses, ScotFarm was configured to restrict the available production possibility set to activities currently observed for the given representative farm. That is, under each scenario, the model chooses the mix and level of farm activities to maximise FBI but only from those activities already present. Activities can expand or shrink, but within bounds. For example, herd sizes can increase, but only up to the capacity of existing capital (such as a milking parlour).

This avoids the need to address investments in human and physical capital required to introduce new activities or expand beyond current infrastructure constraints but does dampen structural responsiveness by limiting scope for resource re-allocation. This approach may be too conservative given the likely pressures for structural change arising from (uncompensated) removal of Pillar 1 direct payments support. Nevertheless, it has been deployed here as a pragmatic initial step.

The next section summarises ScotFarm results for changes in Farm business Income (FBI) under each scenario, by farm type and country. Annex 5.2 presents the accompanying Tables, with Annex 5.3 reporting associated changes in livestock numbers on dairy, LFA grazing and lowland grazing farms. It is important to note that ScotFarm embodies a number of simplifying assumptions, including profit maximisation and linear production technologies, which means that results should be treated as indicative projections of the likely direction and order-of-magnitude of change rather than precise predictions. Similarly, the use of “average” representative farms necessarily masks variation in individual farm circumstances and, again, attention should be focused on the broad pattern of results rather than on specific figures *per se*.

5.4. Results

The combination of four farm sizes with six different farm types modelled across a Baseline and six scenarios generates a relatively large volume of results. Farm income results are summarised below in graphical form (Tables are also presented in Annex 5.2), by farm type and country. For ease of comparison, the same colour keys and vertical scale are used throughout.

In general, the direction of impacts on farm income are similar in each country. For example, incomes rise where output prices are projected to increase, fall where prices are projected to decrease and are higher with support payments than without. Loss of support payments is generally a more significant determinant of income than price changes. Income reductions are most severe under the UTL- scenario and income gains highest under WTO+. The FTA+ scenario has the least impact. However, there are some differences between and within farm types, and across countries. This variation reflects a combination of factors.

Between-type differences largely reflect differential exposure to price changes and/or current dependence on support payments. For example, cereal prices vary by less than livestock prices across the scenarios and dairy farms are generally relatively less reliant upon support payments. There is also some variation between countries in terms of current support payments and cost structures. For example, the BPS rates differ across the UK and, reflecting variation in land quality and remoteness, farm areas and input prices are not uniform. However, some reported variation also arises as an artefact of the farm type classification.

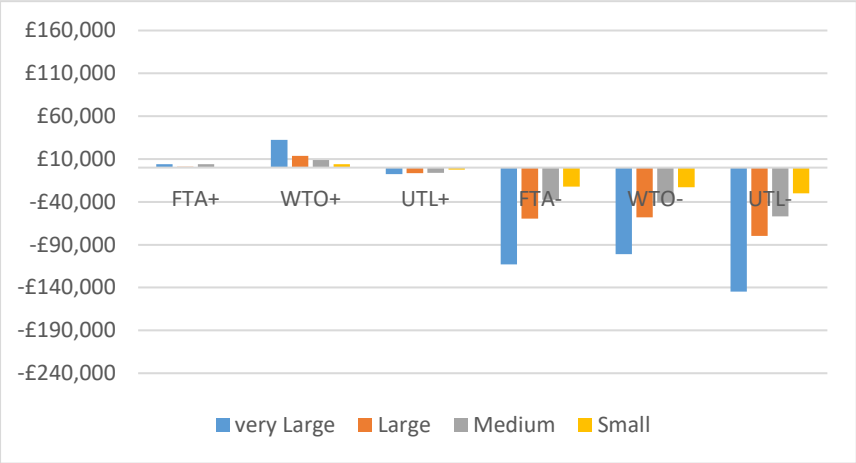
Although some farms are genuinely single-enterprise specialists, many have two or more different activities. For example, livestock and cereal enterprises may co-exist, as can dairy and beef enterprises. Consequently, many farms' output comprises a combination of activities. To reflect this, the farm type classification is based on the predominant enterprise, as measured by output. For example, a farm is classified as specialist dairy if at least two-thirds of its (standard) output arises from a dairy enterprise. This means that there can be some variation in the enterprise mix of individual farms within a given type category,[28] both within and between countries. For example, the mix of cereal crops can vary across "cereal" farms of different sizes and in different countries, as can the mix of beef, sheep and dairy enterprises across livestock farms.

In terms of production patterns, ScotFarm's configuration allows for adjustments within the current farming system and the results reveal varying degrees of responsiveness. In general, significant adjustments only occur under the more extreme scenarios, where prices move beyond their recently observed range and/or support payments are removed. For example, reductions in sheep numbers by up to 100% under WTO and UTL scenarios, particularly if without support payments, on some LFA and Lowland grazing farms of all sizes in all countries. Similarly, reductions in beef cattle numbers of up to 100% under UTL scenarios, with or without support payments, on some LFA and Lowland grazing farms of all sizes in all countries. Some further, brief descriptions of the income results are presented alongside each graph below.

[28] It also means that a farm's type can shift through changes in output prices even if actual physical production activities remain the same.

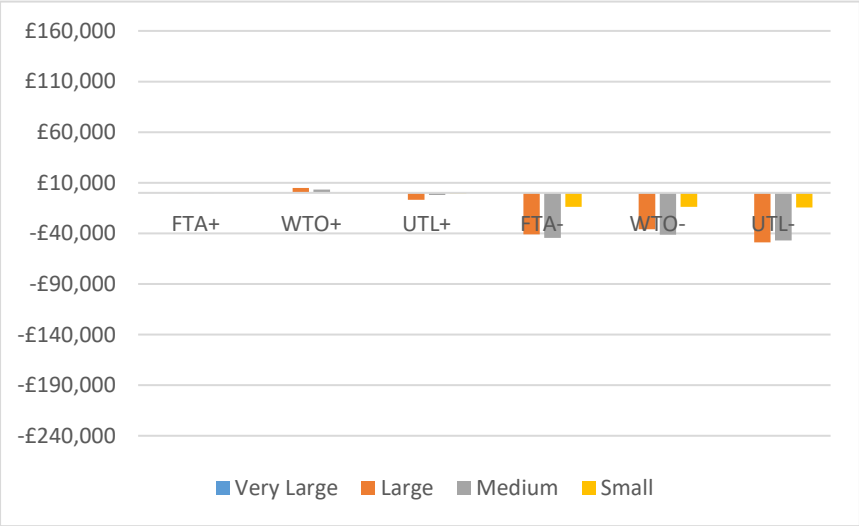
5.4.1. Specialist cereal farms

Figure 5.2. Estimated change in FBI (£) for different sizes of cereal farm in England



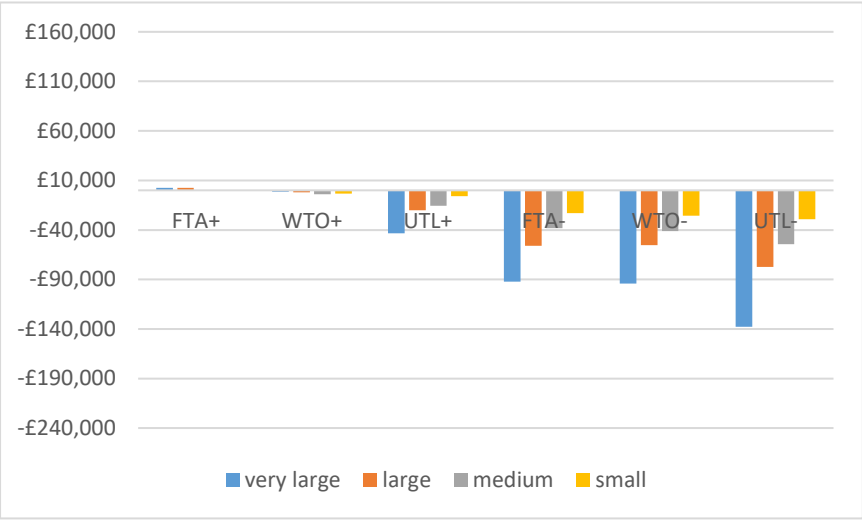
Higher wheat prices under FTA and (more so) WTO improve cereal incomes in England, with lower UTL prices reducing income slightly. However, gains are more than offset by loss of support payments. Gains and losses are essentially proportional to farm size.

Figure 5.3. Estimated change in FBI (£) for different sizes of cereal farm in Northern Ireland



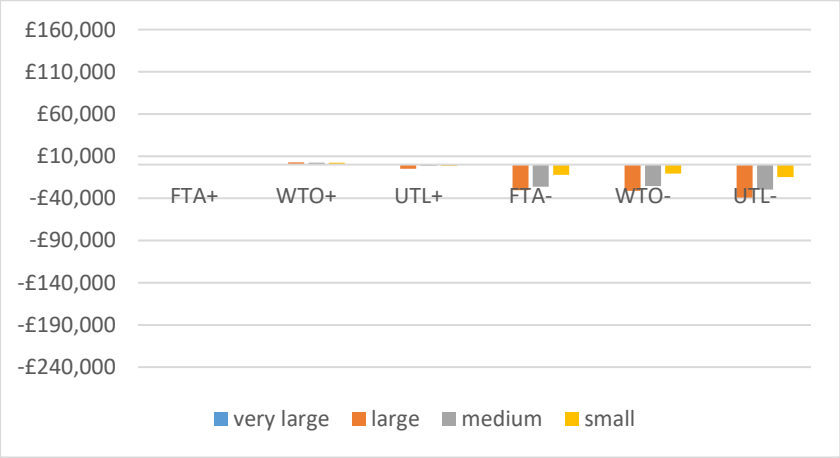
Higher wheat prices under WTO improve cereal incomes for large and medium farms, but lower barley prices hit small farms. UTL affects all farms, with removal of support increasing losses under all scenarios. NB. no very large farms in Northern Ireland sample.

Figure 5.4. Estimated change in FBI (£) for different sizes of cereal farm in Scotland



Slightly higher barley prices under FTA improve incomes very slightly in Scotland, but lower barley prices under WTO and (more so) UTL reduce incomes. Losses are amplified by removal of support payments. Gains and losses are essentially proportional to farm area.

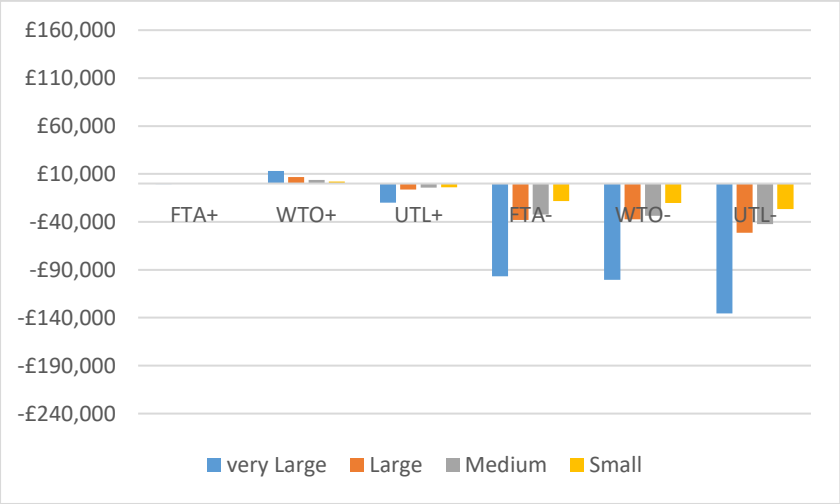
Figure 5.5. Estimated change in FBI (£) for different sizes of cereal farm in Wales



Higher wheat prices under FTA and (more so) WTO improve cereal incomes in Wales, with lower UTL prices reducing income slightly. However, income effects are dominated by loss of support payments. Gains and losses are essentially proportional to farm area. NB: there are no very large cereal farms in Welsh FBS sample.

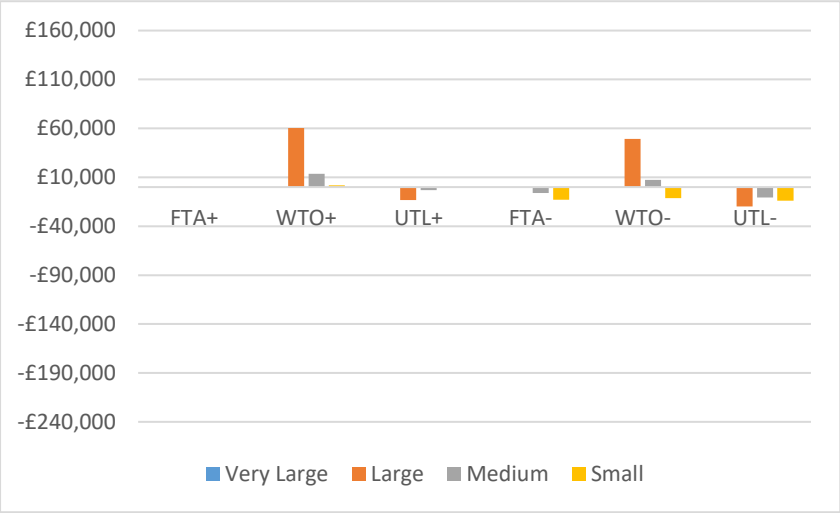
5.4.2. General cropping farms

Figure 5.6. Estimated change in FBI (£) for different sizes of general cropping farm in England



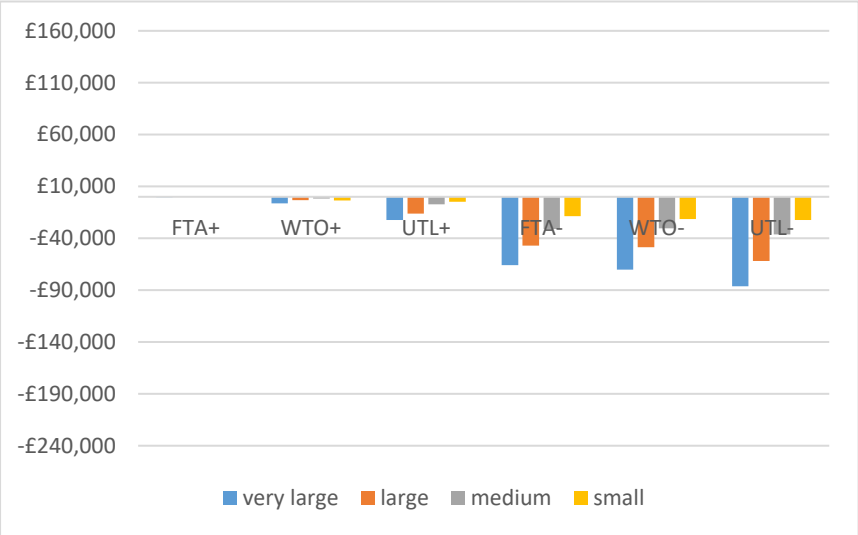
As with cereal farms (but diluted by other crops), higher wheat prices under WTO improve cropping incomes in England, with FTA and (more so) UTL reducing incomes. However, loss of direct payments dominates losses. Gains and losses are essentially proportional to farm area.

Figure 5.7. Estimated change in FBI (£) for different sizes of general cropping farm in N Ireland



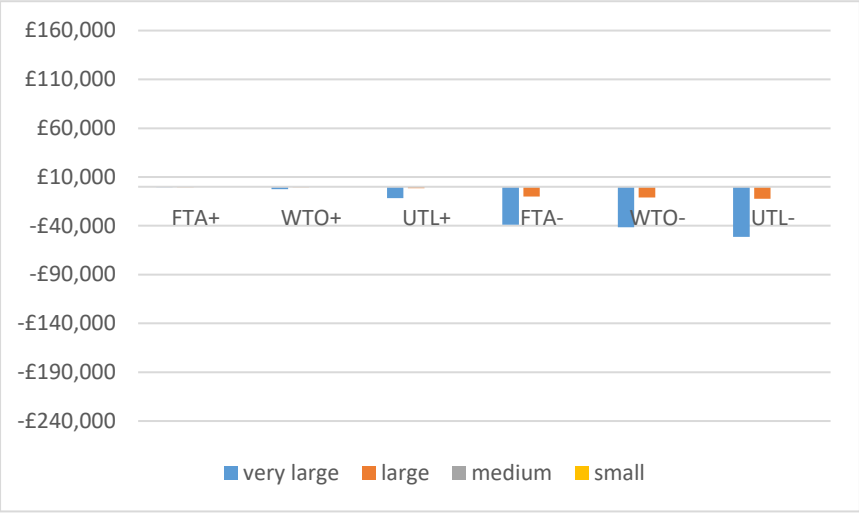
Unlike general cropping farms elsewhere, those in Northern Ireland are dominated by horticulture – which benefits from higher prices under WTO scenarios, and is also less dependent on support payments NB. no very large farms in FBS sample for Northern Ireland.

Figure 5.8. Estimated change in FBI (£) for different sizes of general cropping farm in Scotland



Incomes fall under all scenarios, mostly reflecting lower barley prices but particularly loss of support payments. Losses are essentially proportional to farm area, with Scottish farms having a smaller area than English farms, but bigger than Welsh farms.

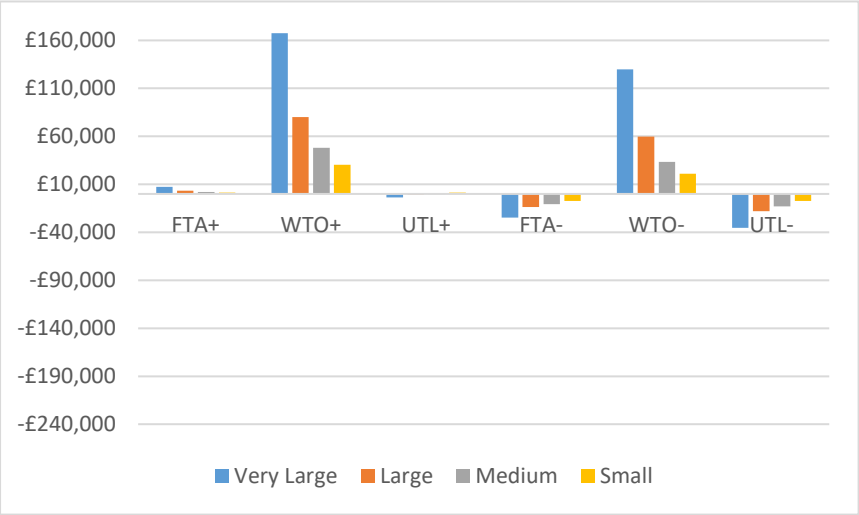
Figure 5.9. Estimated change in FBI (£) for different sizes of general cropping farm in Wales



Relatively little impact from price changes, with removal of support dominating income reductions. Changes essentially proportional to farm area (very large farms more than twice area of large farm). NB. no medium or small farms in Welsh FBS sample.

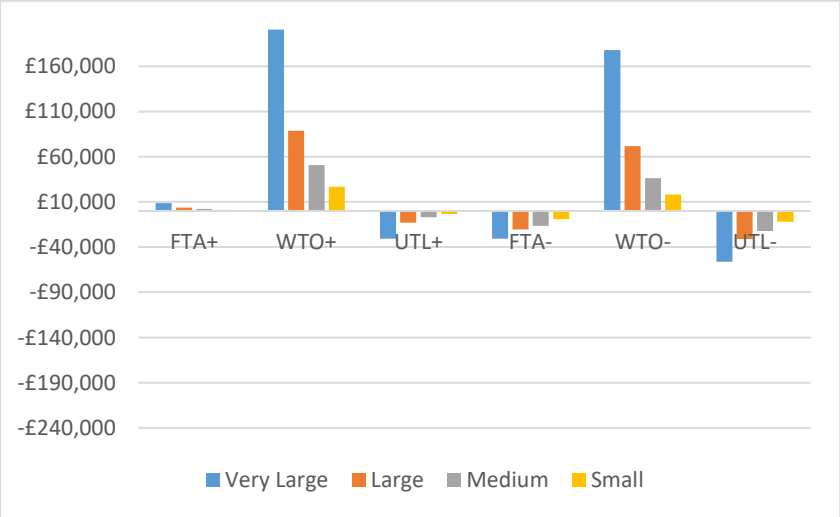
5.4.3. Dairy farms

Figure 5.10. Estimated change in FBI (£) for different sizes of dairy farm in England



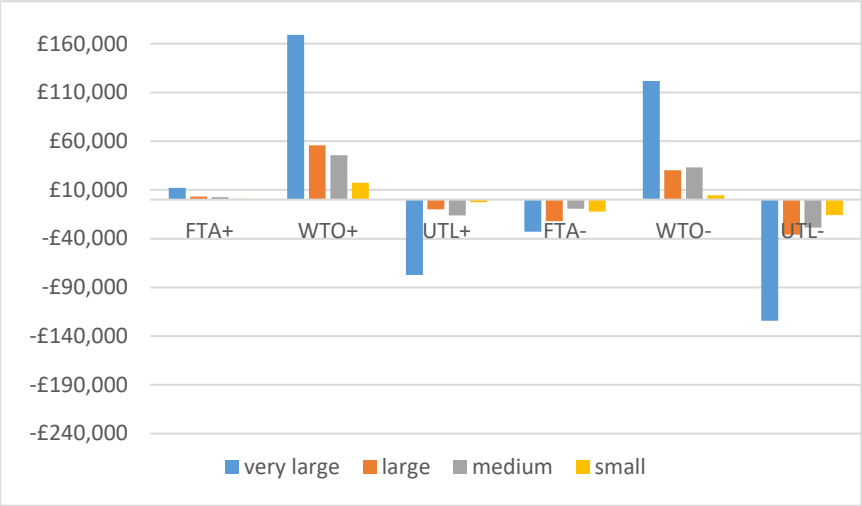
Incomes rise under WTO$^+$ due to higher milk prices. Lower prices under UTL$^+$ lead to slight income losses. Removal of support amplifies losses under UTL, introduces losses under FTA and reduces gain under WTO. Gains and losses are essentially proportional to farm herd size and area.

Figure 5.11. Estimated change in FBI (£) for different sizes of dairy farm in Northern Ireland



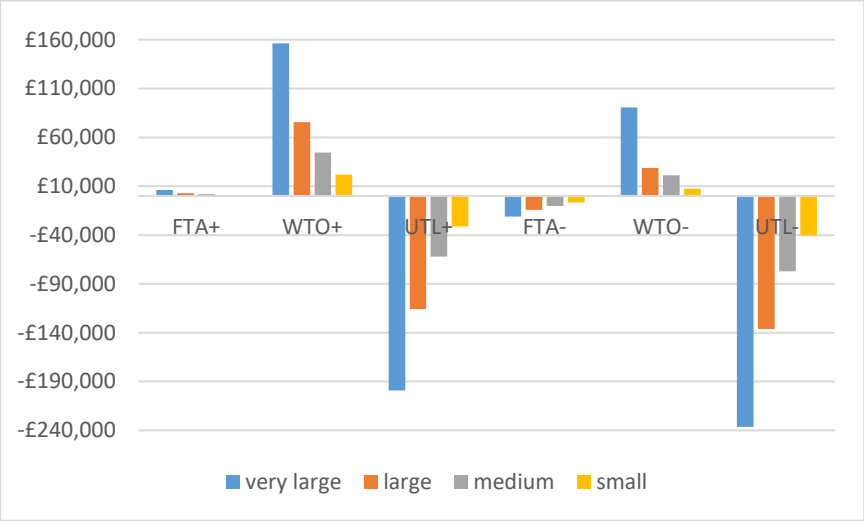
Incomes rise slightly under FTA$^+$ and, much more so, WTO$^+$ due to higher milk prices. Lower prices under UTL$^+$ lead to income losses. Removal of support amplifies losses under UTL, overturns gains under FTA and reduces gain under WTO slightly. Gains and losses are essentially proportional to farm herd size and areas.

Figure 5.12. Estimated change in FBI (£) for different sizes of dairy farm in Scotland



Incomes rise under FTA+ and, especially, WTO+ due to higher milk prices. Lower prices under UTL+ prompt a reduction of 38%-55% in herd size, and hence income falls. Removal of support amplifies losses under UTL, overturns gains under FTA and reduces gain under WTO. Gains/ losses proportional to size.

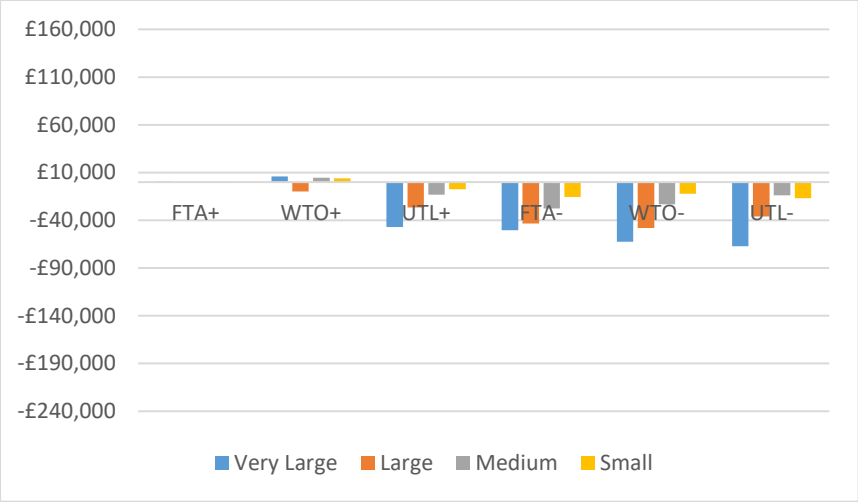
Figure 5.13. Estimated change in FBI for different sizes of dairy farm in Wales



Incomes rise under FTA^{+} and, especially, WTO^{+} due to higher milk prices. Lower prices under UTL+ prompt up to 89% reduction in production and lead to lower income. Removal of support amplifies losses under UTL, overturns gains under FTA and reduces gain under WTO. Gains/ losses proportional to farm herd size and area.

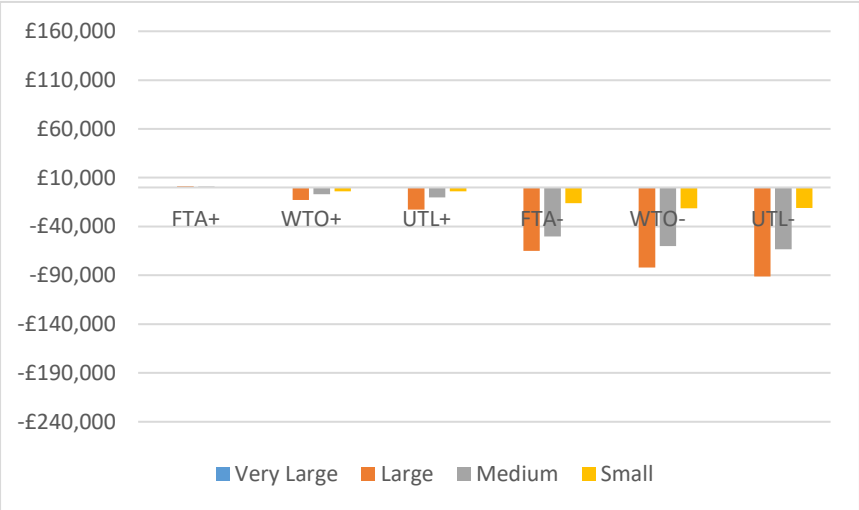
5.4.4. LFA grazing farms

Figure 5.14. Estimated change in FBI (£) for different sizes of LFA grazing farm in England



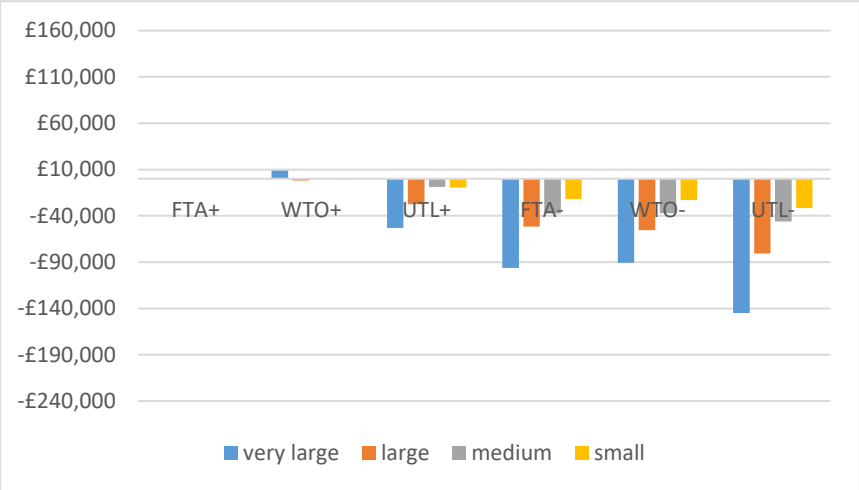
Slight price changes under FTA+ have negligible impact, but higher beef prices under WTO have modest positive income effect on most farm sizes, but sheep price reductions offset this for large farms UTL price reductions lead to income losses, as does removal of support payments, with up to 99% reduction in sheep.

Figure 5.15. Estimated change in FBI (£) for different sizes of LFA grazing farm in Northern Ireland



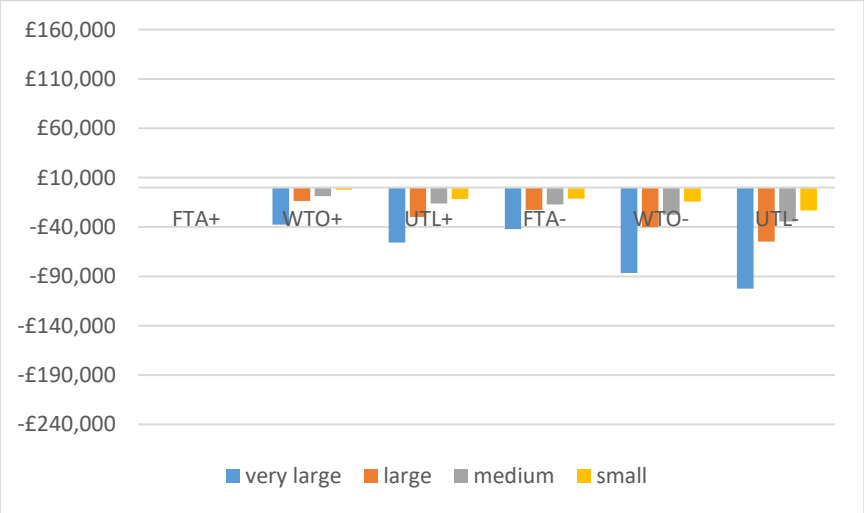
Very slight gains under FTA+ are reversed under WTO+ and UTL+ due to dominance of sheep enterprise, with removal of Pillar 1 support leading to increasing losses under remaining scenarios. Gains/ losses proportional to farm herd size and area. NB. no very large farms in FBS sample for Northern Ireland.

Figure 5.16. Estimated change in FBI (£) for different sizes of LFA grazing farm in Scotland



Higher beef prices under WTO have modest positive income effect on most very large farm size, but sheep price reductions offset this for other sizes. UTL price reductions lead to income losses, as does removal of support payments, with up to 39% reduction in beef numbers and up to 100% in sheep numbers.

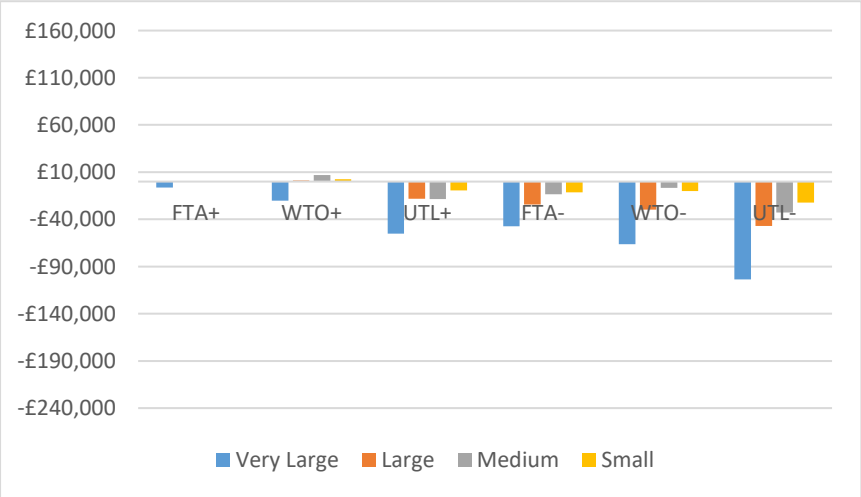
Figure 5.17. Estimated change in FBI (£) for different sizes of LFA grazing farm in Wales



Sheep price reductions lead to income losses for all farm sizes under all scenarios, due to greater reliance on sheep. Losses are amplified by removal of support payments. UTL- leads to sheep reductions of up to 96%.

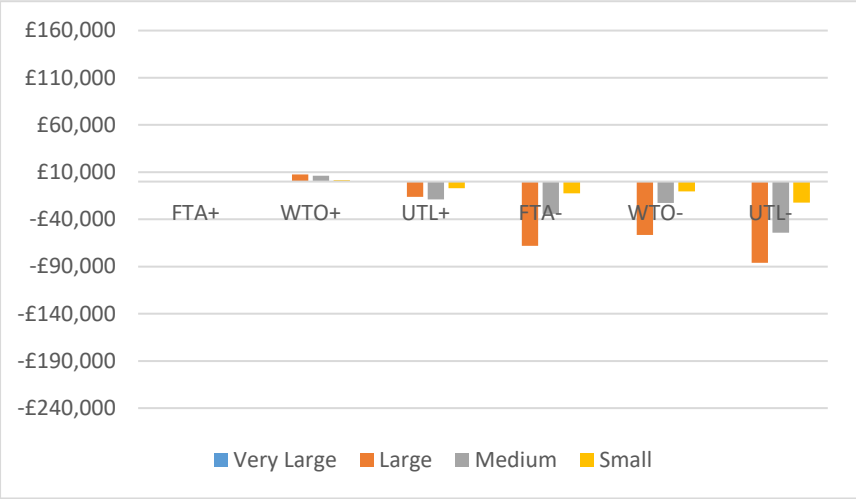
5.4.5. Lowland grazing farms

Figure 5.18. Estimated change in FBI (£) for different sizes of lowland grazing farm in England



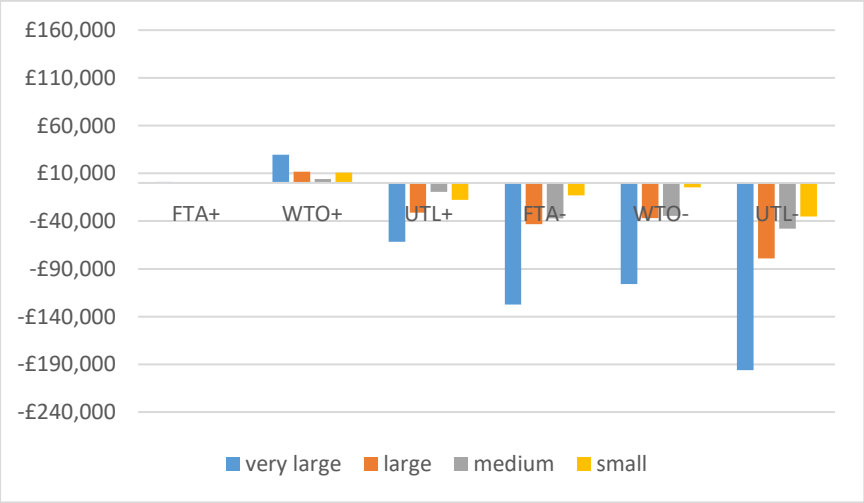
Price changes under FTA+ have negligible impact, but lower sheep prices lead to income reductions on large farms whilst higher beef prices lead to income gains on medium and small farms. Removal of support payments leads to income reductions across all farm sizes, mostly proportional to farm area.

Figure 5.19. Estimated change in FBI (£) for different sizes of lowland grazing farm in Northern Ireland



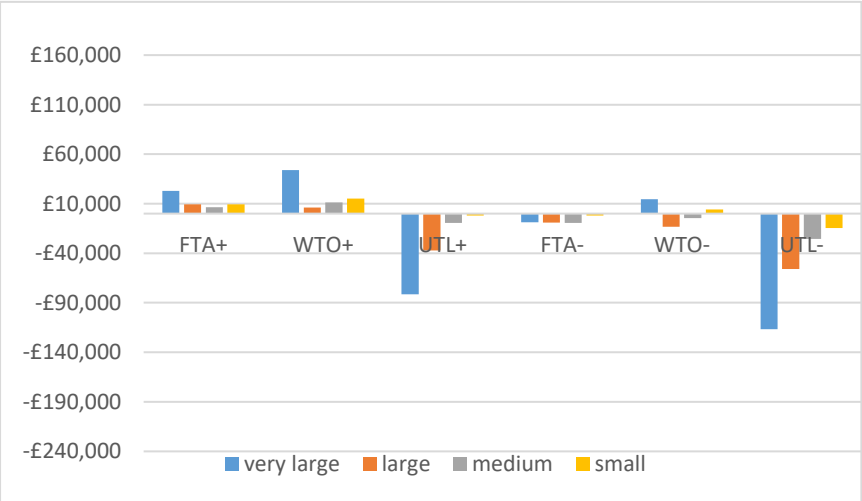
FTA+ has negligible effect on incomes, but beef price rises under WTO+ raise incomes slightly, but price falls under UTL- lead to income losses. Removal of support leads to larger income losses across all remaining scenarios, proportional to farm size. NB. no very large farms in FBS sample for Northern Ireland.

Figure 5.20. Estimated change in FBI (£) for different sizes of lowland grazing farm in Scotland



FTA+ has negligible effect on incomes, but beef price rises under WTO+ raise incomes, but price falls under UTL- reduce income and lead to up to 100% reductions in beef and sheep numbers. Removal of support payments leads to income reductions across all farm sizes, mostly proportional to farm area.

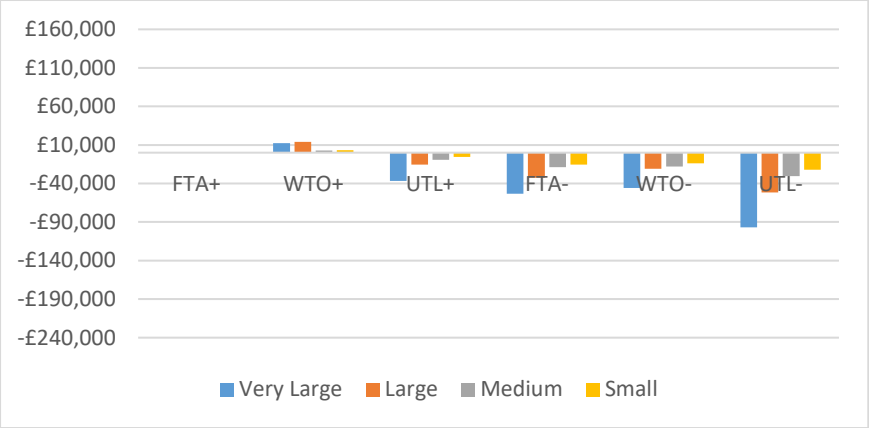
Figure 5.21. Estimated change in FBI (£) for different sizes of lowland grazing farm in Wales



Price rises under FTA+ and (more so) WTO+ raise incomes, particularly for very large and small farms. Price falls under UTL- reduce income and lead to up to 82% reduction in sheep numbers. Removal of support payments leads to income reductions in most cases.

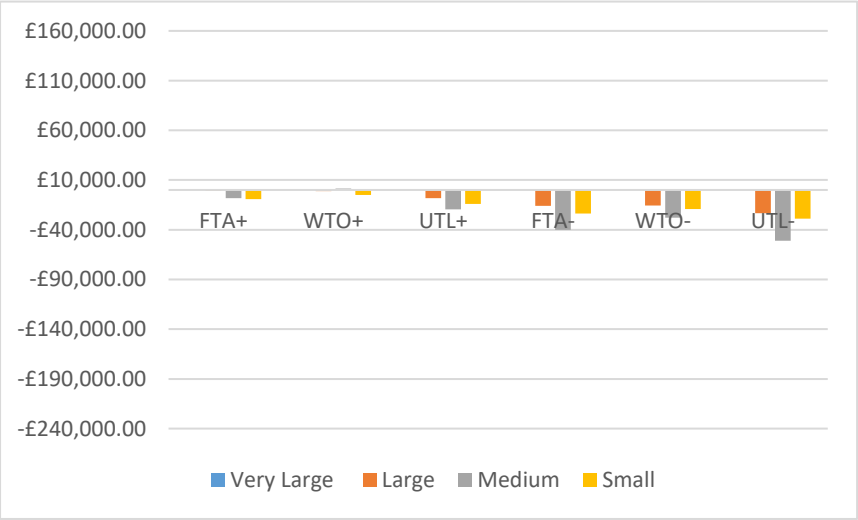
5.4.6. Mixed farms

Figure 5.22. Estimated change in FBI (£) for different sizes of mixed farm in England



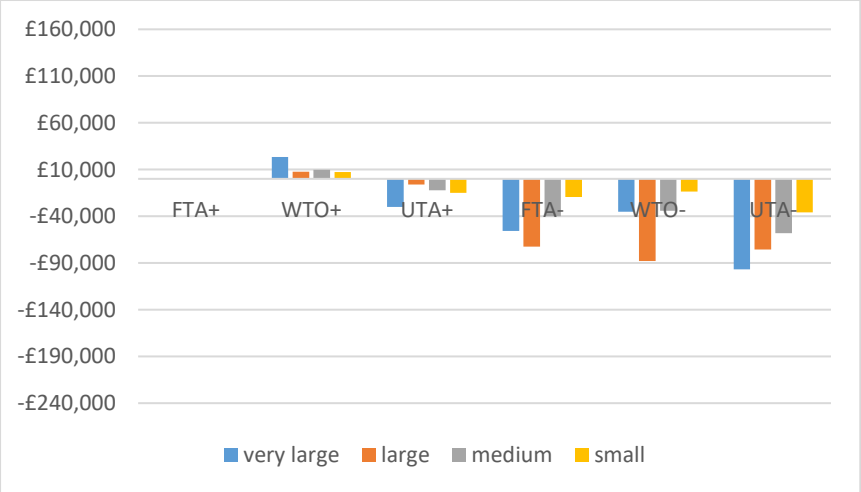
Price changes under FTA+ have negligible effect, but price rises for beef, milk and wheat lead to income gains under WTO+. UTL price falls lead to reductions in incomes for all farm sizes, as does removal of support payments.

Figure 5.23. Estimated change in FBI (£) for different sizes of mixed farm in Northern Ireland



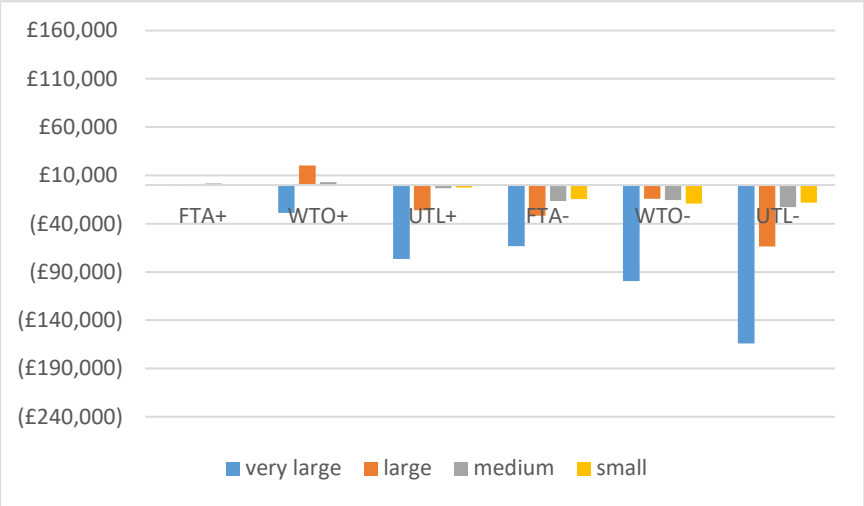
Pig and poultry enterprises support high labour usage on large (by SLR criterion) mixed farms but occupy less land than grazing enterprises on medium (by SLR criterion) size farms – which leads to the latter suffering more from removal of support payments. NB. no very large farms in FBS sample for Northern Ireland.

Figure 5.24. Estimated change in FBI (£) for different sizes of mixed farm in Scotland



Price changes under FTA+ have negligible effect, but price rises for beef, milk and wheat lead to income gains under WTO+. UTL price falls lead to reductions in incomes for all farm sizes, as does removal of support payments. Very similar to results for England, but slightly different to those for Wales.

Figure 5.25. Estimated change in FBI (£) for different sizes of mixed farm in Wales



Price changes under FTA+ have negligible effect, but price rises for beef, milk and wheat lead to income gains under WTO+ for some farm sizes whilst price falls for sheep and barley lead to income reductions for others. UTL price falls lead to reductions in incomes for all farm sizes, as does removal of support.

5.5. Conclusion

This section summarises results of modelling farm-level production and income levels under different trade and domestic support scenarios following Brexit. Using FBS data to define and configure representative farms, ScotFarm has been used to estimate effects across different farm types and sizes in different parts of the UK. Although it is important to note that the modelled impacts are based on a number of assumptions (see Annex 5.4) and will not precisely represent actual impacts for individual farms, they are indicative of the likely direction of travel and of where pressures for structural adjustment are likely to be felt most keenly. The findings are broadly consistent with those of other studies also using FBS data (Bradley & Hill, 2017; Swales *et al*., 2017).

For example, it is apparent that certain farm types are more vulnerable to farmgate price reductions than others. In particular, price reductions under WTO+ would adversely affect the profitability of sheep farms whilst price reductions under UTL+ would adversely affect the profitability of beef farms. Conversely, some farms would experience increased profitability through higher beef, milk and wheat prices under the WTO+ scenarios. The UTL+ scenario is the most disruptive to current profitability. However, it is also apparent that domestic decisions on Pillar 1-type support will potentially have more significant effects on farm profitability. This is true for all farm types and the magnitude of projected reductions in income are such that the viability of many farms is questionable under any trade scenario if Pillar 1 support is abolished without some concomitant increase in other (i.e. Pillar 1-type) support and/or alternative income support measures. Indeed, the reductions in beef cattle and sheep numbers imply that many livestock farms would simply cease production.

Within the aggregate results, there is some variation across different farm sizes and between countries. The latter probably reflects differences in farming systems arising from biophysical conditions (e.g. climate, soils) as well as structural characteristics (e.g. farm size, enterprise mix). For example, Scottish dairy farms more commonly have beef enterprises than English dairy farms. However, it should be noted that support payment rates and funding levels also vary between countries. Variation in impacts across farm sizes probably reflect economies of scale and scope, but larger units' higher Pillar 1 support levels can make them more exposed to funding withdrawal even if they benefit from possible efficiency advantages.

Given the magnitude of projected income reductions (particularly from removal of support payments), it is clear that the pressure for structural change will be significant and hence a more open model configuration may be required. In particular, ScotFarm has been configured to restrict the available production possibility set to activities currently observed for the given representative farm. This is a pragmatic initial step, focusing on adjustments to the scale and mix of existing activities without the need to address more radical structural adjustments or capital investments. Moreover, although projected price movements are substantial, they do mostly lie within the range of prices observed in the recent past. However, addressing the possibilities of changes to factor prices (e.g. lower land rents, higher labour costs) and reconciling farm-level and sectoral or macro projections will require a more flexible approach and exploration of sensitivity to some of the current assumptions. This probably implies recourse to simulation analysis, considering what degree of farm-level change in productivity, scale and enterprise mix would be required to achieve outcomes consistent with those suggested by the CGE and sectoral models.

6. Farm level analysis: A Budget Simulation Model[29]

The objectives of Phase 4 were to:

- quantify potential effects of UKAP scenarios on the welfare of farm households
- identify segments within the farming population likely to be most vulnerable to UKAP scenarios.

These objectives were addressed using a budgetary simulation model to estimate potential effects of Brexit scenario on the distribution of farm incomes by UK nation and main farm enterprise. Further analysis decomposes the estimated impacts to ascertain characteristics of more vulnerable segments of the farm population We also use sensitivity analyses to investigate mitigating factors such as farm productivity improvements, greater reduction in land rents and pound devaluation. The final analytical component of phase 4 (Chapter 7) provides a more comprehensive investigation of welfare impacts on farm households utilising a viability typology.

6.1 Data

Our analysis utilises data from the UK Farm Business Surveys (FBS) for 2013/14, 2014/15 and 2015/16. The necessary data files were obtained through Special Licence from the UK Data Archive in the case of England and Wales, and directly from DAERA and SG RESAS for Northern Ireland and Scotland, respectively. The FBS is recognised as the most detailed and extensive source of financial and physical performance on UK farming businesses. The survey includes fully reconciled management accounts including crop and livestock enterprise gross margins, overhead costs, income statement and balance sheet data. The UK-wide FBS data files, in total, comprised survey responses from approximately 3,300 individual farming businesses in each year of the data period (Table 6.1). The FBS sample is weighted using calibrated inverse sampling fractions to provide statistically representative data for a population of approximately 100,000 commercial farming businesses with output of at least €25,000 per annum and at least 0.5 Standard Labour Requirement (SLR). These businesses represent c. 47% of UK holdings in 2015/16 but they account for more than 90 percent of total agricultural output.

While the FBS provides comprehensive data on farm business characteristics (including on-farm diversification) and financial performance, it's coverage of off-farm income is more limited. Notably, the English FBS ceased collecting off-farm income data in 2014/15. Moreover, non-response issues and the broad income ranges used for categorising off-farm income levels restricted the utility of the available off-farm income from a modelling perspective. Accordingly, our initial plan to model a more comprehensive measure of farm household income was necessarily modified to focus primarily on farm income metrics. However, the FBS is a survey of *commercial* farm businesses and therefore farming tends to be the predominant source of income for these households. To some extent this aspect mitigates the limitation caused by a paucity of off-farm income data. Nonetheless, in the final part of the work-package, more comprehensive evaluation of household welfare impacts (using the limited off-farm income data available) is approached through classificatory analysis using viability criteria thresholds.

[29] This chapter was largely written by Michael Wallace.

We purposefully selected some 250 FBS variables comprising a comprehensive set of physical and financial metrics that are defined equivalently for each FBS administration in the UK. A balanced panel sample was constructed comprising farm businesses recorded in each of the three years of the data period (2013/14, 2014/15, 2015/16). The panel approach helped to control for inter-year variability (see below) while the availability of 3-years of records for each farm provided a useful consistency check. However, due to the normal turnover in the FBS sample, construction of the balanced panel reduced the available records by approximately 15% to 2,803 farm businesses that then formed our initial data sample (Table 6.1).

Table 0.1. FBS survey sample and weighted sample of population (number of farms)

	England	Wales	Scotland	N. Ireland	Total - UK
Initial FBS sample					
2013/14	1,907	550	500	360	3,317
2014/15	1,897	550	505	363	3,315
2015/16	1,811	550	501	357	3,219
Initial weighted sample (population)					
2013/14	58,370	9,898	12,023	22,800	103,091
2014/15	57,541	9,783	12,143	22,853	102,320
2015/16	56,469	9,826	11,968	23,731	101,994
3-Year balanced panel (2013/14-2015/16)					
Sample	1,535	481	457	330	2,803
Weighted sample (population)	46,537	8,605	11,089	20,573	86,804
3-Year balanced panel & farm size >= 0.5 SLR					
Sample	1,498	477	457	286	2,718
Weighted sample (population)	44,061	8,443	11,089	9,615	73,208

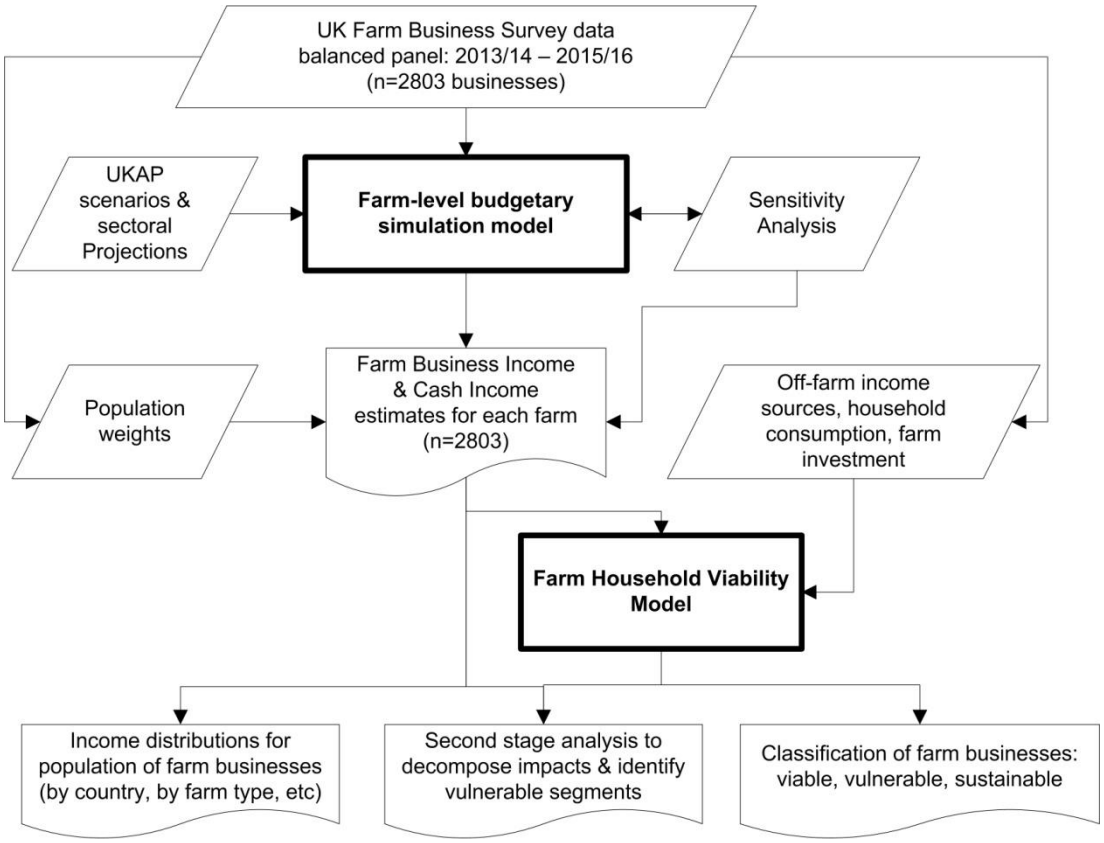
FBS coverage in England, Wales and Scotland excludes 'spare-time' businesses while the NI survey includes a sub-sample of these smaller businesses. Accordingly, for consistency when comparing between UK nations, we restricted our data sample only to commercial businesses with a Standard Labour Requirement (SLR) of at least 0.5 Full-Time Equivalent (FTE) labour units. The resulting dataset on 2,718 commercial farming businesses formed the primary sample used in our farm-level simulations. This sample was weighted (using FBS sampling weights) to be statistically representative of c.73,200 commercial farming businesses across all main farm enterprise types in the UK (Table 6.1).

In preparing the reference dataset for modelling purposes we applied a data normalisation procedure to control for inter-year variability using the panel data for 2013/14, 2014/15 and 2015/16. Specifically, arithmetic means of the physical and financial variables for each farm were calculated over the three-year data period. This approach smoothed data aberrations and enhanced the 'representativeness' of the primary data used in modelling.

6.2 . Modelling Strategy

A flow chart of the modelling process in Phase 4 is shown in Figure 6.1. The analysis harnessed the strengths of the rich FBS dataset by individually modelling all farm businesses in the combined FBS samples for England, Wales, Scotland and Northern Ireland. This approach embraced the inherent heterogeneity within the UK farm population and, using FBS weights, simulated scenario impacts for the individual farm businesses could be 'raised' to provide a robust assessment of those impacts across the farm population as a whole. While modelling all farms in the large data sample necessarily required a relatively parsimonious model specification, it was felt that this limitation was justified by the enhanced scope for more general analysis of impacts across the overall farm populations by enterprise type and region.

Figure 6.1. Flow chart of Phase 4 modelling process



A farm-level budgetary simulation model was constructed to evaluate the potential effects of Brexit scenarios. The model utilised a standardised management accounting framework to individually simulate financial performance for each farm in the data set (n=2803). Revenue, cost and income equations were implemented within Excel worksheets so that scenario projections for prices, support payments or productivity could be quantified for each farm in the sample. The modelling procedure used enterprise-level data detailing outputs and variable costs for each farm enterprise. Totalled enterprise gross margins were augmented by whole-farm estimates of direct payments, diversification and other revenues, and then overhead costs were deducted.

The financial results from the model simulations included Farm Business Income and Cash Income. Farm Business Income (FBI) is DEFRA's headline measure of farm income. It represents the return to all unpaid labour (farmer, spouse and others with an entrepreneurial interest in the business). Cash Income is simply trading (cash) receipts less trading (cash) expenditure and it excludes notional items such as depreciation and the effects of livestock and crop valuation changes. It is a measure of the cash return to all those with an entrepreneurial stake in the business and, since it excludes costs associated with maintenance of the capital assets of the business, it provides an indicator of short-run business viability.

The model was used to simulate year-2026 projections for the six selected UKAP scenarios and a reference Baseline (status quo) situation. Additional scenarios such as changes in land rental values, devaluation of pound and farm productivity changes were considered in supplementary simulations (sensitivity analysis). Each trade scenario (FTA, UTL, WTO) was simulated under two alternative assumptions about future domestic support policy in 2026.

The price projections simulated for each policy scenario have been discussed in Chapters 3 and 4 but are summarised in Table 6.2. Specifically, we used UK-FAPRI model projections for output prices and variable costs as these were suitably disaggregated at the product level as required for the farm-level simulations. However, the FAPRI model did not provide projections of factor market impacts, thus projections for land rents and wage costs were obtained from the CGE model (Chapter 3).

Table 6.2. Output price and input cost projections under each scenario in model simulations

	FTA+	FTA-	UTL+	UTL-	WTO+	WTO-
Livestock Prices						
Beef	+0.6%	+1.9%	-42.4%	-42.3%	+17.3%	+17.5%
Sheep meat	-0.4%	+4.3%	-19.4%	-18.8%	-23.4%	-23.0%
Milk	+1.0%	+1.1%	-7.5%	-7.5%	+27.7%	+27.9%
Pig meat	+0.5%	+0.7%	-4.2%	-4.2%	+24.7%	+24.7%
Poultry meat	+0.2%	+0.4%	-3.1%	-3.1%	+14.6%	+14.6%
Other Livestock	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Crop Prices						
Wheat	-0.0%	+1.0%	-1.8%	-1.5%	+6.6%	+7.8%
Barley	-0.4%	+0.5%	-8.3%	-8.1%	-5.5%	-5.2%
Oats	-0.4%	+0.5%	-7.8%	-7.6%	-5.2%	-4.9%
Rapeseed	0.0%	+0.0%	-0.3%	-0.2%	-0.5%	-0.4%
Other Cash Crops	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Variable Costs						
Purchased feed	-0.05%	+0.16%	-1.18%	-1.13%	0.00%	+0.12%
Other Livestock VCs	-0.05%	+0.16%	-1.18%	-1.13%	0.00%	+0.12%
Crop variable costs	-0.02%	+0.05%	-0.44%	-0.42%	-0.10%	-0.06%
Fixed Costs						
Land rents	+1.2%	-14.9%	-2.8%	-18.8%	+4.9%	-10.6%
Wage rates	+5.1%	+5.0%	+5.0%	+4.9%	+5.3%	+5.3%

Note: Projected price changes for each scenario in 2026 relative to 2026 Baseline
Output prices and variable costs projections from FAPRI-UK Model
Fixed cost projections from CGE model estimates

Since the beef and sheepmeat price projections from FAPRI were for finished cattle and finished lambs, respectively, we assumed that projected changes in deadweight prices would be fully transmitted through the production chain to the prices and valuations of immature stock. For example, a given percent reduction in the price of finished cattle was assumed to result in an equivalent percentage change in beef calf and store cattle prices. Similarly, projected changes in prices of cull cows and cull ewes were assumed equivalent to the projected percentage changes in beef and sheepmeat prices, respectively. However, prices of replacement dairy heifers were assumed to change in proportion to changes in milk prices.

The farm-level simulation was essentially a comparative static analysis. The projected annual farm management account under each scenario was contrasted with the equivalent account under a Baseline (status quo) situation. Farm structural characteristics (e.g., land areas, stocking, cropping) and technical efficiencies (e.g., stocking rates, yields, input-output ratios) were held constant. Accordingly, it is emphasised that model estimates are first-order effects that may represent an upper bound of potential impacts (before accounting for farm-level adaptations). This is a recognised limitation of the analysis as farmers would be expected to respond to price or policy shocks by adjusting their production systems to mitigate impacts.

Potential farm management responses to Brexit scenarios include enterprise substitution, diversification, productivity change, disinvestment or abandonment of farming. However, adjustment capacity, at least in the short term, will be a function of human factors (e.g. management skills, preferences), and physical and financial resource constraints that determine adaptive flexibility.

Such constraints cannot readily be inferred from FBS data; consequently more comprehensive modelling of production responses would have relied on potentially arbitrary assumptions about magnitudes of potential adjustments. For this reason we instead utilised sensitivity analysis to evaluate potential mitigating responses such as productivity improvement (see below). Moreover, the representative farm modelling in Phase 3 accounted for potential enterprise substitutions but subject to the existing range of activities for each farm. Additionally, by providing projections of Cash Income we assessed, albeit in a stylised manner, the potential of farmers to mitigate income losses in the short-term by deferring investment.

The simulated financial performances of farms in our data sample are weighted using official FBS sample weights to provide results that are statistically representative of the farm population as a whole. These weighted estimates underpin our simulation of income distribution curves for farm populations according to farm type and UK nation. Importantly, these income distribution curves provide a compact, visual presentation of scenario results. Proportions of the farm population with incomes above or below any given threshold value on the income scale can be readily observed. For example, the estimated proportion of businesses that become loss-making under a scenario or whether there are differential impacts on higher versus lower income farms. Finally, we provide more in-depth assessment of farm types likely to be most vulnerable to Brexit scenarios by disaggregating the impacts using regression and impact-quintile analyses.

6.3 . Results

Results from the farm-level budgetary simulations are organised as follows. Section 6.3.1 estimates mean incomes (cash income and FBI) and income distributions under each UKAP scenario according to farm populations in each UK nation. This is followed in section 6.3.2 by similar analyses according to main enterprise type. In 6.3.3 farms are classified into quintiles based on severity of scenario impact and we quantify characteristics of farms that are most and least vulnerable to the policy projections. Scenario impacts are further decomposed in section 6.3.4 using regression analysis to quantify the relationships between key farm characteristics and estimated changes in Farm Business Incomes. Finally, in section 6.3.5 sensitivity analyses are used to evaluate potential mitigating factors such as productivity improvements, Sterling devaluation and sharper reductions in land rents.

6.3.1. Impacts on farm income distribution by country

Projected mean Farm Business Incomes (a) and Cash Incomes (b) for each scenario and the UK nations are shown in Figure 6.2. In each case the Baseline or reference scenario is shown as a dashed red line. Under the FTA+ scenario, where Pillar 1 DPs were maintained, estimated mean incomes were virtually identical to their Baseline levels. The WTO+ scenario increased mean FBI by between 32% (Wales) and 85% (Northern Ireland) due to the elevating effects of tariffs on most domestic farm prices. In contrast the UTL+ scenario reduced mean FBI by between 52% (England) and 130% (Scotland) as liberalised trade exposed UK agriculture to greater international competition and reduced commodity prices.

Given the important contribution of Pillar 1 DPs to Baseline farm income it was not surprising that the scenarios that simulated their removal resulted in sharp declines in farm incomes. Under FTA- Farm Business Income declined by between 58% (England) and 135% (Scotland), with an average reduction of 69% for the UK as a whole. Under WTO-, increases in output prices almost fully offset the loss of Pillar 1 DP on average farm Business Incomes for England and NI. However, this contrasted with a less favourable potential outcome in Wales and Scotland where incomes remained well below Baseline levels. A combination of trade liberalisation along with elimination of Pillar 1 DPs (UTL-) was found to be most challenging with projected mean FBI becoming negative in each all four nations. The results highlighted the potential variation in scenario impacts across the UK. Notably, impacts were less negative, on average, for England compared to the UK as a whole. Scotland stood out as most vulnerable to the Brexit scenarios and, even on a Cash Income basis, average Scottish farm incomes became substantially negative under UTL-.

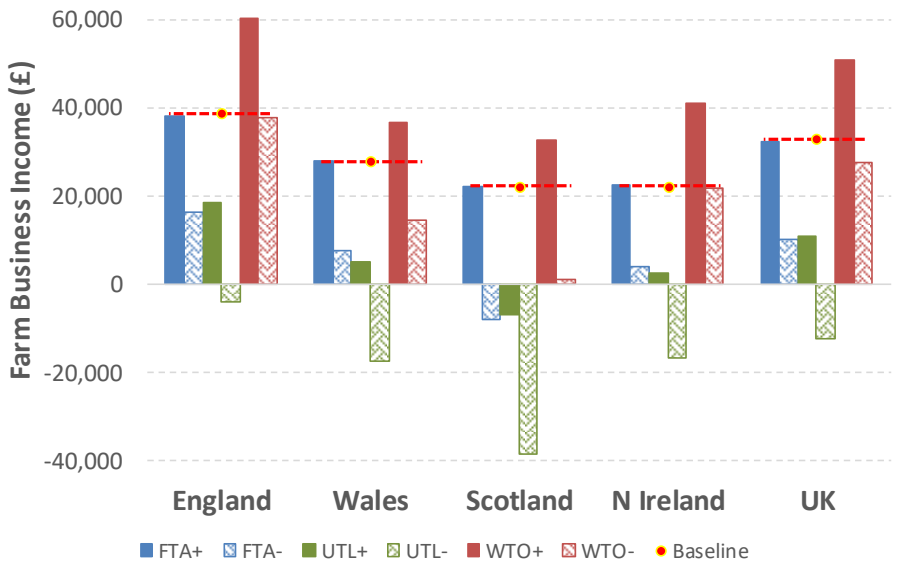
Estimated population distributions for (a) FBI and (b) Cash Income for each scenario are shown in Figures *6.3-6.7* for UK, England, Wales, Scotland and Northern Ireland, respectively. Across the UK around 15% of businesses were loss making in the Baseline FBI distribution. The FTA+ scenario resulted in income distributions that were virtually unchanged relative to the Baseline. FTA-, UTL+ and WTO- increased the proportion of loss-making businesses based on FBI to between c.40% (England) and c.60% (Scotland). On a Cash Income basis, the proportion of loss-making businesses under these scenarios ranged from c.20% (England) to c.30% (Scotland).

Importantly, WTO had greatest impact on the *shape* of the income distribution curves as price increases under this trade scenario were relatively more advantageous to larger or more profitable farming businesses at the upper end of income distribution. As expected, UTL- (extreme trade

liberalisation coupled with Pillar 1 removal) was the most challenging scenario for farm businesses. In FBI terms the proportion of loss-making businesses under UTL- ranged from 62% (England) to 90% (Scotland). Even on a Cash Income basis the proportion of loss making businesses is c.50% for the UK as a whole.

Figure 6.2. Average Farm Income Estimates by Scenario, UK (2026)

(a) Farm Business Income



(b) Cash Income

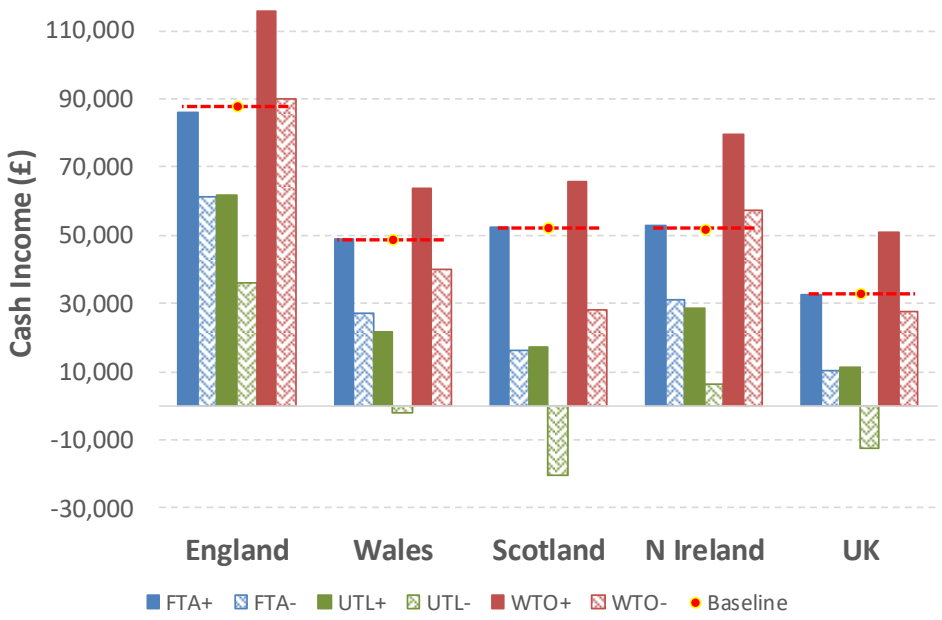
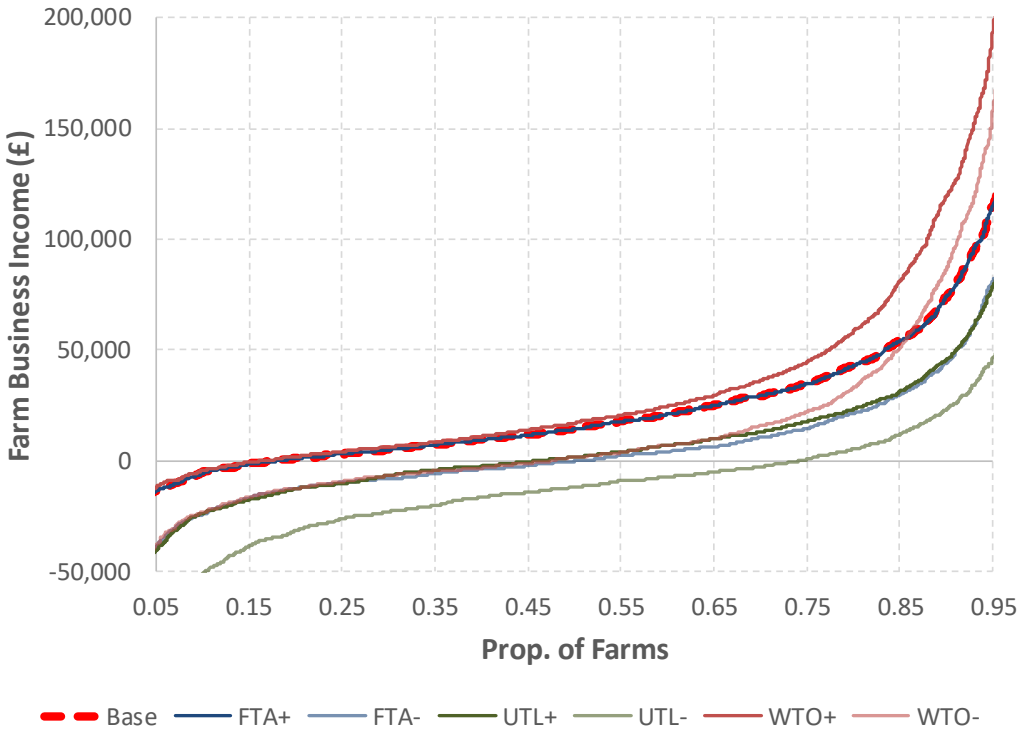


Figure 6.3. Estimated Farm Income Distribution by Scenario (All UK, N=73,208)

(a) Farm Business Income



(b) Cash Income

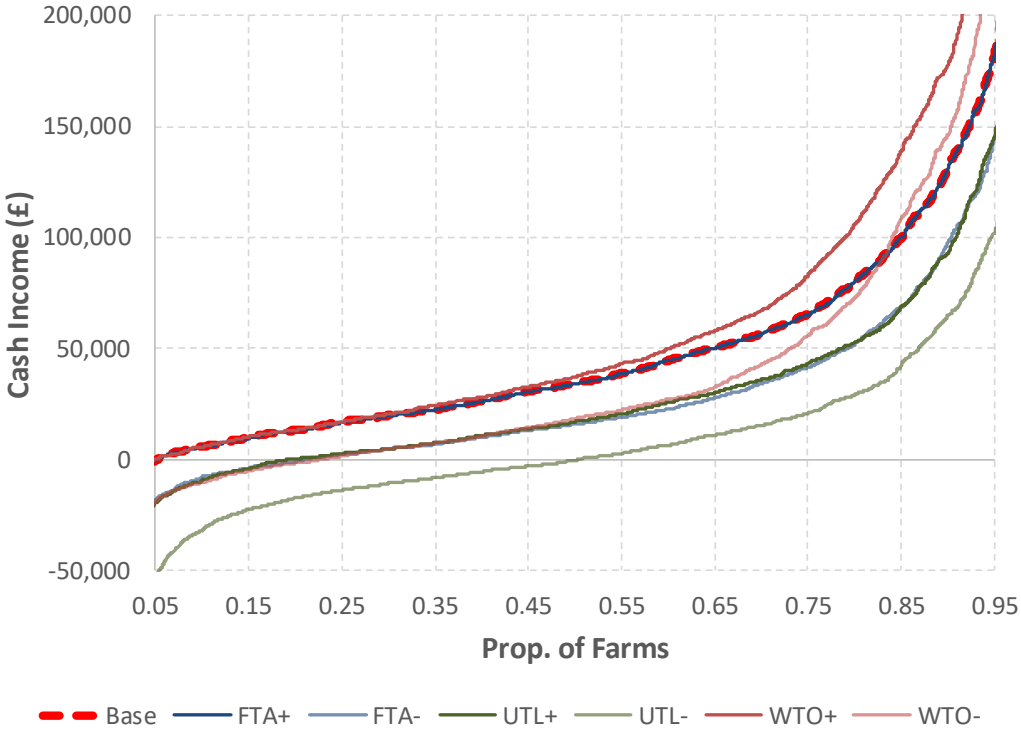
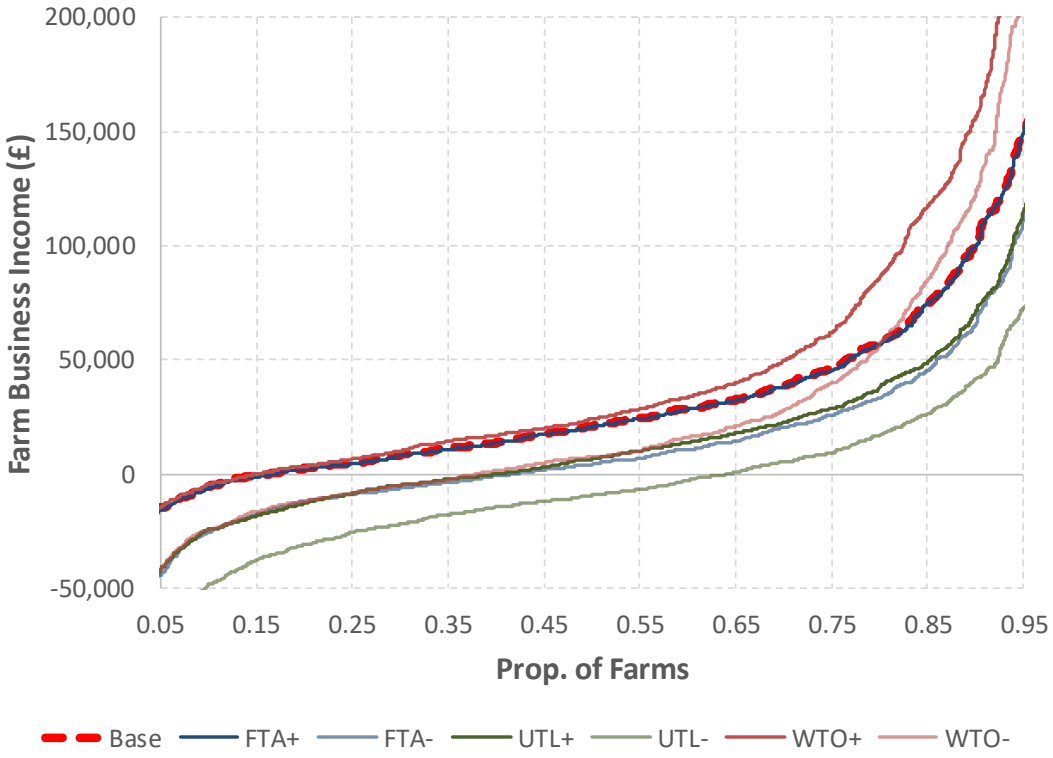


Figure 6.4. Estimated Farm Income Distribution by Scenario (England)

(a) Farm Business Income



(b) Cash Income

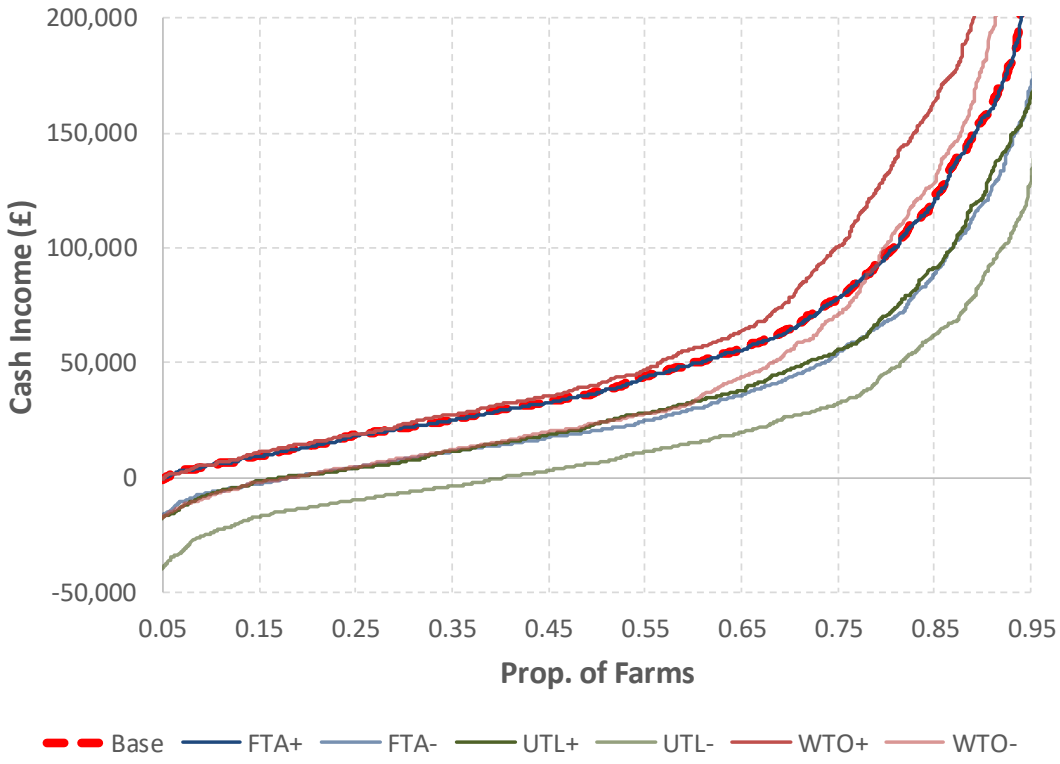
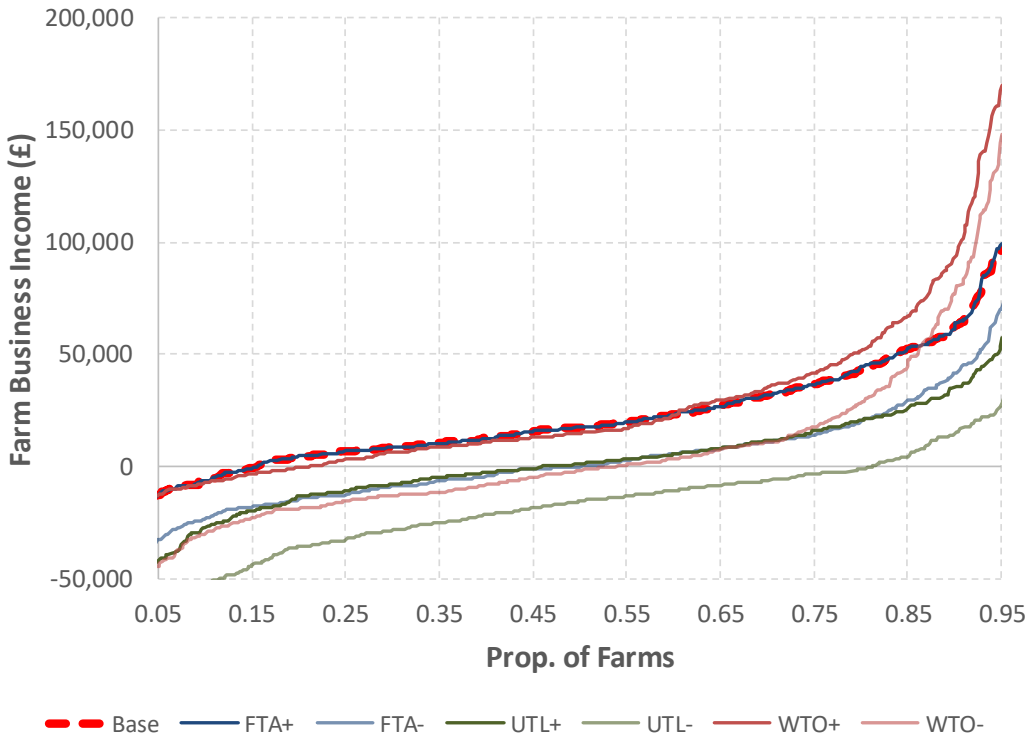


Figure 6.5. Estimated Farm Income Distribution by Scenario (Wales)

(a) Farm Business Income



(b) Cash Income

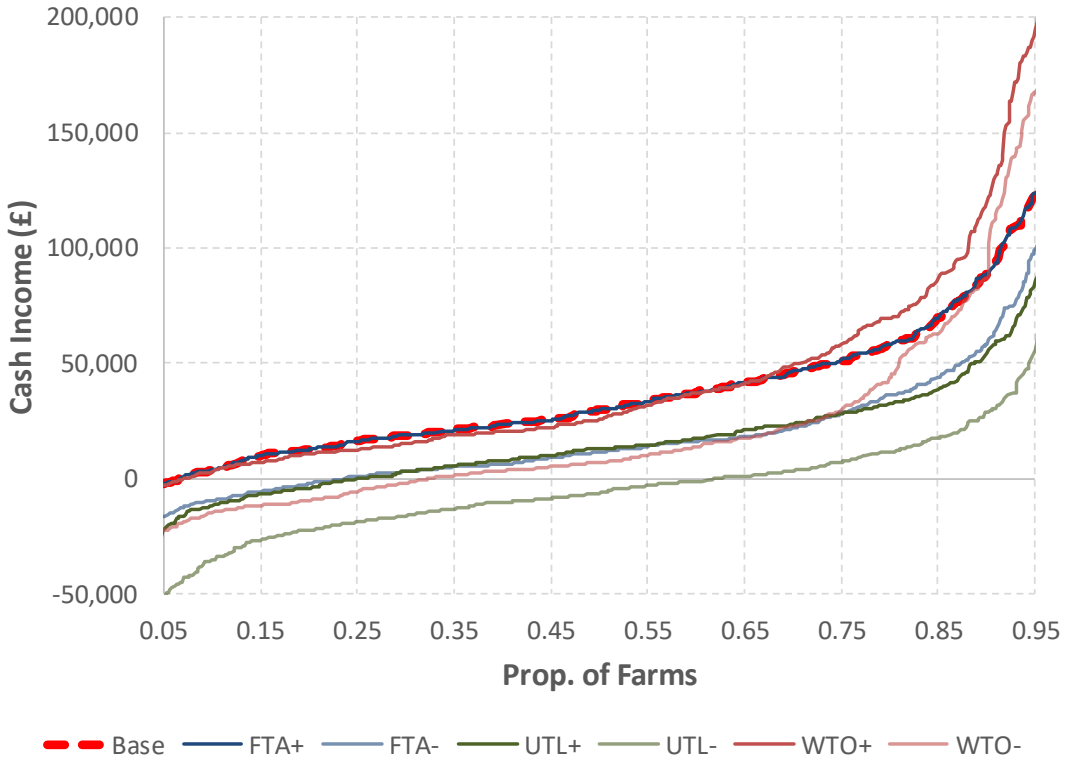
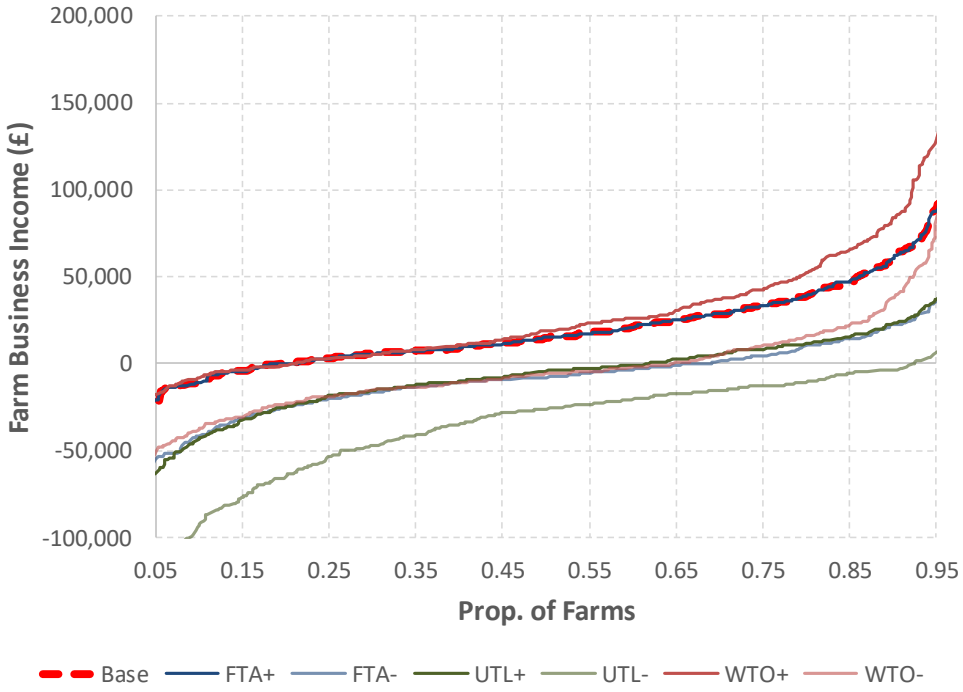


Figure 6.6. Estimated Farm Income Distribution by Scenario (Scotland)

(a) Farm Business Income



(b) Cash Income

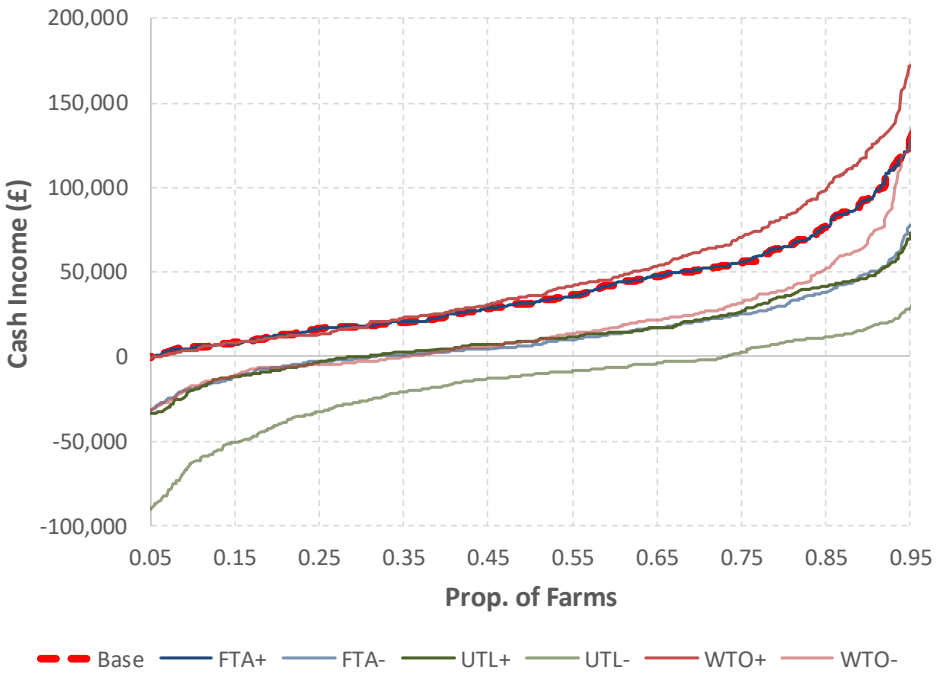
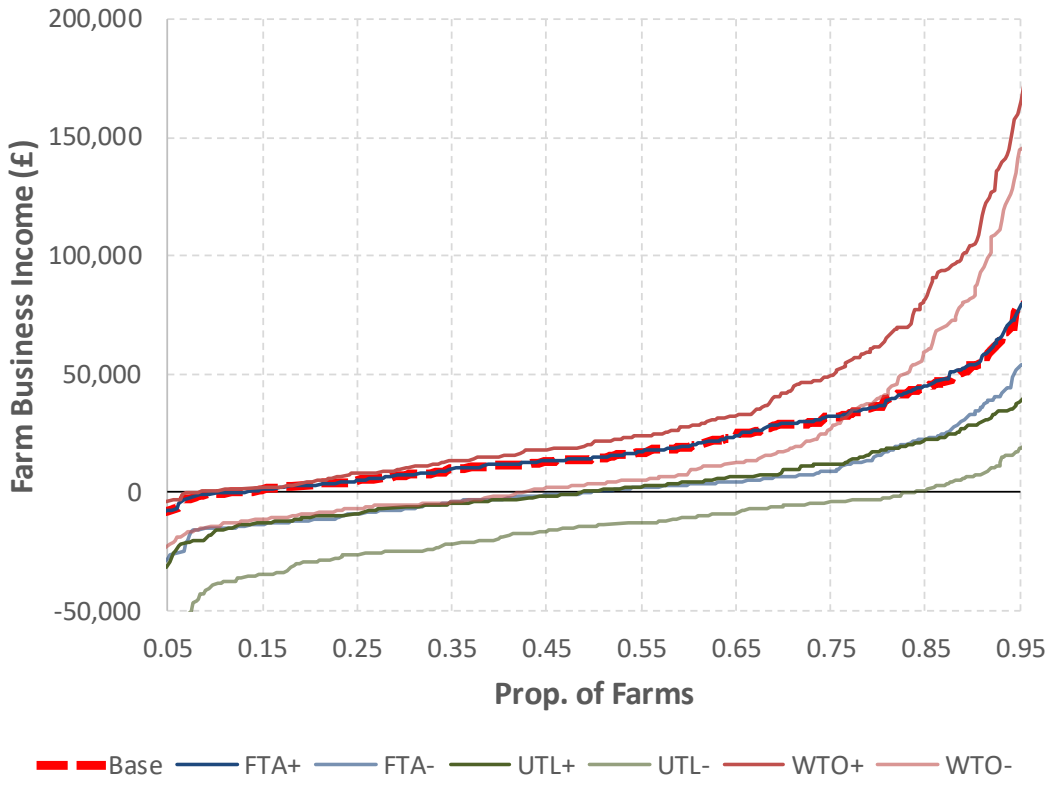
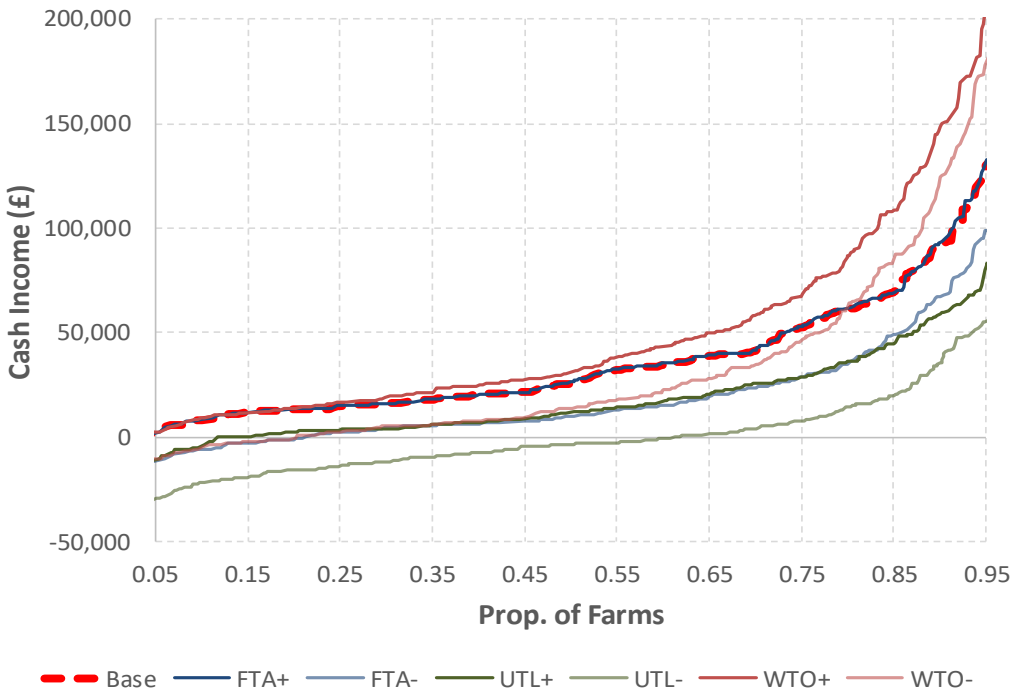


Figure 6.7. Estimated Farm Income Distribution by Scenario (Northern Ireland)

(a) Farm Business Income



(b) Cash Income



6.3.2. Impacts on income distribution by farm type

Projected mean Farm Business Incomes (a) and Cash Incomes (b) for each scenario and by main enterprise type are shown in Figure 6.8.

Under FTA+, average Farm Business Income and Cash Income per farm remained very similar to their Baseline levels, reflecting the modest price changes under the FTA scenario. The WTO scenarios resulted in a more than doubling of average incomes for dairy and pig farms reflecting the projected increases in milk and pig meat prices under the scenario. For other farm types, incomes remained at or slightly above the Baseline when Pillar 1 direct payments were maintained (WTO+) but declined sharply below the Baseline when these payments were removed (WTO-). This result indicated that projected price increases under the WTO scenario would be insufficient, on average, to offset loss of the direct payments for farms with arable or beef/sheep enterprises as their main activity.

As noted previously, UTL was identified as the most challenging scenario across all farm types but especially for those involved in beef and sheep production. Obviously, this impact was especially severe where UTL was combined with removal of direct payments (UTL-). In that situation grazing livestock farms, on average, had negative margins even when defined on a Cash Income basis. This highlighted the specific vulnerability of beef and sheep enterprises to greater international competition in a trade liberalisation scenario. Moreover, the particular dependence of beef/sheep farm incomes on Pillar 1 support makes them acutely vulnerable to any reductions in those payments as highlighted in Figure 6.8.

Figure 6.9 shows the simulated income distribution curves for dairy farms under each scenario. The extreme range between the highest (WTO+) and lowest (UTL-) income distribution curve highlights the degree of uncertainty around potential Brexit outcomes. In the Baseline, less than 10 percent of dairy farms were loss-making based on FBI. The dairy income distribution was little impacted by FTA+ but shifted downward under FTA- such that close to 20% of UK dairy farms became loss-making under FTA when Pillar 1 payments were removed. The WTO+ and WTO- scenarios resulted in a sizeable upward shift in the income distribution curve for dairy farms with the greatest gains captured by larger more profitable farms at the top of the distribution. In contrast, the UTL scenarios shifted the income distributions downward with proportionately larger impacts on farms at the top and bottom of the distribution. Some 55 percent of dairy farms became loss-making under UTL- on an FBI basis while 30 percent became loss-making according to Cash Income.

Projected income distribution curves for cereal farms under each scenario are shown in Figure 6.10 The simulated income distributions were more sensitive to removal of Pillar 1 payments than to the trade scenario price projections. This was highlighted by the two clusters of income curves for scenarios with ("+") and without ("-") Pillar 1 direct payments. According to the Farm Business Income measure, UTL+ increased the proportion of loss-making cereal farms to 25 percent compared to 18 percent under the Baseline and FTA+. In contrast, with removal of Pillar 1 payments the proportion of loss-making cereal farms increased to between 45 percent (WTO+) and 55 percent (UTL-) based on FBI. On a Cash Income basis, the worst scenario (UTL-) resulted in 25 percent of cereal farms losing money compared to 5 percent loss-making (in Cash Income terms) under the Baseline.

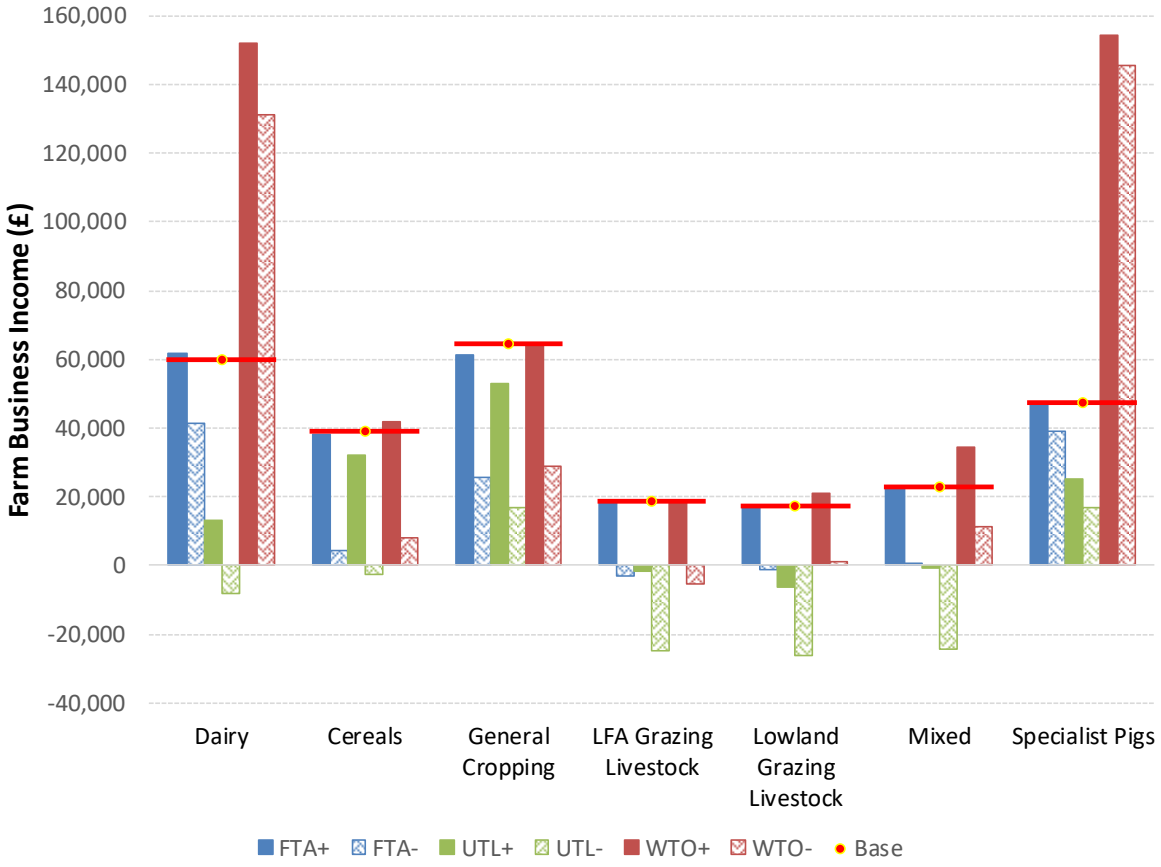
Figure 6.11 displays the simulated income distribution curves for grazing livestock farms. The FTA+ and WTO+ scenarios resulted in income distribution curves that were almost identical to the Baseline. Under these scenarios, approximately 16 percent and 5 percent of grazing livestock farms were loss-making according to the FBI and Cash Income definitions, respectively.

FTA-, WTO- and UTL+ each resulted in similar income distribution curves and the proportion loss-making businesses increased to around 60 percent according to FBI and 30-35% based on Cash Income. The most challenging scenario for grazing livestock farms was UTL- where the proportion of loss-making farms increased to 90 percent and 60 percent according to FBI and Cash Income measures, respectively. With reference to the population size this would equate to between 22,300 and 33,500 grazing livestock farm businesses that could become financially unviable under UTL-.

The simulated income distribution curves for specialist pig farms are shown in Figure 6.12. Pig farm businesses appeared less adversely impacted by the Brexit scenarios compared to other farm types. This was highlighted by the narrower spread between the income distribution curves. However, the WTO scenario was a notable extreme that produced substantially elevated income especially for larger businesses at the top of the distribution. This result reflected the strong projected increase in pig meat prices with very modest projected increases in feed prices. Given the remarkable increase in profitability, reflecting the sensitivity of pig margins to the ratio of pig meat prices to feed prices, the WTO estimates should be treated with caution. It is unlikely that such high margins could be sustained in the longer term as a likely supply response would be expected to return margins to more 'normal' levels. A similar logic also applies when interpreting the extreme increase in profitability of dairy farms observed under the WTO scenarios.

Figure 6.8. Average Farm Income Estimates by Scenario and Farm Type

(a) Farm Business Income



(b) Cash Income

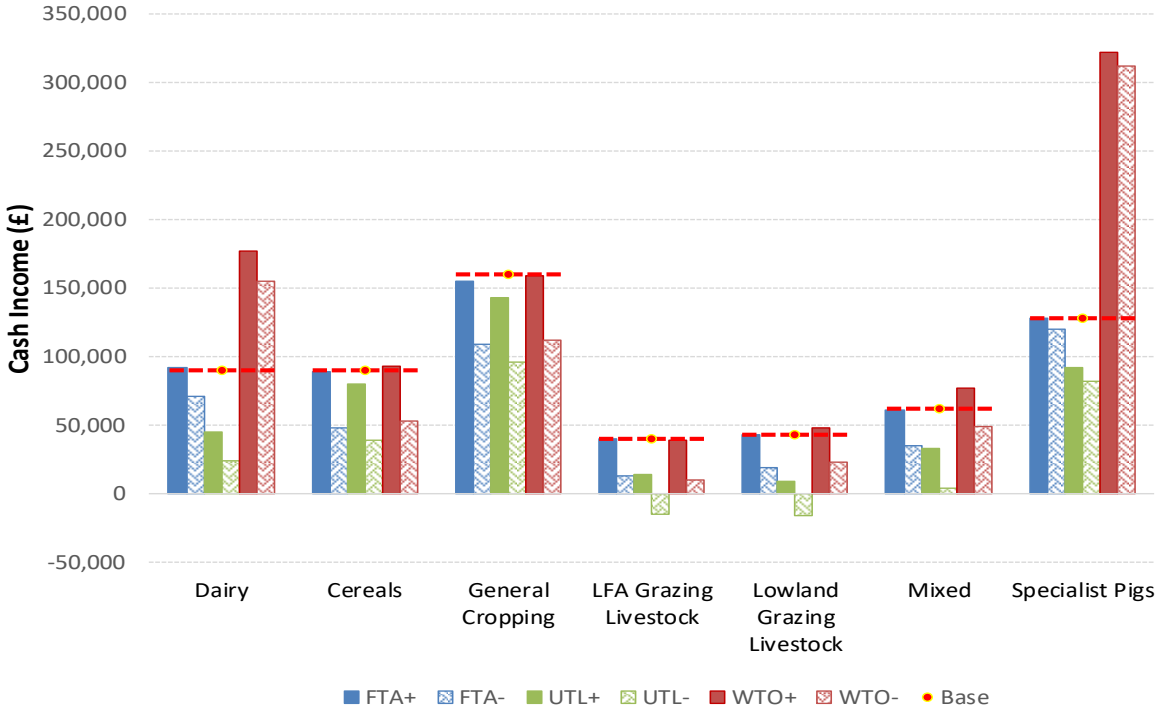
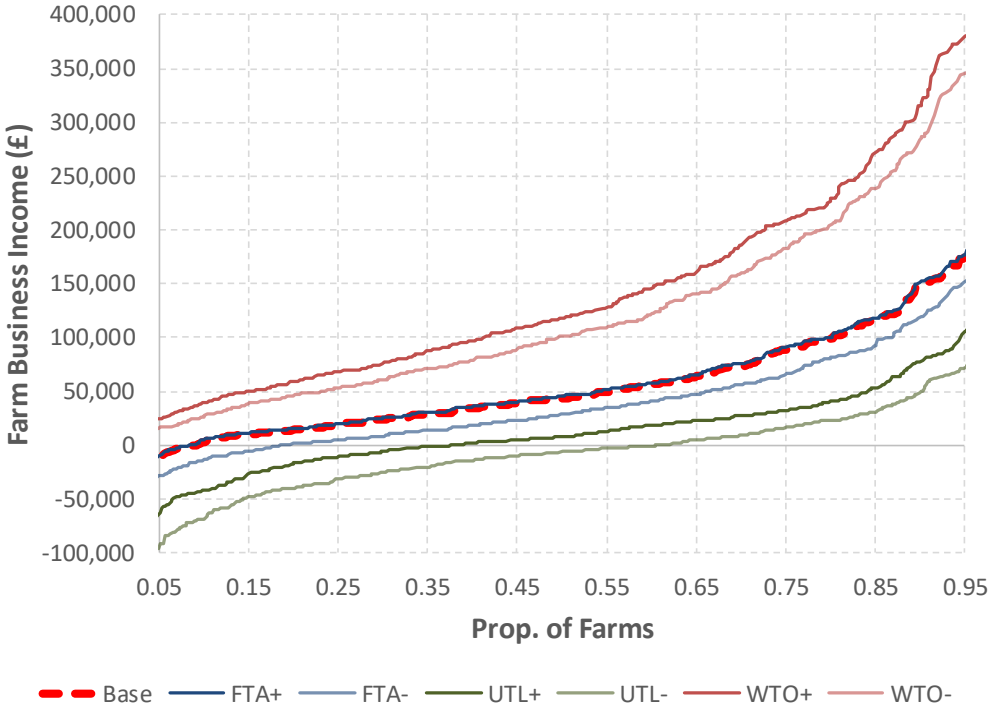


Figure 6.9. Estimated Farm Income Distribution by Scenario (Dairy Farms, N=9,894)

(a) Farm Business Income



(b) Cash Income

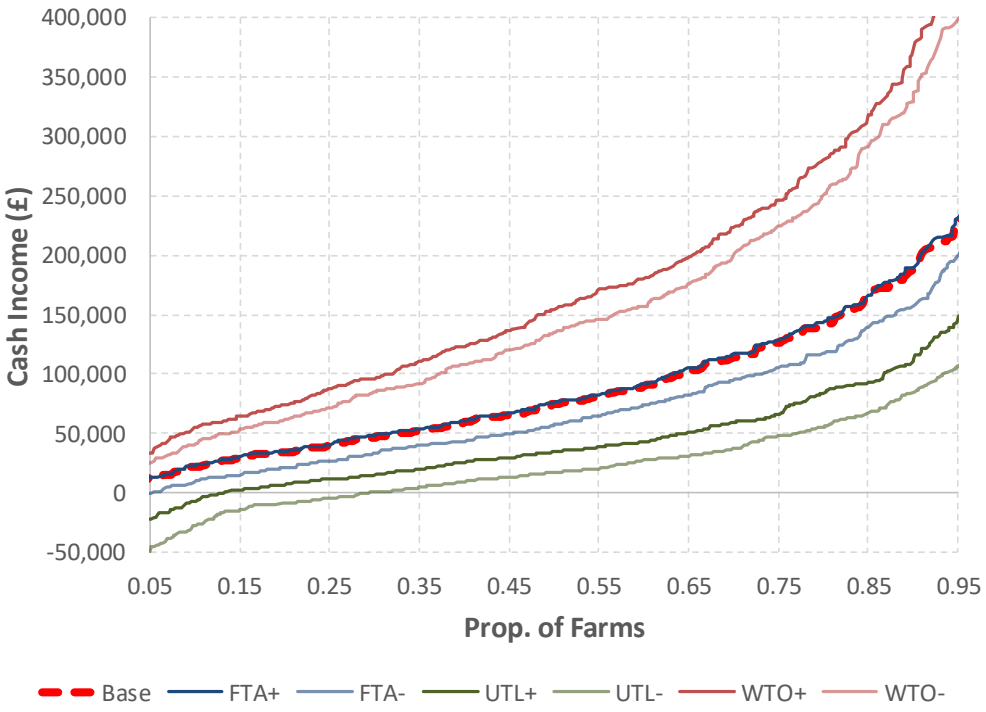
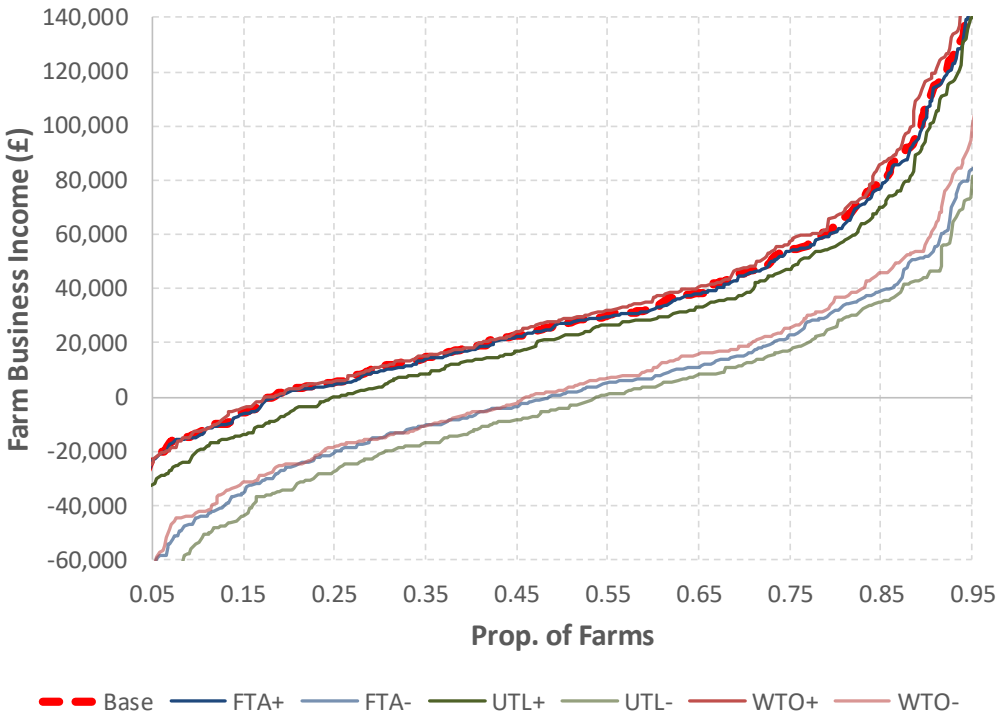


Figure 6.10. Estimated Farm Income Distribution by Scenario (Cereals, N=11,716)

(a) Farm Business Income



(b) Cash Income

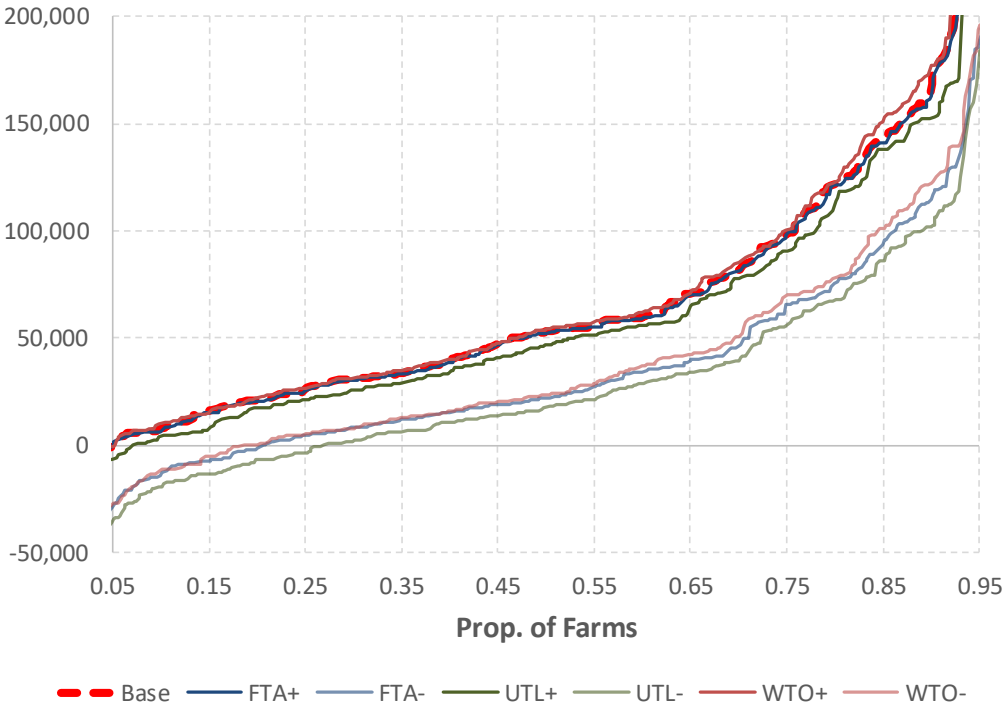
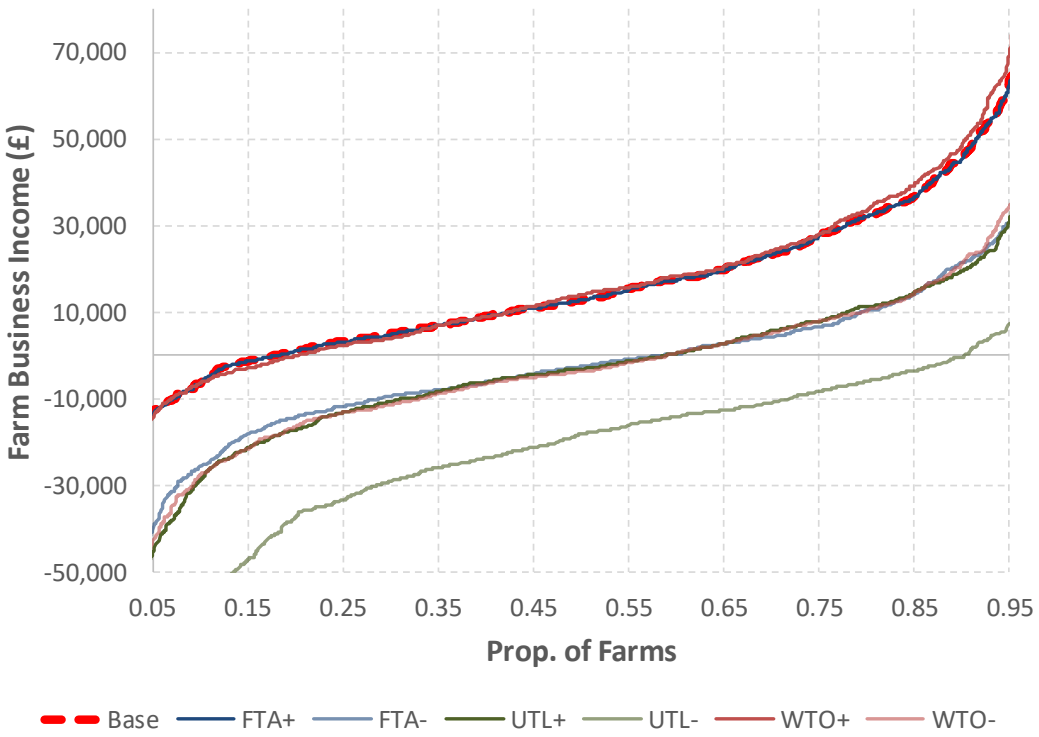


Figure 6.11. Estimated Farm Income Distribution by Scenario (Grazing Livestock, N=37,179)

(a) Farm Business Income



(b) Cash Income

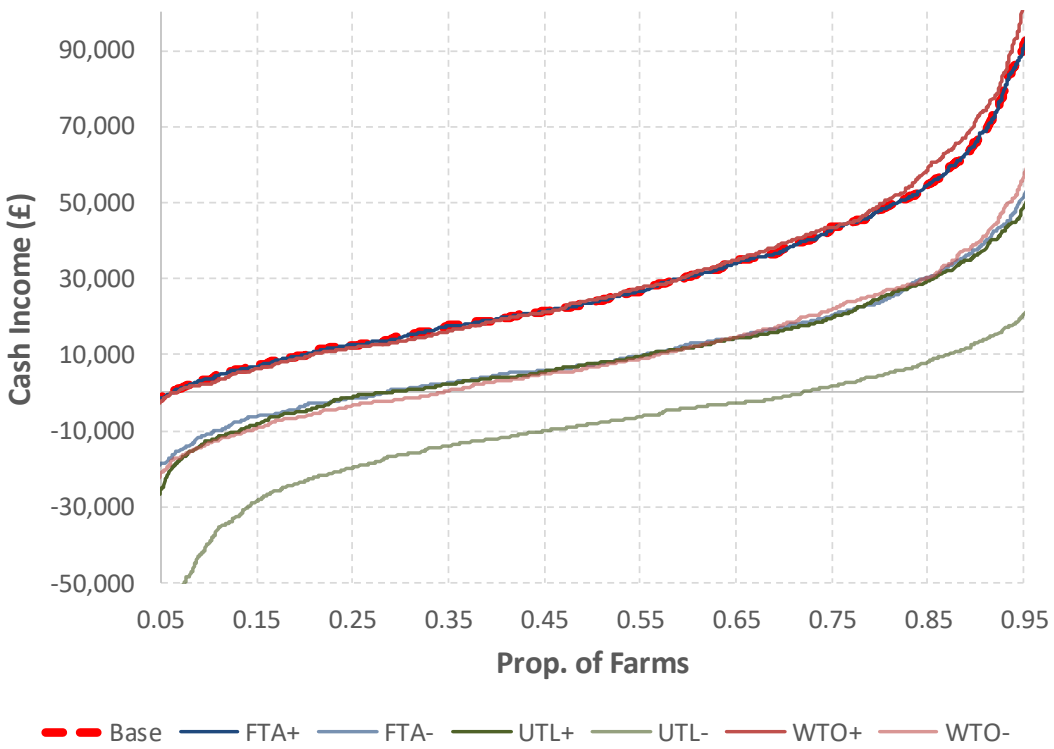
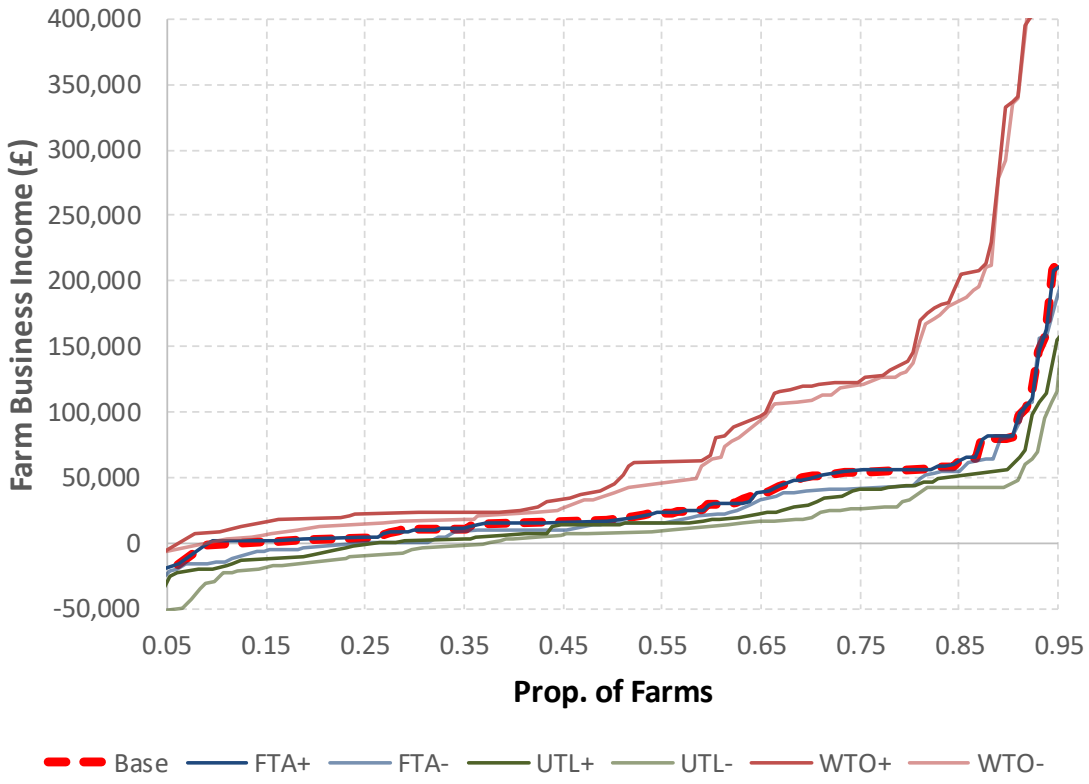
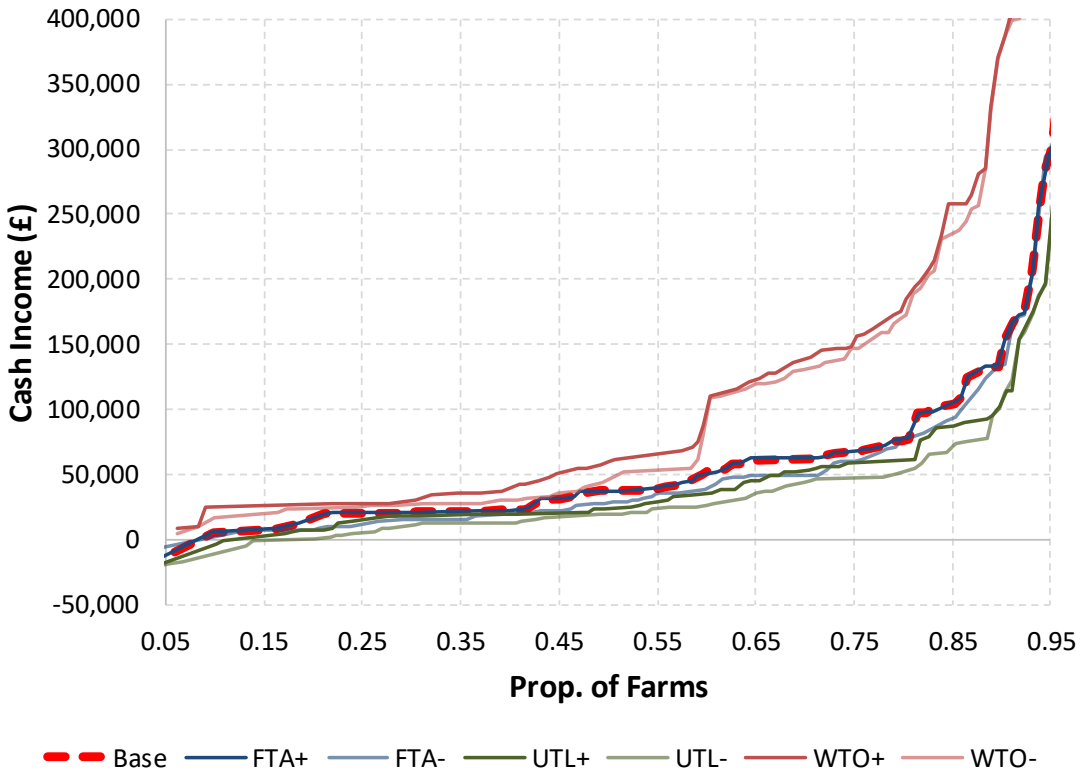


Figure 6.12. Estimated Farm Income Distribution by Scenario (Specialist Pigs, N=1,331)

(a) Farm Business Income



(b) Cash Income



6.3.3. Analysis of impact quintiles

To evaluate attributes of farms likely to be most vulnerable to Brexit scenarios, businesses were grouped into quintiles according to projected percentage changes in Farm Business Income relative to the Baseline. Under this classification quintile 1 comprised the fifth of farms that suffered the largest declines in FBI under a given Brexit scenario. Similarly, quintile 5 comprised the fifth of farms that were least exposed to the scenario. In the following, we focus particularly on UTL- as this scenario resulted in the largest impacts on FBI. Figure 6.13 shows the farm type composition of the worst impacted quintile under UTL- and highlights the vulnerability of LFA and lowland grazing livestock farms. In total grazing livestock farms accounted for two-thirds of farms in the worst impacted quintile.

Figure 6.13. Farm type composition of most adversely impacted quintile for UTL-

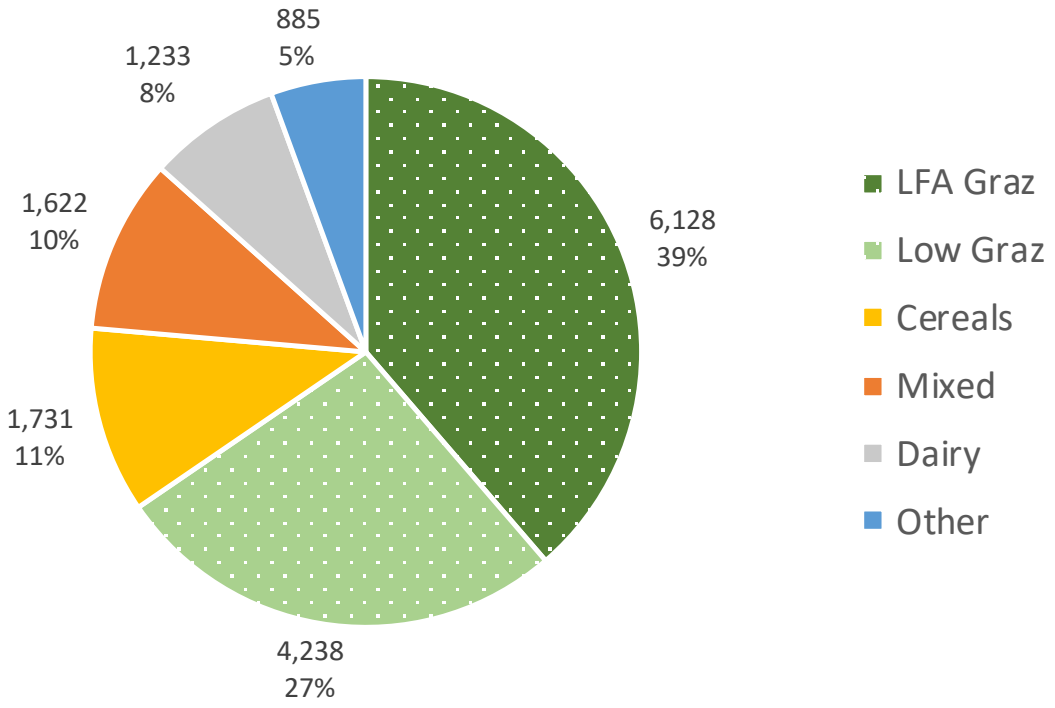


Figure 6.14 highlights the extent to which individual farm types may be over-represented in the worst impacted quintile. This was calculated as the share of a given farm type observed in the quintile relative to the share of that same farm type in the population, i.e.

$$R = \frac{\text{\% of Farm Type } i \text{ in Quintile}}{\text{\% of Farm Type } i \text{ in Population}} - 100$$

Where:

$R > 0$ Farm Type *i* is over-represented in the quintile relative to population share

$R < 0$ Farm Type *i* is under-represented in the quintile relative to its population share

Figure 6.14 highlights the extent to which Grazing livestock farms were over-represented in the worst impacted quintile under all scenarios except FTA+. Dairy and Pig farm types were less likely to be observed in the bottom quintile for all scenarios.

Figure 6.14. Over/under-representation of farm types in worst impacted quintile by scenario

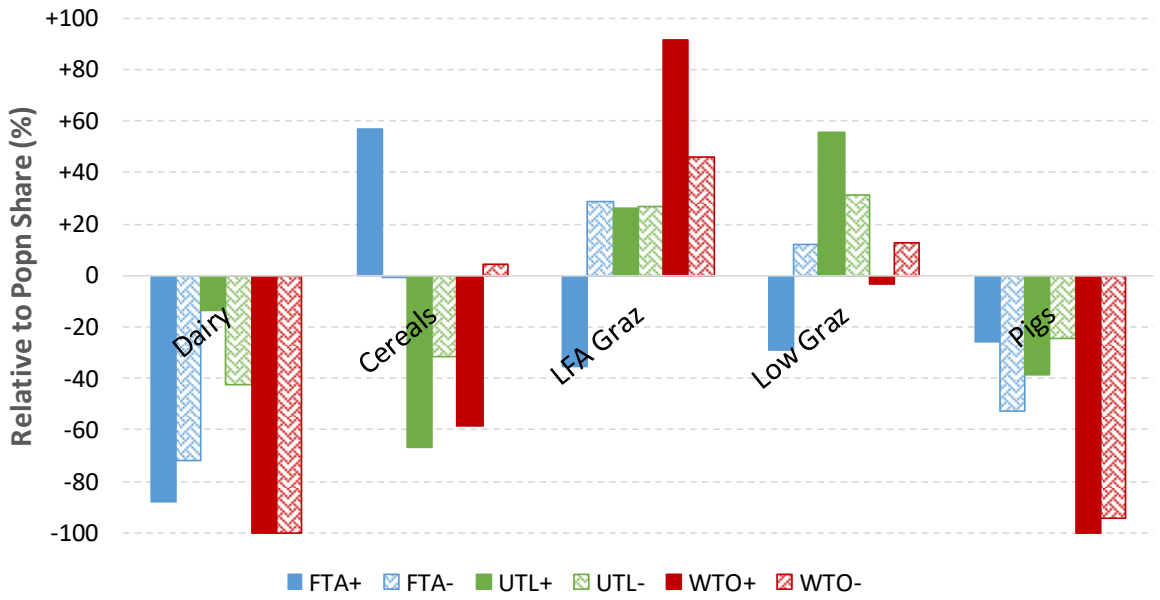


Table 6.3 provides a more detailed summary of characteristics of farm businesses in each quintile under UTL- as well as for the total population. This highlighted the already noted concentration of beef and sheep farms in quintile 1, while quintile 5 (least impacted) tended to be characterised by cropping, pigs, poultry and horticulture. The results also identified a greater concentration of English farms in the least impacted quintile while Scottish farm were more heavily represented in the worst impacted quintile.

Least affected farms, on average, tended to be much larger in scale with a mean size of 4 SLR compared to 2.4 SLR for the worst impacted quintile. LFA farms tended to be more strongly represented in the worst impacted quintile and conversely lowland farms tended to predominate the least impacted quintile. This reflected the farm-type effects already described with Grazing Livestock being the predominant enterprise in LFAs.

There was little variation in the proportion of rented land across the quintiles and likewise average age of farmers was very similar across the quintiles. Farms in the least impacted quintile tended to have a higher proportion of hired labour (relative to family labour) which reflected their larger average business size. The financial variables showed that farms in the worst impacted quintile tended to have lower financial performance in the Baseline with much lower average performance ratio, FBI and Cash income. Importantly, they tended to have substantially lower levels of diversification relative to farms in the least affected quintile.

Table 6.3. Descriptive statistics (means) for impact-quintiles under UTL-

	Quintile (1 = worst impacted, 5= least impacted)					
	1	**2**	**3**	**4**	**5**	**All**
N =	*15,837*	*15,421*	*14,504*	*14,961*	*12,485*	*73,208*
Farm Type (prop. of N)						
Dairy	0.08	0.08	0.16	0.22	0.15	0.14
LFA Grazing	0.39	0.37	0.41	0.26	0.05	0.30
Lowland Grazing	0.27	0.31	0.20	0.16	0.05	0.20
Cereals	0.11	0.10	0.13	0.20	0.28	0.16
General Cropping	0.04	0.02	0.04	0.07	0.11	0.05
Mixed	0.10	0.09	0.06	0.07	0.04	0.07
Pigs	0.01	0.00	0.00	0.02	0.06	0.02
Poultry	0.00	0.00	0.00	0.00	0.07	0.01
Horticulture	0.00	0.01	0.00	0.01	0.19	0.04
Nation (prop. of N)						
England	0.52	0.53	0.49	0.66	0.86	0.60
Wales	0.10	0.14	0.14	0.12	0.07	0.12
Scotland	0.22	0.21	0.19	0.09	0.03	0.15
Northern Ireland	0.16	0.13	0.19	0.12	0.05	0.13
Farm size						
SLR (labour units)	2.37	2.57	2.55	2.80	4.01	2.82
Land						
LFA (prop.)	0.44	0.42	0.49	0.36	0.12	0.37
SDA (prop.)	0.30	0.29	0.34	0.24	0.07	0.25
Utilised Agricultural Area (ha)	138.96	159.73	169.93	165.27	130.97	153.49
Adj Area Farmed (Ha)	122.03	140.17	153.50	141.58	108.95	133.85
Rented land (prop of UAA)	0.33	0.31	0.30	0.28	0.30	0.31
Demographic						
Farmer Age (yrs)	59	59	60	59	58	59
Family Labour (hrs/annum)	2,969	2,981	3,251	3,124	3,288	3,114
Hired labour (hrs/annum)	1,413	1,432	1,075	1,674	4,276	1,892
Financial						
Performance Ratio (%)	102	112	123	133	138	121
Diversification Revenue (£)	9,659	12,733	11,239	17,644	39,559	17,351
Pillar1 DPs (£)	24,427	26,945	25,855	26,177	22,505	25,270
Pillar2 DPs (£)	6,550	8,083	7,762	8,524	5,649	7,363
Farm Business Income (£)	3,072	14,490	26,270	46,114	85,765	32,972
Cash Income (£)	25,464	36,778	46,296	70,414	119,198	57,146
External Liabilities £ '000	131	142	100	138	186	138

6.3.4. Regression analysis of scenario impacts

To decompose the estimated impacts a series of regression equations were estimated for the projected change in FBI under each scenario. Specifically, the following regression model was estimated for each scenario (*s*):

$$\Delta FBI_{si} = f(Age_i, Crop_{ij}, Lstock_{ij}, Loc_{ij}, LandR_i, Debt_i, Hlab_i, DP_{ij}, Divers_i, PerfR_i, LFA_i)$$

Where

ΔFBI_{si} is change (£) in Farm Business Income (cf. Baseline) of farm *i* under scenario *s*

Age_i age of operator of farm *i*

$Crop_{ij}$ areas (ha) of crops of type *j* (*j* = cereals, oilseeds+pulses, other crop)

$Lstock_{ij}$ numbers of livestock of types *j* (*j* = dairy cows, beef cows, other cattle, ewes, sows, hens broilers, other poultry)

Loc_{ij} indicator variables for location of farm *i* in nation *j* (*j* = Scotland, Wales, NI) with base category: England

$LandR_i$ area rented by farm *i* in hectares

$Debt_i$ external liabilities of farm *i* in £'000

$Hlab_i$ hired labour hours of farm i

DP_{ij} direct payments (£) of type *j* (*j*= Pillar 1, Pillar 2)

$Divers_i$ diversification revenue per annum (£)

$PerfR_i$ performance ratio (i.e.output (£)/Input (£)) of farm *i* (%)

LFA_i indicator variable which takes value 1 if farm *i* is in LFA, zero otherwise.

The regression estimates are provided in Table 6.4 with each equation explaining around 90% or more of the variation in projected scenario impacts across farms. The regression coefficients for the livestock and crop variables show the estimated changes in margin per head or per hectare under each scenario. For example, under UTL- the margin for cereals declined on average by £29 per hectare while suckler beef, sheep and dairy margins per head were reduced by £214, £10, and £193, respectively.

Impacts on enterprise margins were very modest under FTA while WTO substantially increased most enterprise margins. The main exception under WTO was sheep where margins were reduced by between £17/ewe (WTO-) and c. £20/ewe (WTO+). This result reflected the potential impact of tariffs on UK sheep exports to the EU under that scenario.

Farmer age was significant in some scenarios with older farmers tending to be less impacted under UTL and WTO but the opposite was true under FTA-.

The location dummy variables indicated the presence of country-specific factors that further conditioned scenario impacts after controlling for other variables that explain FBI. For example, relative to England, Scotland was more severely impacted under UTL by an average of £5,400 per farm even after controlling for other factors in the equation for ΔFBI. However, the opposite was true for Scotland under WTO+ and this suggested that the country-specific effect related to Scotland's particular exposure to the beef sector.

Performance ratio was significant only under three scenarios and surprisingly the sign on the coefficient was negative. This would suggest that higher performing farms were more adversely impacted after controlling for other factors that affected ΔFBI. However, the magnitude of the estimated coefficient suggested that this effect was relatively small.

Levels of Pillar 2 and Diversification revenues tended to moderate the negative impacts of the scenarios but to a very limited extent. For example, under UTL each £1.00 of Pillar 2 support only moderated the impact of the scenario by about £0.07 after controlling for other factors related to ΔFBI.

A farm's presence in a Less Favoured Area (LFA) was not significant after controlling for other variables in the farm income equation. Farms with hired labour were more adversely impacted under FTA and UTL by between £0.35 and £0.40 per hour employed.

Table 6.4. OLS regression estimates for scenario impacts on Farm Business Income

	FTA+	FTA-	UTL+	UTL-	WTO+	WTO-
Age (yrs)	0.9 (0.983)	-11.165 (4.297)***	38.25 (16.392)**	30.613 (16.930)*	49.571 (27.290)*	41.832 (28.313)
Cereals (ha)	-4.042 (0.872)***	20.76 (4.191)***	-44.847 (12.359)***	-27.169 (13.480)**	-1.459 (12.355)	19.663 (13.276)
Oilseed+Pulses (Ha)	-0.607 (2.177)	28.12 (11.083)**	44.203 (32.568)	71.04 (37.308)*	50.499 (36.842)	86.127 (39.208)**
Other Crop (ha)	-10.275 (2.748)***	29.733 (7.435)***	-12.426 (14.265)	25.672 (17.092)	-11.86 (26.608)	27.742 (28.572)
Dairy Cows (hd)	19.518 (0.588)***	33.401 (1.666)***	-206.017 (7.611)***	-193.299 (7.620)***	624.547 (14.055)***	639.183 (14.413)***
Beef Cows (hd)	2.892 (0.575)***	16.667 (2.843)***	-219.516 (17.248)***	-213.657 (17.387)***	59.971 (13.472)***	65.832 (14.415)***
Other Cattle (LU)	4.946 (0.494)***	23.18 (2.161)***	-339.324 (16.460)***	-331.602 (16.918)***	126.528 (11.085)***	134.356 (11.144)***
Ewes (hd)	-0.535 (0.090)***	5.617 (0.766)***	-13.292 (1.189)***	-10.281 (1.794)***	-19.779 (1.082)***	-17.018 (1.081)***
Sows (hd)	6.315 (0.429)***	14.166 (1.796)***	-66.331 (4.227)***	-60.267 (3.439)***	456.99 (27.308)***	461.893 (28.107)***
Pigs (hd)	0.202 (0.103)*	0.58 (0.181)***	-2.441 (0.673)***	-2.153 (0.657)***	15.397 (5.278)***	15.67 (5.297)***
Hens (no.)	-0.036 (0.016)**	-0.027 (0.036)	-0.596 (0.326)*	-0.607 (0.351)*	2.992 (1.447)**	2.971 (1.422)**
Broilers (no.)	0.018 (0.002)***	0.033 (0.007)***	-0.242 (0.018)***	-0.236 (0.023)***	1.462 (0.099)***	1.463 (0.096)***
Other Poultry (no.)	-0.004 (0.002)	0.18 (0.077)**	-0.135 (0.041)***	0.041 (0.045)	0.891 (0.298)***	1.058 (0.368)***
Scotland (D)	121.878 (47.816)**	-755.881 (160.869)***	-4,570.46 (754.015)***	-5,443.42 (776.092)***	1,467.49 (736.742)**	545.194 (752.594)
NI (D)	-221.699 (60.247)***	-71.775 (121.924)	947.169 (452.580)**	1,133.34 (478.588)**	-1,243.51 (587.925)**	-1,068.29 (595.468)*
Wales (D)	-53.684 (42.431)	-623.198 (168.063)***	3,278.81 (536.531)***	2,948.09 (566.440)***	-898.131 (678.263)	-1,225.21 (694.757)*
PerfRatiox100	1.817 (0.403)***	-4.267 (1.443)***	-5.561 (5.784)	-12.191 (5.952)**	-6.621 (13.616)	-12.563 (13.788)
Rented Land (Ha)	-0.157 (0.103)	3.002 (1.346)**	1.626 (1.013)	4.94 (2.072)**	0.705 (0.939)	3.926 (1.816)**
Debt ('000)	0.215 (0.132)	-1.163 (0.516)**	0.061 (1.066)	-1.249 (1.194)	0.057 (2.549)	-1.299 (2.654)
Pillar1 DP (£)	-0.004 (0.002)*	-1.017 (0.011)***	-0.051 (0.032)	-1.067 (0.032)***	0.015 (0.043)	-1 (0.045)***
Pillar 2 DP (£)	0.001 (0.002)	-0.014 (0.012)	0.073 (0.024)***	0.069 (0.027)***	0.048 (0.030)	0.043 (0.034)
Diversification Rev (£)	-0.003 (0.001)***	0.002 (0.003)	0.007 (0.005)	0.012 (0.005)**	0.001 (0.011)	0.006 (0.013)
Hired Labour (hrs)	-0.412 (0.016)***	-0.364 (0.014)***	-0.4 (0.045)***	-0.35 (0.040)***	-0.184 (0.145)	-0.147 (0.148)
LFA (D)	3.921 (42.434)	55.544 (118.886)	-277.664 (419.185)	-262 (452.207)	608.012 (486.548)	666.551 (493.978)
Constant	-125.228 (88.216)	1,148.68 (375.642)***	-362.803 (1,353.958)	745.878 (1,378.507)	-3,772.26 (2,504.351)	-2,772.18 (2,581.858)
Observations	2,795	2,795	2,795	2,795	2,795	2,795
R-squared	0.97	0.99	0.893	0.953	0.928	0.931

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6.3.5. Sensitivity analysis of mitigating factors

We used the budgetary simulation model to evaluate the sensitivity of estimated scenario impacts to variation in the value of the Pound, land rental costs, hired labour costs and farm productivity. For brevity, we focus on the UTL- and WTO- scenarios. Figure 6.15 shows simulated mean FBI for UK commercial farms (N=73,208) under the 'original' projections (Table 6.2) versus estimates under alternative assumptions about Sterling, land rental costs and labour supply. Each sensitivity scenario was tested independently with reference to the 'original' or central set of projections from the sectoral models (Table 6.2).

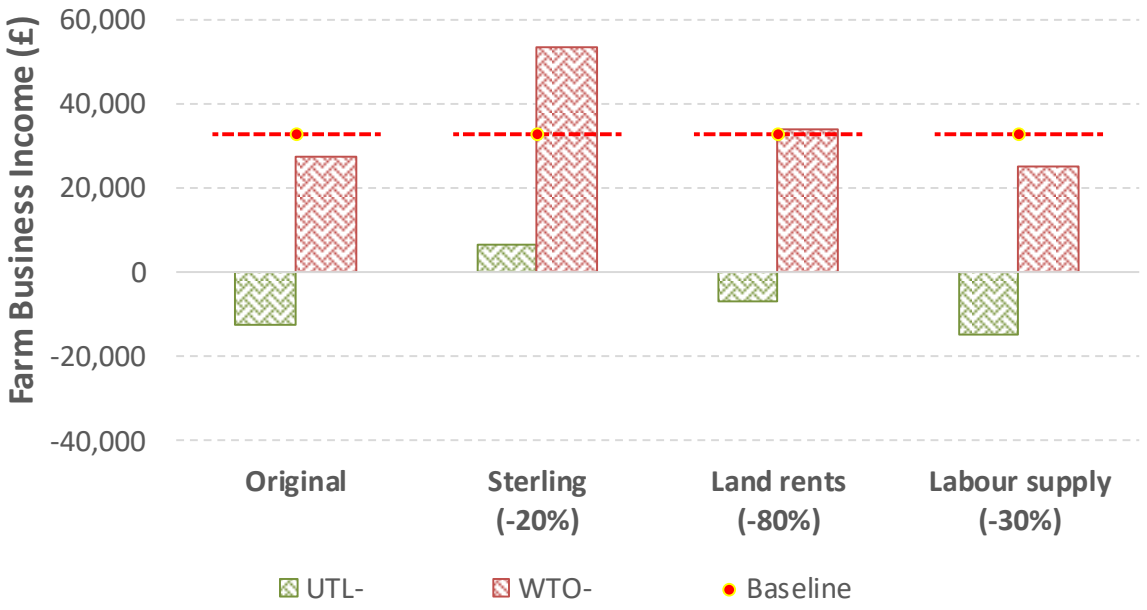
The first sensitivity test comprised FAPRI price projections for a 20 percent devaluation of Sterling in 2026. These projections have been documented in sub Chapter 3.7.2. Compared to our 'original' projections, a 20 percent Sterling devaluation was shown to substantially moderate the projected price reductions or elevate projected price increases. For example, beef price changes under UTL- and WTO- were -31% and +38% with Sterling devaluation compared to -42% and +18% under the 'original' projections for these scenarios, respectively.

Compared to the default projection under UTL- the devaluation increased FBI by almost £19,000 and mean FBI went from a loss of almost £12,500 to a small profit of £6,500. However, despite this improvement average FBI remained substantially below its Baseline level. In the case of WTO-, the devaluation increased average FBI by almost £26,000 compared to the 'original' projection. Average FBI for UK commercial farm businesses increased to a level where they now exceeded the Baseline by £20,300, as higher output prices more than compensated for the assumed removal of Pillar 1 payments. Consequently, the future value of the Pound was shown to be a critical factor influencing potential scenario effects.

Brexit trade scenarios and envisaged reductions in Pillar 1 direct payments may have sizeable impacts on the UK land market. Accordingly, the second sensitivity scenario tested an 80 percent reduction in land rents. This compared to 'original' projections of 19% and 11% reductions in land rents under UTL- and WTO-, respectively. An 80 percent reduction in land rents increased FBI by an average of £6,600 after accounting for loss of income by some farm businesses that were letting land. This equated to a 24% increase in FBI under WTO- relative to the 'original' projection. Combined with the projected price increases under WTO- the reduction in land rents was sufficient to restore average FBI to Baseline level despite removal of Pillar 1 payments. However, for UTL- while the reduction in land rents almost halved the average farm loss under that scenario, overall FBI remained very substantially below Baseline level. The relatively modest impact on mean FBI, from a substantial reduction in rents reflected the fact that only one third of farmed area in the UK is rented. However, this situation varies across farms and regions. Clearly, tenanted farms or those with a higher shares of rented land experience proportionately greater increases in FBI when rents are reduced.

It is anticipated that Brexit may reduce the supply of migrant labour for farm businesses. The 'original' projections were based on a 10% reduction in labour supply which resulted in an increase in wage rates of c.5% (see Table 6.2). The third sensitivity scenario assumed a 30% reduction in labour supply which were projected (CGE model) to increase wage rates by approximately 18 percent. This scenario reduced average FBI per farm by approximately £2,500 relative to the 'original' projection. Obviously, the effect on FBI varies across farms with larger businesses and labour-intensive sectors (e.g. horticulture) being relatively more exposed to wage impacts.

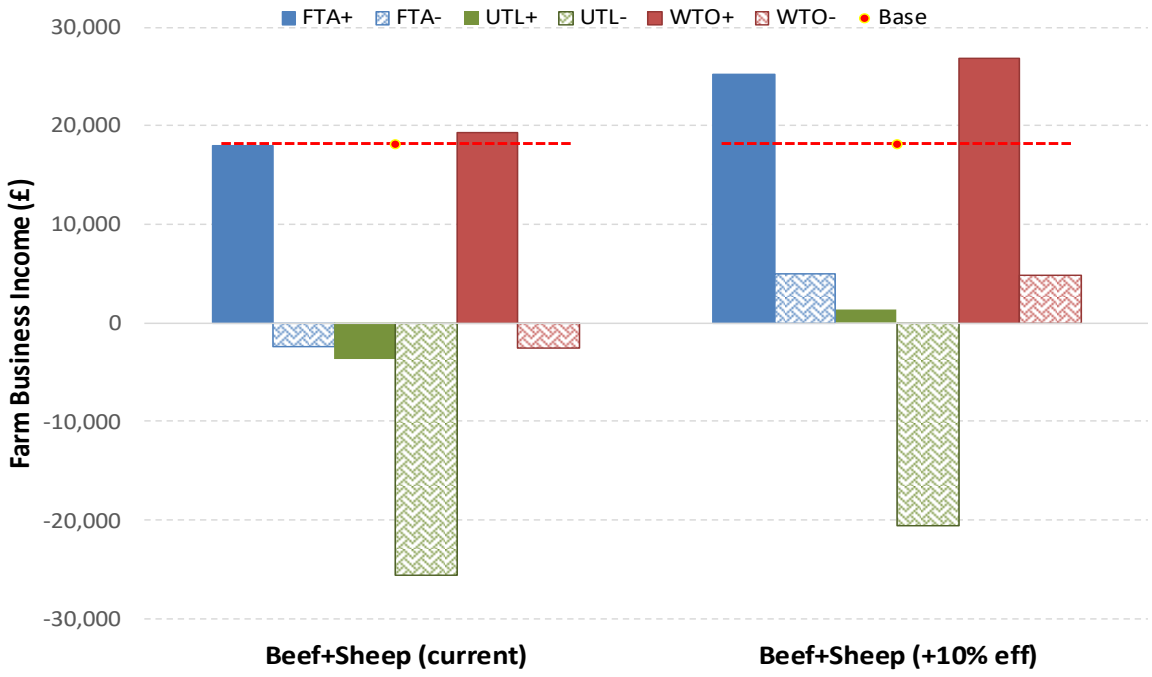
Figure 6.15. Sensitivity analysis of Sterling devaluation, land rent and labour supply, UTL- and WTO-



The financial impacts of Brexit scenarios, especially where support payments are reduced, may be mitigated by farm management responses including a renewed focus on productivity and efficiency. In Figure 6.16, we present estimates of the effect of a 10% increase in productivity of all grazing livestock farms.

Increasing productivity by 10% across beef and sheep enterprises raised FBI by c.£7,300, c.£5,100 and c.£7,500 under FTA, UTL and WTO, respectively. However, this sizeable improvement in productivity of grazing livestock farms would not be sufficient to offset the impacts of reductions in Pillar 1 payments nor the projected price reductions under UTL. Consequently, for grazing livestock farms, productivity improvement seems unlikely be a 'silver bullet' solution to the adverse financial impacts of reduced support payments.

Figure 6.16. Impact of a 10% improvement in productivity of Grazing Livestock farms, all scenarios



6. Conclusion

Our farm modelling shows some interesting results regarding the distribution of farm business income across the devolved administrations and by farm type and the importance of retaining and eliminating direct payments. As with other EU member states, direct payments are a crucial component of farm business income in the UK. Thus, while some farm businesses will survive, many might not. The negative impact on farm business income is reflected across all trade scenarios, especially UTL *with or without* direct payments (DPs). Average farm income varies significantly across the devolved administrations and by farm type, with most farms worse off (relative to the Baseline) under all scenarios but one, *WTO+*.

Noticeably, under this scenario dairy farms will particularly benefit as their average farm income could almost triple as compared to the Baseline scenario. Beef and sheep farms will be the most affected under *UTL-*. Indeed, our extreme free trade scenario leads to some striking results regarding farm income distribution. Whereas 15-20 percent of the farms were not making any money at all (even in the Baseline scenario), this rises to 45 percent under the UTL scenario with direct payments still in place (*UTL+*). The elimination of direct payments further increases this figure to 70 percent (*UTL-*).

As expected, UTL combined with the elimination of direct payments (*UTL-*) was identified to be the most challenging for farm businesses. The proportion of loss-making businesses under this specific scenario ranged from 62 percent (England) to 90 percent (Scotland). Our regression results also show farms in Scotland as the most severely affected under UTL scenario.

7. Exploring the effects of Brexit scenarios on the welfare of farm households[30]

7.1. A brief introduction to viability analysis

The measurement of farm economic viability provides more comprehensive investigation of welfare impacts on farm households. This viability assessment provides further insights into the economic assessment of vulnerable and sustainable farms. Farms are deemed to be economically sustainable if the farm business is not viable but either the farmer or spouse earns off-farm income while farms are economically vulnerable if the farm business is not viable and neither the farmer nor spouse has an off-farm employment.

The specific objectives of this second component of Phase 4 are:

1) To explore the impact of Brexit scenarios on viability, sustainability and vulnerability (hereafter Via-Sus-Vul) levels by major UK farm enterprises.
2) To assess how the major UK farm types are impacted by Brexit scenarios and their Via-Sus-Vul levels.
3) To investigate the impact of Brexit scenarios on farmers demographic characteristics and consequently on their Via-Sus-Vul levels.

To address these objectives, a farm household viability model was employed to estimate the potential effects of post-Brexit trade and domestic policy scenarios on the economic viability of farm households both at regional and national level.

7.2. Farm household data

As described in Chapter 6, the Farm Business Survey (FBS) data is recognised as the most detailed source of financial and physical performance of UK farming businesses. Three years data sample from 2013/14 to 2015/16 were obtained and averaged in order to control for inter-year variability. The sample was weighted to provide statistically representative data for a population of over 100,000 commercial farm businesses. These businesses represent around 47 percent of UK holdings in 2015/16 but they account for more than 90 percent of total agricultural output. To compare data across UK countries, we restricted the sample to commercial farm businesses with output of at least 0.5 Standard Labour Requirement and at least €25,000 per annum. The resulting dataset of 2,718 commercial farming businesses forms the primary sample used for the Via-Sus-Vul simulation models. This sample was weighted (using FBS sampling weights) to be statistically representative of 73,200 commercial farming businesses across all main farm enterprise types in the UK.

While the FBS provides comprehensive data on farm business characteristics (including on-farm diversification) and financial performance, its coverage regarding the incidence of off-farm income is more limited especially in England. Using the available data, estimation of the impact of Brexit policy scenarios on the welfare of farm households by employing a classificatory analysis coupled with viability criteria threshold. To allow for a comprehensive assessment of the demographic characteristics of farm

[30] This chapter was extensively written by Mercy Ojo.

households, farmers were grouped according to the following age categories: Very Young (<35 years), Young (35-44 years), Middle aged (45-54 years), Old (55-64 years), Very Old (>65 years). Due to small sample sizes, the very young farmers were excluded from the analysis. The FBS sample for each farm type and their corresponding demographic classifications are shown in Annex 7.1.

7. 3. Farm viability model

For each observed farm, farm household analysis was run under each of the six Brexit scenarios with the Baseline Scenario as the comparator. The major two components used in the farm household income include, Farm Business Income (FBI) and off-farm income. Total non-farming income as a variable used in the analysis aggregates self-employment, investments, pensions, social payments and other income.

The combination of both Farm Business Income and off-farm income determines the extent to which household income is adequate to generate a basic standard of living, hence the major focus of the household income analysis. A threshold minimum wage is used as a measure below which farm households are regarded as non-viable. This is based on the National Living Wage for 2018/19. It also follows the UK government criterion for the eligibility for Universal Credit, which aims to support living costs for people who have low income or are out of work[31].

Thus, a farm business is deemed to be economically viable if the farm business income is sufficient to remunerate family labour at the UK minimum agricultural wage (for persons aged 25 years and older) and provide 5 percent return on capital invested in non-land assets (e.g. machinery and livestock) (Table 7.1).

Farms that are not economically viable but have an off-farm income, earned by either the farmer or the spouse, are considered economically sustainable. Farm households that are operating non-viable farm businesses and neither the farmer nor the spouse has an off-farm income are considered economically vulnerable. Vulnerable farms are in precarious economic position as the farm business is not producing enough profit to sustain itself and there is no other form of income in the household. In this context, Via-Sus-Vul concepts are summarised in Table 7.1 as follows.

Table 7.1. Defining Via-Sus-Vul classifications[32]

[31] It is paid monthly (or twice per month for some people in Scotland) and it replaces the following benefits: child tax credit, housing benefit, income support, income-based jobseeker's allowance, income-related employment and support allowance, Working tax credit. The maximum standard allowance for Universal Credit for a couple aged over 25 is £498.89 per month (approximately £6,000 per year) (https://www.gov.uk/universal-credit, last accessed 13 February 2019).

[32] Viability, Sustainability and Vulnerability indices decoded as Via-Sus-Vul indices

Concept	Definition
Viable	A farm business is viable if the farm income can remunerate family labour at the minimum agricultural wage[33] and provide a 5% return on the capital invested in non-land assets.
Sustainable	The farm business is not viable, but the household is still considered sustainable if the farmer or spouse has an off-farm income.
Vulnerable	A farm household is considered vulnerable if the farm business is not viable and neither the farmer nor spouse has an off-farm income.

Based on O'Donoghue *et al.,* (2016), farm businesses are considered viable if they meet the following condition:

$$\frac{Farm\ Business\ Income - Cost\ of\ tenants\ Capital}{Hours\ worked\ on\ farm} > Threshold\ wage$$

As seen in the above model, Cost of tenant's capital is defined as a fixed percentage (5 percent return) on all non-land assets. It reflects the farmer's ability to cover his/her cost of capital, enabling farmers to continue to invest in farm operations. Without this specific condition, farming can be interpreted as a 'way of life' rather than a money-making activity. As inspired by O'Donoghue *et al.*, 2016, the minimum UK agricultural wage of £7.83/hour is employed as a threshold wage thereby serving as a reference income to the income earned by the farmer. Thus, farms having a relatively modest income can be viable if they have a small labour input and a low capital investment while farms with high income may be classified as being vulnerable if their labour input is high with a significant cost of capital.

To foster viability levels, a two-tier analysis is suggested which distinguishes between Via-Sus-Vul farms with the use of some cut off values as shown in Table 7.2. In a first step, the viability breakdown ensures that farms are classified as viable or not viable while in a second step, the non-viable category in the first step is classified as either sustainable or vulnerable depending on whether (or not) the farmer has an off-farm income. This means that loss making farms may be sustained by off-farm income, thereby classifying farms as economically sustainable where off-farm is present. In a case where this does not hold true, farms then belong to the vulnerability category.

The presence or absence of off-farm income is applied with a condition of £6,000, the annual maximum standard allowance/universal credit (2018/19) for a couple aged 25 years and above. Since many farms in the sample recorded rather small amounts of non-farm incomes (e.g. savings interest), it is therefore appropriate to apply a lower threshold as a filter. Hence, for each observed farm, if the off-farm income is less than £6,000/year, the farm is categorised as economically vulnerable.

[33] Minimum UK hourly wage rated at £7.83

In contrast, if off-farm income is greater than £6,000 then the farm would be categorised as economically sustainable, on the assumption that the presence of off-farm income contributes to the household's basic standard of living.

The overall, analysis covered the projection period 2017 to 2026, with Brexit scenarios beginning in 2019. However, for this analysis, we focus on the final year (2026) of the modelled horizon thereby evaluating the longer run impacts of the scenarios. Table 6.2 (Chapter 6) shows the projected price changes for each scenario according to farm populations in the UK which forms the basis of our economically Via-Sus-Vul assessments. Additionally, using a farm household viability model, the estimates of FBI income under each of these scenarios (averages are presented in Annexes 7.2 and 7.3) are employed to explore the impact of Brexit policy scenarios on the welfare of farm households.

Table 7.2. Two-tier Viability Analysis

Viability breakdown	Classification	
Viable	Definite	>=50% above threshold
	Moderate	< 50% above threshold
Non Viable	Definite	>50% below threshold
	Moderate	<=50% below threshold

Non Viability breakdown	Presence of off-farm income (>£6 000)	Status
>50% below threshold	Definite	Less Sustainable
	Moderate	More Vulnerable
<=50% below threshold	Definite	More Sustainable
	Moderate	Less Vulnerable

Following the methodology used for the assessment of our Via-Sus-Vul ratings, the next section summarises the results for farm household assessment under each scenario, by farm type, country and age classifications.

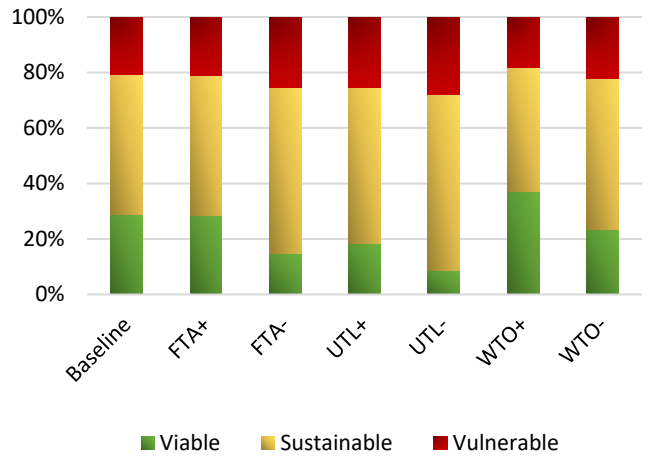
7.4. Results

This section focuses on the impacts of trade and domestic policy scenarios on the economic viability of farms. For each farm in the FBS sample, the Via-Sus-Vul rating is assessed under the different scenarios which encapsulates with or without direct payment. The viability of farms is categorised into two major groups depending on whether they are Definite (High Viability) or Moderate (Low Viability). This classification describes the impact of the scenario at individual farm level and this helps to consider whether the farms benefit or are negatively impacted by Brexit scenarios in terms of farm income which consequently affects farms viability. Farms are deemed to be viable based on the extent to which farm households can cover the costs incurred on the farm.

It is worthy to state that there is an alignment between the direction of impacts of scenarios and farm viability ratings. This connotes that viability ratings increase with an increase in price projection and decrease with price reduction. More so, scenarios with and without direct payments increases and reduces farm viability ratings respectively. Some farms generally benefit from Brexit scenario by improving viability ratings and for some farms the price projections will result in lower viability levels. For example, the FTA+ scenario has the least impact compared to the Baseline scenario while a lot of farms experience severe reductions under a more extreme scenario such as UTL- with some others having the highest viability ratings under WTO+. The outcome shows that differences largely occur between countries, farm types and demographic classification. Irrespective of the scenario, farm households with off-farm income may have greater resilience against farm income fluctuations (Mishra *et al.*, 2002, Hennessy and Moran, 2015). Accounting for off-farm income in farm-household welfare analysis is therefore pivotal in safeguarding the sustainability of the farm households. Some further brief descriptions of the Via-Sus-Vul results are presented in the graphs below.

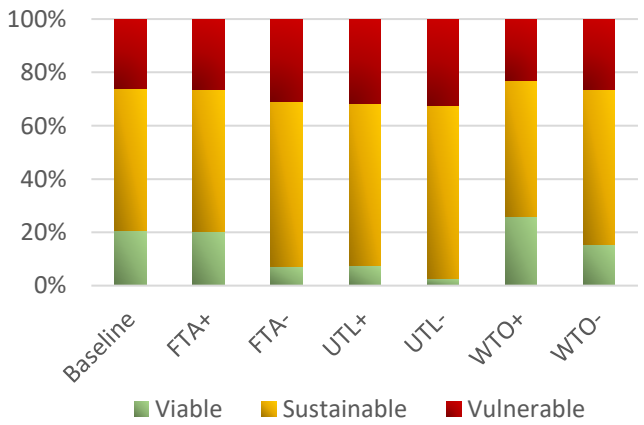
7.4.1. Viability assessment by Country and Scenario

Figure 7.1. Viability of farms (%) by scenario for all farms, England



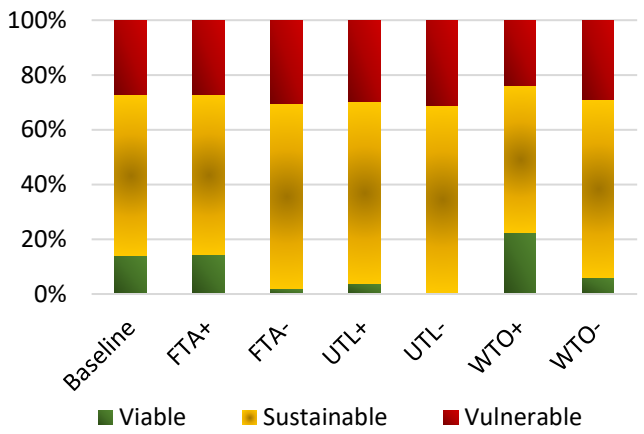
Almost one-third of the farms in England are economically viable under the baseline scenario. FTA+ has the least impact on viability rates and highest (38%) under WTO+ scenario. UTL- has the least proportion of viable farms and highest proportion of vulnerable farms. Some farms that are loss making (non viable) can still be economically sustianable because of off-farm income. For example under the UTL- scenario, just 9% of the farms were viable and 63% are sustainable.

Figure 7.2. Viability of farms (%) by scenario for all farms, Wales



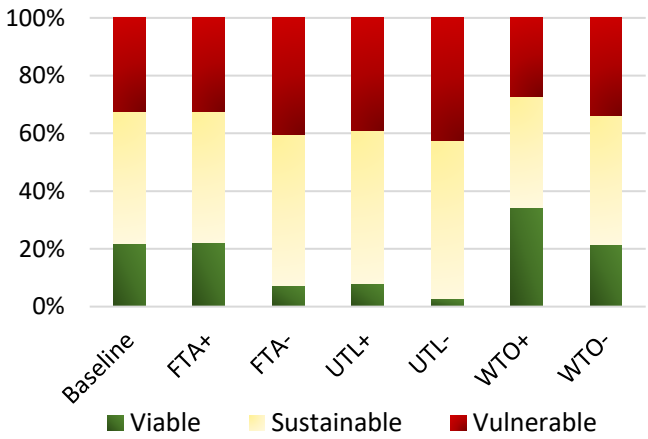
One-fifth of the farms in Wales were deemed economically viable even from the baseline scenario. Just 3% were viable under the UTL- scenario and WTO+ has the highest viability rate of 26%. FTA+ has the least impact on the viability levels of farms with the highest viability ratings under WTO+ scenario.

Figure 7.3. Viability of farms (%) by scenario for all farms, Scotland



Farms under UTL- scenario have the poorest viability rating with no farms left as being viable. However, higher proportion of the farms were sustained with the presence of off-farm income. When direct payments are removed, reduction of viability rates are amplified under the FTA-, WTO- and UTL- Scenarios. 22% of farms are viable under the baseline scenario.

Figure 7.4. Viability of farms (%) by scenario for all farms, Northern Ireland

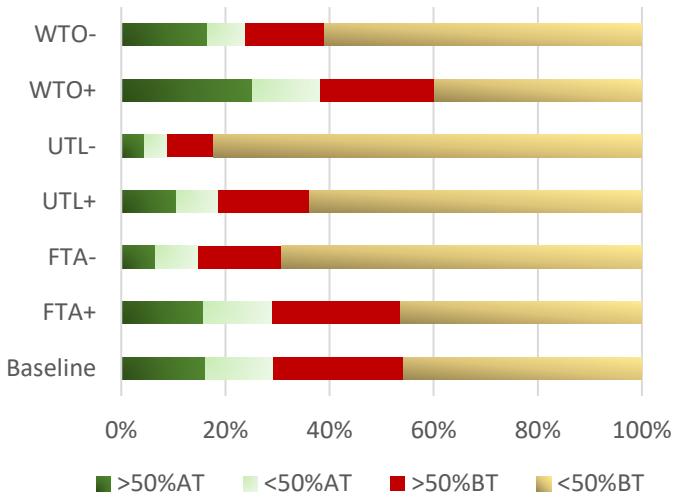


22% of the farms in Northern Ireland were viable under the baseline scenario. This rate remains the same with FTA+. It increased to 34% under WTO+ scenario but reduced to 8% under UTL+. Viability rates leaves FTA+ with no impact but increased under WTO+ due to higher milk prices. Lower prices under UTL- reduced viability rates drastically.

For simplicity and due to the sizeable number of English farm households, we restrict the tier 2 step of the analysis (non-viability breakdown) to only English farms. Hence, figures 7.5 and 7.6 shows the Via-Sus-Vul breakdown of farms in England thereby unveiling the breakdown of viability and non-viability components of each classification.

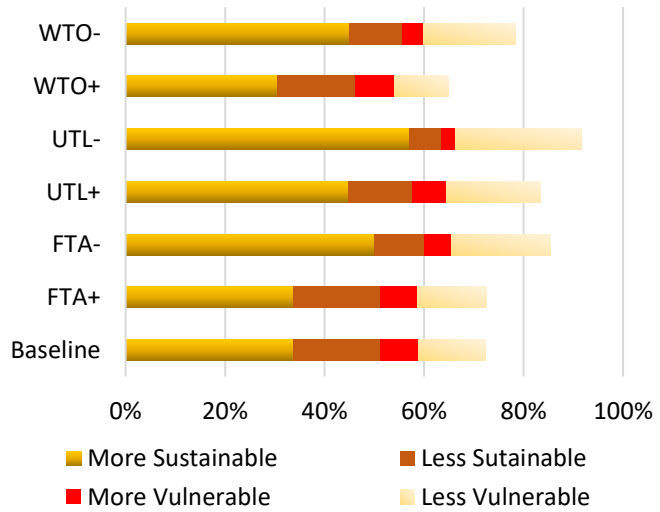
7.1.1.1. Via-Sus-Vul breakdown by scenario

Figure 7.5. Viability of farms (%) by scenario for all farms, England



Under each scenario, the proportion of farms in the category >50%AT (definite) has higher viability rate than those in the <50%AT (moderate) viability class. However, the category >50%BT (definite-non-viable) has lower proportion of non viable farms compared to <50%BT (moderate- non viable). This shows that farms earning less than 50 percent below threshold were conspicuously non-viable than those earning more than 50 percent below threshold.

Figure 7.6. Non-Viability (>50% BT and <50% BT) breakdown of farms by scenario, England



The figure here shows that higher proportions of the farms under each scenario were classified as More sustainable thus showing how off-farm income could help in improving the economic conditions of the farm households.

To summarise the results by country, Figure 7.1 shows that English farms has the highest proportion of viable farms with almost one third of the farm population (14,687 out of 44,061) classified as economically viable while Scottish farms (Figure 7.3) have the poorest viability ratings with just 14 percent of viable farms (1,552 out of 11,089) and 27 percent vulnerable farms. Almost 3,000 farm households in Scotland are in an economically vulnerable position while 6,542 farm households are sustainable. The proportion of farms in Wales (Figure 7.2) and Northern Ireland (Figure 7.4) that achieved the viability threshold were 21 and 22 percent, respectively. However, despite these low viability rates, it is evident

that the much higher sustainability rates strengthen the importance of off-farm income sources, thereby improving the economic situation of the farm households in all the regions. Indeed, there is a great improvement in the sustainability ratings of farms because of the accessibility to off-farm income. However, the sustainability ratings of farms in England, Wales and Scotland are much higher than farms in Northern Ireland.

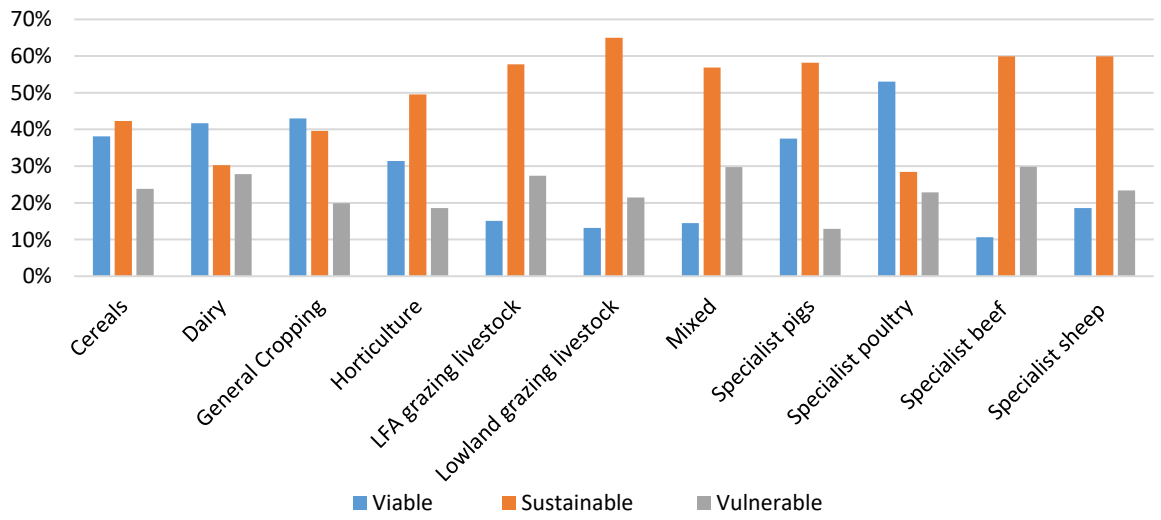
Regarding the importance of direct payments, our results shows that the removal of direct payment amplifies the reduction of viable farms under the FTA-, WTO-, and UTL- scenarios, thereby increasing the vulnerability levels of farm households. Under the viability levels of WTO, increases in output prices almost fully offset the loss of Pillar 1 DP. Farms under the UTL- scenario have the poorest viability ratings, infact, no farms were found to be viable in Scotland under UTL-. However, a greater proportion of farms were sustained with the presence of off-farm income which is amplified to a greater extent due to the removal of direct payments. Notably, with or without direct payments, one in three farms was vulnerable under the UTL scenario in Wales.

Due to the elevating effects of WTO+ tariffs on most domestic farm prices, viability levels increase across all UK devolved administrations while, in contrast, the UTL+ scenario increases the proportion of vulnerable farms as liberalised trade expose UK agriculture to reduced commodity prices, hence making them less competitive relative to the cheap(er) imports. Trade liberalisation combined with removal of Pillar 1 direct payments (UTL-) was found to be the most challenging with projected vulnerabilty levels becoming positive in each of the four nations. This tends to leave households in a worse situation, with viability levels below Baseline levels. In each of the four UK countries, the proportion of vulnerable farms increases under FTA- with Scotland showing a drastic and more conspicuous reduction in the number of viable farms.

In the next section, the viability levels by farm type is presented, showing how these ratings vary substantially by farm types. This reinforces, however, the large differences between countries and between UK farming systems.

7.4.2. Viability Assessment for all farm types: UK

Figure 7.7. Viability of farms (%) for all UK farms under the Baseline scenario



Under the Baseline scenario, Figure 7.7 displays the Via-Sus-Vul levels of each individual farm types for the UK as a whole. The viability of dairy farming is high relative to the other farm types, with 42 percent of dairy farm businesses economically viable. In contrast, only 11 percent of specialist beef farm met the business viability threshold. Nearly 60 percent of beef and sheep farms are sustainable because of the presence of off-farm income. Over 30 percent of beef farms and 23 percent of sheep farms are classified as economically vulnerable. However, the number of economically viable farms which declines in farm types such as Beef, Sheep, Pigs, Mixed, Lowland Grazing Livestock, LFA and Horticulture were deemed sustainable with the presence of off- farm income.

7.4.2.1. Impact of Scenarios on Viable farms by farm types: with Direct Payments

Figure 7.8. Viability Assessment (%) by farm types impacted by Scenario with DP

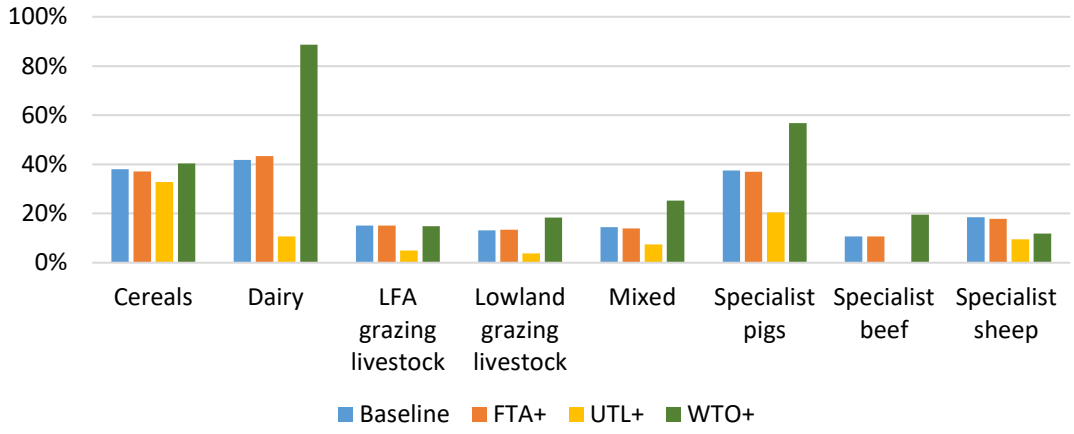


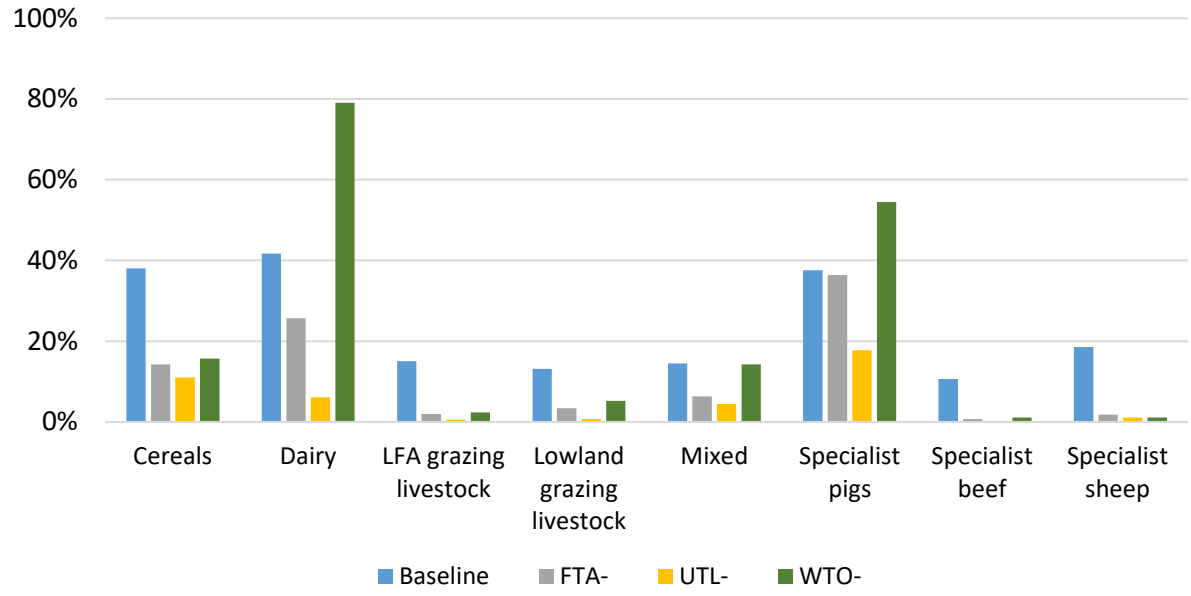
Figure 7.8 shows FTA+ has negligible impacts on the viability of farms regardless of the farm types. Higher wheat prices under WTO improved the viability rating of cereal farms while lower FTA+ prices reduce the percentages of viable farms slightly. The percentages of viable Dairy farms under WTO^{+} increases (89% of viable farms) due to higher milk prices while there is massive reduction in viability levels under UTL+ (11% viable farms) scenario due to lower prices.

In the same vein, the viability ratings in pig farms increased under WTO+ (57% viable farms) due to higher prices and reduced under UTL+ (20% viable farms) because of lower pig prices. For the LFA farms, Slight price changes have negligible impact on the viability ratings of the farms under FTA+ but higher beef prices under WTO+ have modest positive effect on the farm's viability ratings.

Regarding the beef and sheep sectors, price changes under FTA+ have negligible impacts on the viability levels of both farms but lower sheep prices lead to lower viability level under the WTO+ (12% viable farms as against 19% under the Baseline scenario) while on the contrary, higher beef prices under the WTO^{+} scenario lead to 20% increase in viable farms from 11% under the Baseline scenario.

7.4.2.2. Impact of Scenarios on Viable farms by farm types: without Direct Payments

Figure 7.9. Viability Assessment (%) by farm types and by Scenario without DP



The viability levels of all the farm types reduced substantially due to loss of income support as shown in Figure 7.9. Relative to the Baseline scenario, all the other scenarios were greatly impacted without support. Most of the farms in the beef and sheep sectors ended up disappearing due to loss of direct payment. Without Direct payment, 10% (under WTO-) of the farm households in the dairy sector will end up going out their farm business. Since the pig sector is less dependent on support payments, just 3% of the pig farms would be impacted by the loss of direct payments.

7.4.2.3. Impact of Scenarios on Sustainable farms by farm types: with Direct Payments

Figure 7.10. Sustainability Assessment (%) by farm types and by Scenario with DP

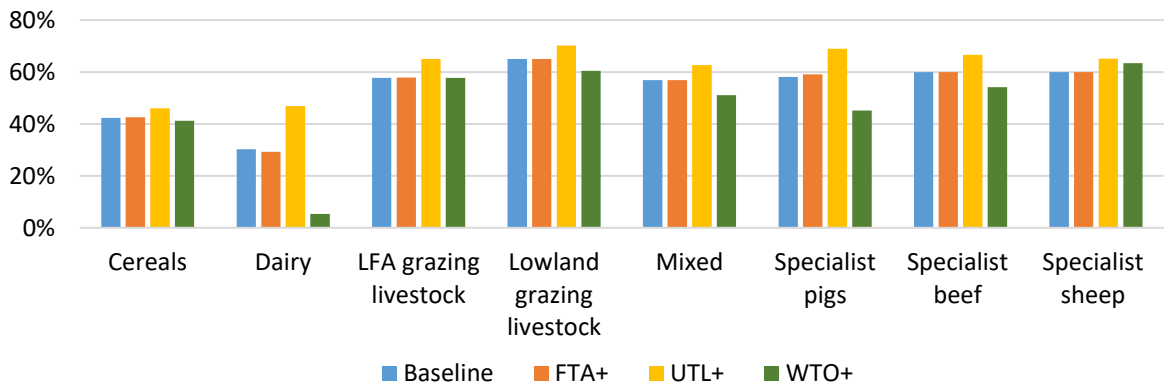
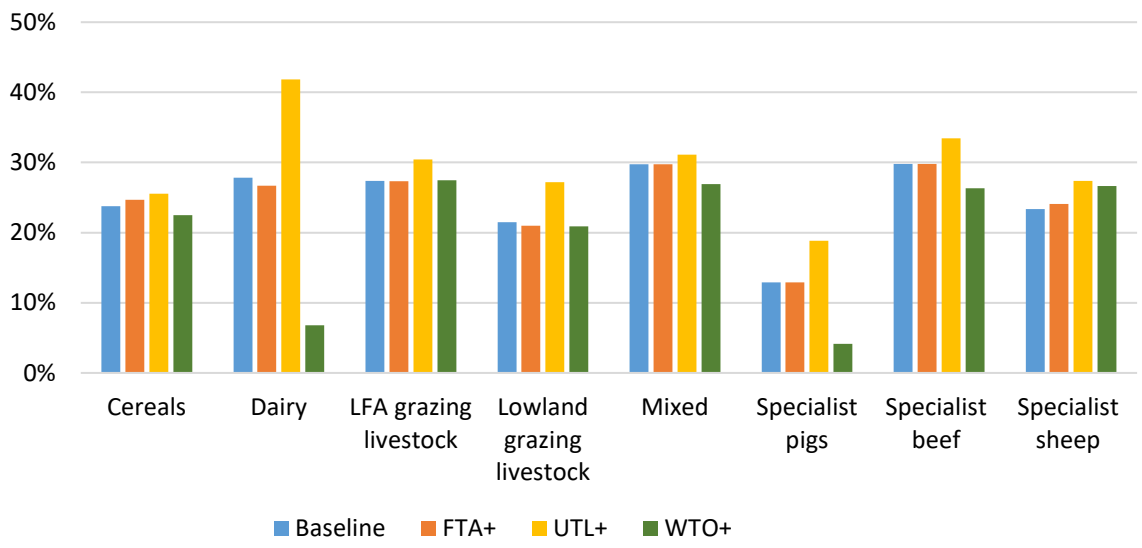


Figure 7.10 shows the incidence of the farm households that were sustainable because of off-farm income. For example, the beef and sheep sectors with almost the lowest proportion of viable farms could be tagged as having almost a higher proportion of sustainable farms due to the incidence of off-farm income. Indeed, it is clear that the future sustainability of many farm households might be dependent on farmers and their spouses' ability to secure employment off the farm.

7.4.2.4. Impact of Scenarios on Vulnerable farms by farm types: with Direct Payments

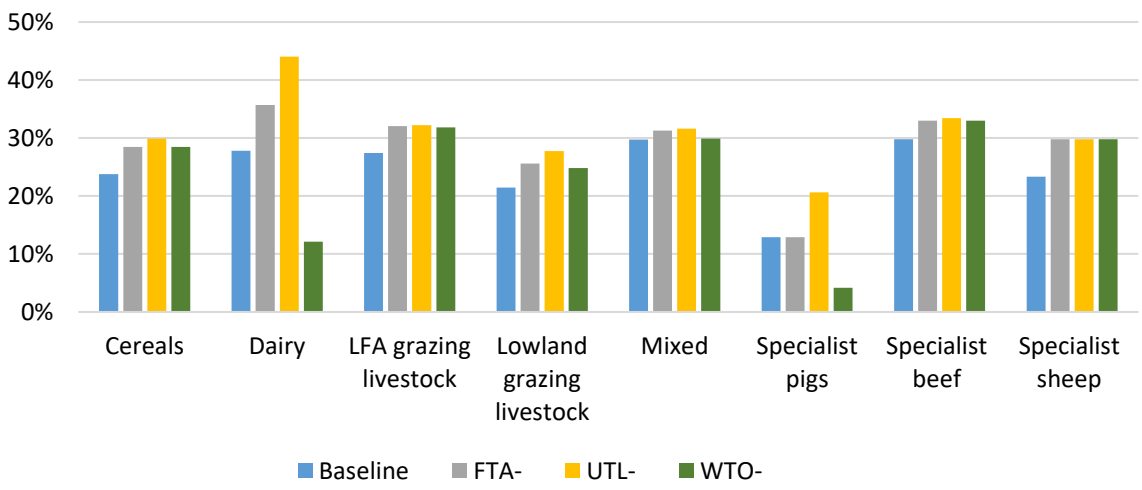
Figure 7.11. Vulnerability Assessment (%) by farm types and by Scenario with DP



Vulnerability assessment displaying farm household that are economically unviable and neither the farmer nor spouse secures off-farm income is shown in Figure 7.11 above. The UTL+ scenario leaves all the farms highly vulnerable.

7.4.2.5 Impact of Scenarios on Vulnerable farms by farm types: without Direct Payments

Figure 7.12. Vulnerability Assessment (%) by farm types and by Scenario without DP



Following the loss of direct payments, the incidence of vulnerable farms increased across all farm types (irrespective of the scenarios) as displayed in Figure 7.12. Except for pigs and dairy sector with the lowest vulnerability levels under WTO-, the remaining sectors were highly vulnerable. The combination of loss of direct payment and elimination of import tariff (UTL) amplifies farmers' vulnerability to Brexit scenarios.

7.4.3. Impact of Scenarios on farm households by Age and Country

Figure 7.13. Viability Assessment (%) by Age classification with DP, ENGLAND

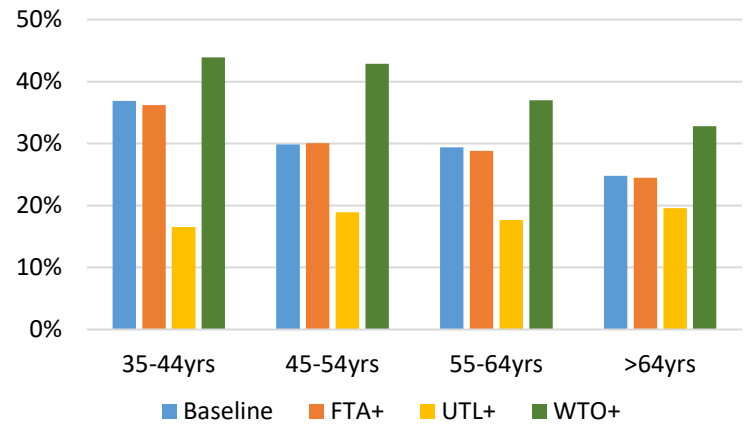
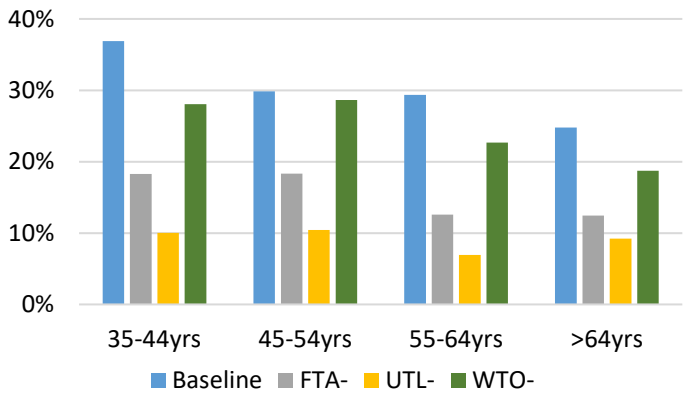


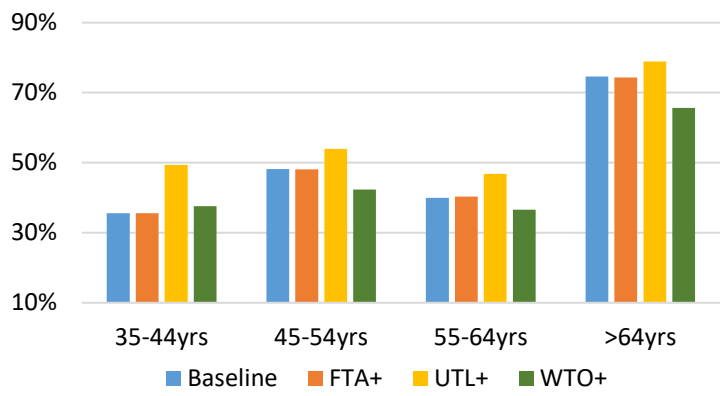
Figure 7.13 shows that farm households within the age group 34-44years have their highest viability rating under WTO+ Scenario while the lowest WTO+ viable farms falls within >64 years age group. Relative to the baseline and across all scenarios, younger farm households have higher viability ratings than their older counterparts.

Figure 7.14. Viability Assessment (%) by Age classification without DP, ENGLAND



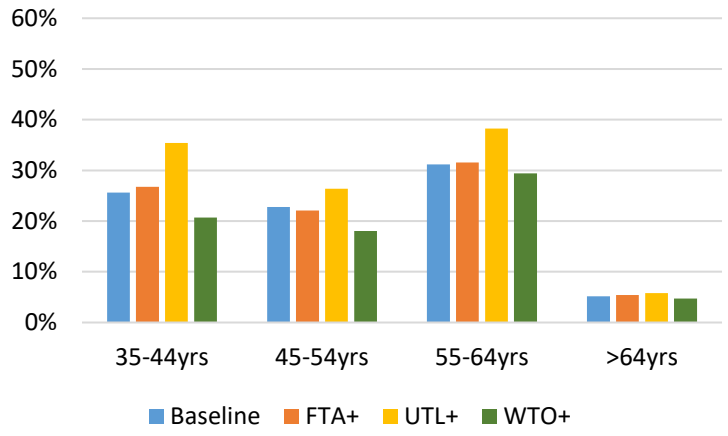
For each of the age category, loss of support payment reduced the viability levels of most English farms. Even WTO- negatively impact all the age category when compared to the baseline. Younger farm households (Age 35-44 and 45-54 years) have better viability ratings than the older category of farm households. This shows that older farmers rely more on Direct payment than young farmers

Figure 7.15. Sustainability Assessment (%) by Age classification with DP, ENGLAND



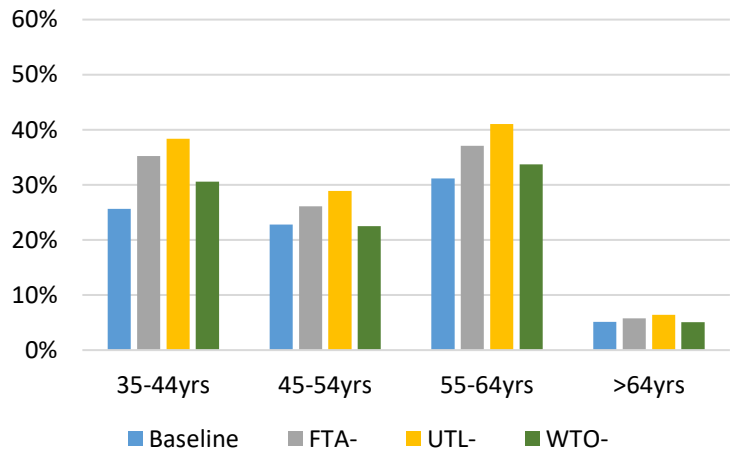
Older farm households (>64 years) are most sustainable under each scenario. This shows that they earn off-farm income more than the other age groups. This could be due to the money they get from pension or benefits. For each age category, farms are deemed to be most sustainable even under the most extreme scenario (UTL+) showing the importance of off-farm income.

Figure 7.16. Vulnerability Assessment (%) by Age classification with DP, ENGLAND



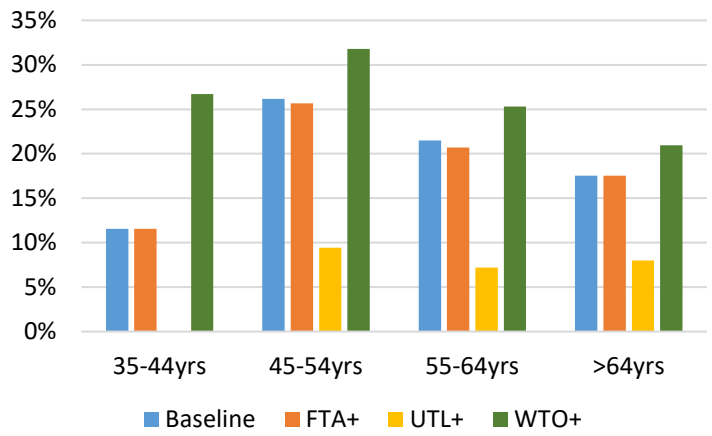
Apart from older farm households (> 64), the incidence of economic vulnerability increased with the contraction of off-farm income across all the other age category of the farm households. Thus, showing these group of farm households does not have access to off-farm income compared to the >64 age group.

Figure 7.17. Vulnerability Assessment (%) by Age classification without DP, ENGLAND



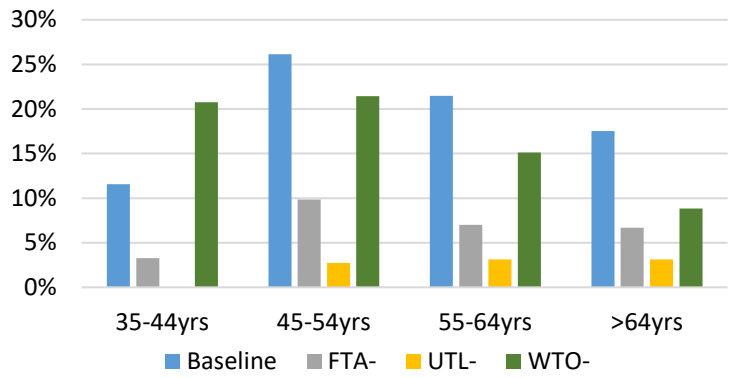
Across each scenario, most farm households within the age category of 35-44, 45-54 and 55-64 were economically vulnerable without direct payment while the older farmers age 64 and above would be economically sustainable even without farm income support.

Figure 7.18. Viability Assessment (%) by Age classification with DP, WALES



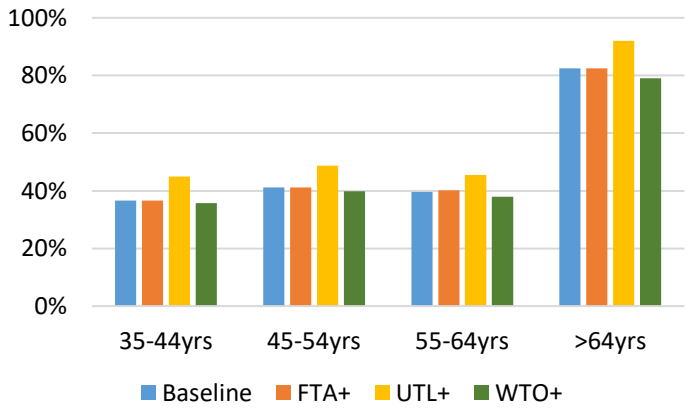
Across all scenarios and age categories, UTL+ has the worst impact on farm households with no viable farms in younger farm households (35-44 years). Slight price changes under FTA+ have negligible impact on the age categories of the farm households but higher prices under WTO+ have positive impact on farm's viability ratings.

Figure 7.19. Viability Assessment (%) by Age classification without DP, WALES



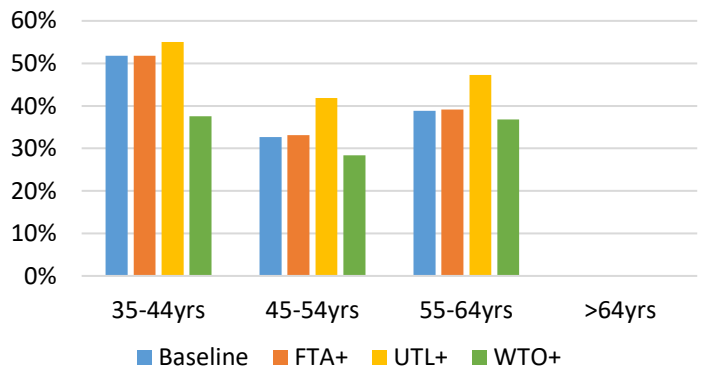
Without direct payments, the viability ratings of the farm households dropped conspicuously across all age categories and scenarios. In comparison with the baseline scenario, farms managed by younger farmers were more viable as opposed to farms were farmers are older.

Figure 7.20. Sustainability Assessment (%) by Age classification with DP, WALES



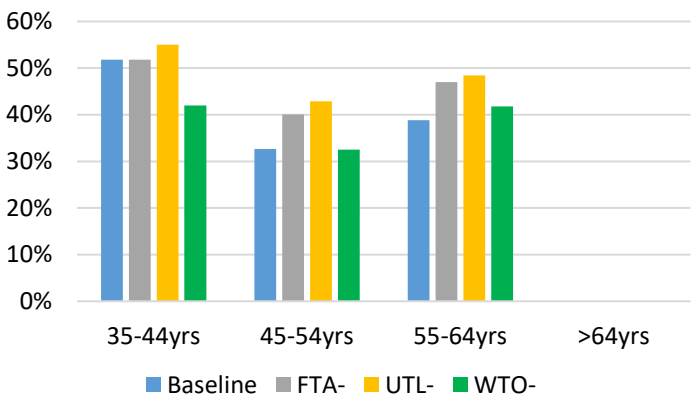
Farm households with farmers age 64 years and above were the most sustainable under each scenario. For each age category, farms are deemed to be most sustainable even under the most extreme scenario (UTL+). This shows the impact of off-farm income which improves the economic condition of the farm households.

Figure 7.21. Vulnerability Assessment (%) by Age classification with DP, WALES



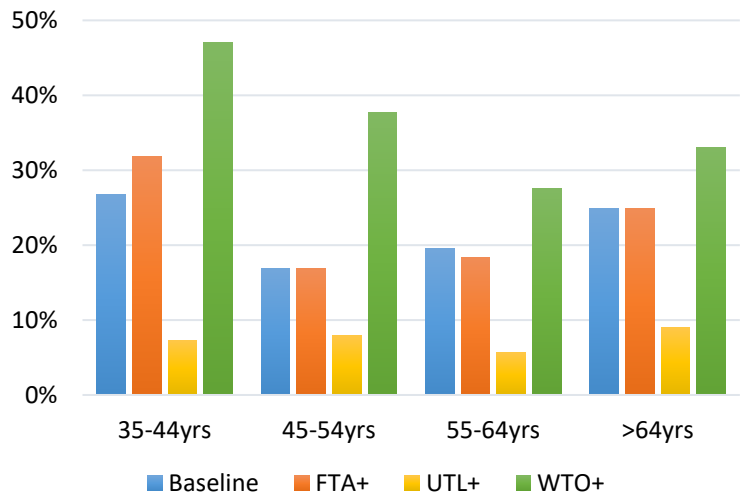
The incidence of economic vulnerability increased with the contraction of off-farm income across all the age categories except farm households >64 years where none of the farms was vulnerable.

Figure 7.22. Vulnerability Assessment (%) by Age classification without DP, WALES



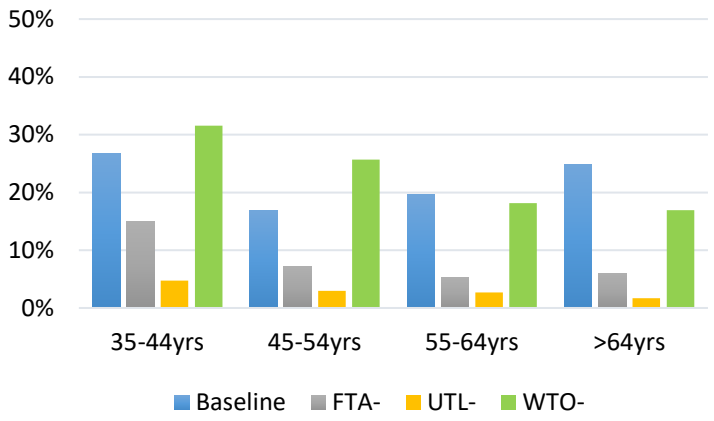
Without income support, there is no incidence of vulnerability for old farmers. This does not hold true for the other age categories as there is a great increase in Vulnerability levels under all scenarios.

Figure 7.23. Viability Assessment (%) by Age classification with DP, NORTHERN IRELAND



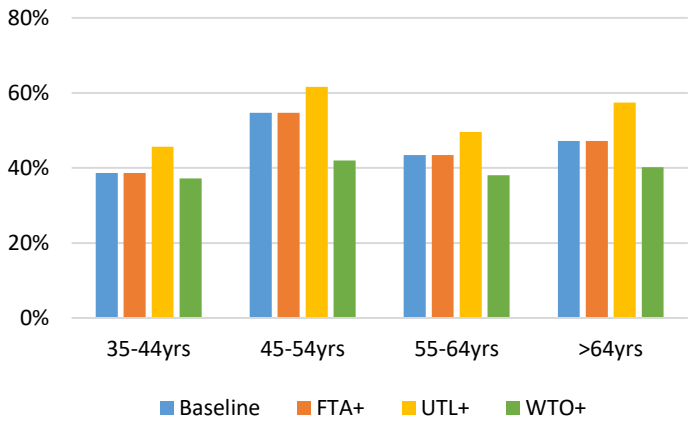
UTL+ scenario has the poorest viability ratings on all farm households irrespective of the age classification. The younger farm households have higher viability ratings than their older counterparts.

Figure 7.24. Viability Assessment (%) by Age classification without DP, NORTHERN IRELAND



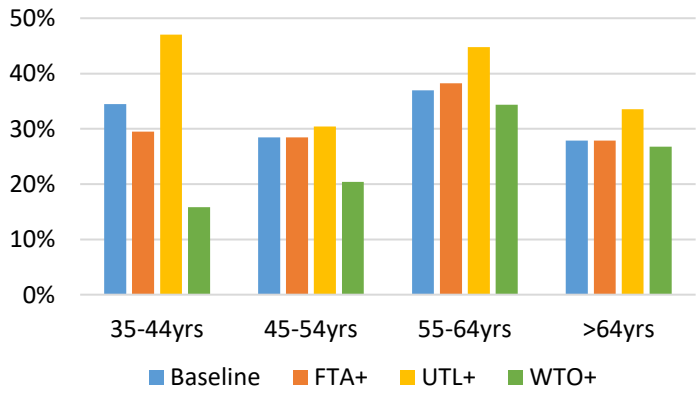
Without income support, FTA- scenario greatly impact the viability ratings of the farm households. Despite the fact that the viability ratings of the farm household dropped without farm income support, farm households aged 35-44 and 45-54 years were performing relatively well under WTO- scenario.

Figure 7.25. Sustainability Assessment (%) by Age classification with DP, NORTHERN IRELAND



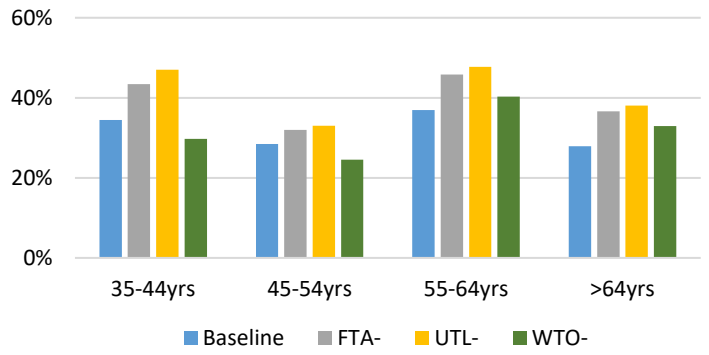
With farm income support, virtually all the farms within each classification are sustainable because of the influence of off-farm income. FTA+ scenario has the least effect, while UTL- greatly affects the sustainability of the farm households.

Figure 7.26. Vulnerability Assessment (%) by Age classification with DP, NORTHERN IRELAND



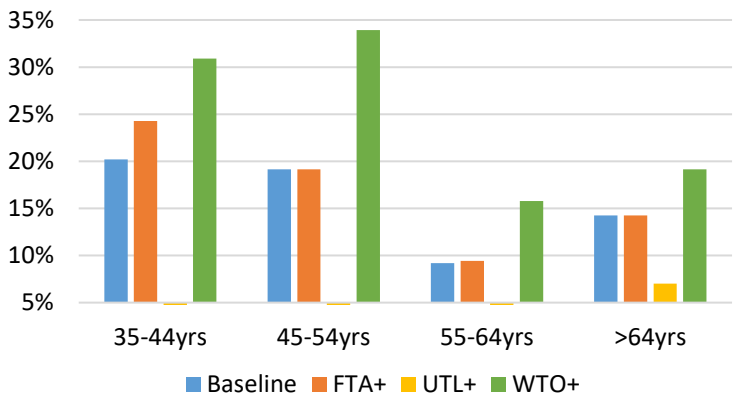
The contraction of off-farm income caused the incidence of economic vulnerability to increase. Most farms are vulnerable under UTL+ with the least vulnerability levels from WTO+.

Figure 7.27. Vulnerability Assessment (%) by Age classification without DP, NORTHERN IRELAND



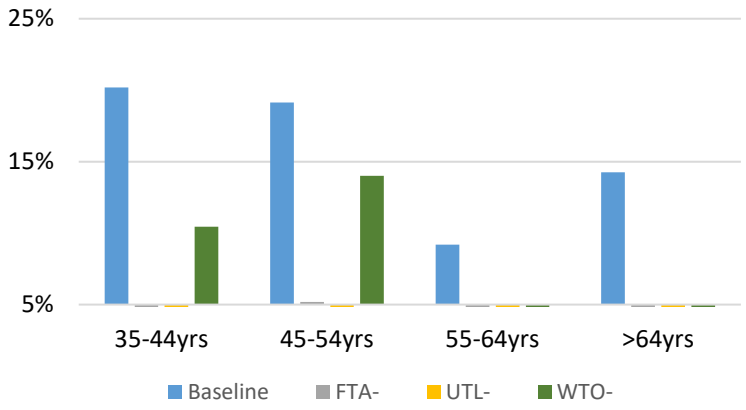
Lack of farm income support coupled with lack of off-farm income caused the incidence of vulnerability to increase. This incidence is more pronounced in farms age groups 35-44 and 55-64.

Figure 7.28. Viability Assessment (%) by Age classification with DP, SCOTLAND



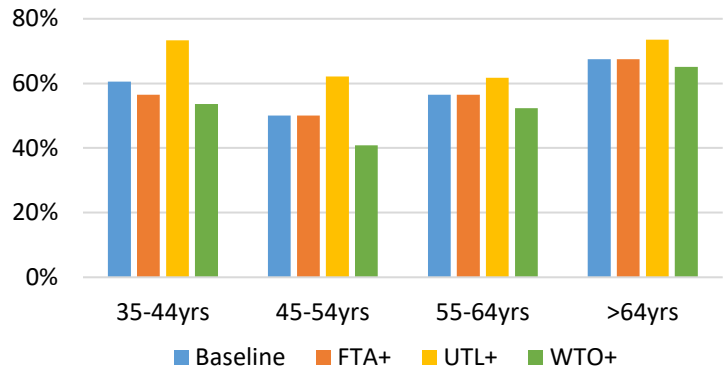
With income support, the viability ratings under the WTO+ scenario is higher compared to other scenarios. Most specifically, it is highest within 45-54 years of age, while on the contrary, viability levels drastically reduced under UTL+ scenario.

Figure 7.29. Viability Assessment (%) by Age classification without DP, SCOTLAND



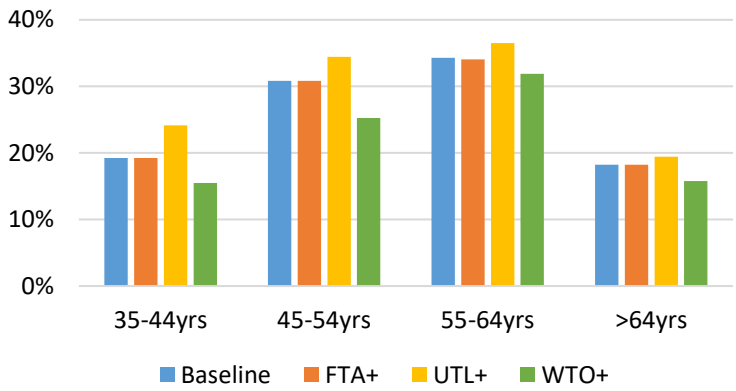
Relative to the baseline scenarios, removal of support payments amplifies the reduction of viability ratings under each scenario. Young farmers have better viability ratings under the WTO scenario compared to their very old counterparts with no viability ratings.

Figure 7.30. Sustainability Assessment (%) by Age classification with DP, SCOTLAND



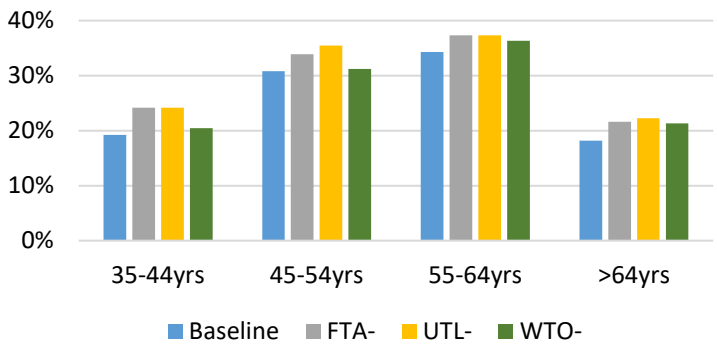
Irrespective of the age category, farm households under the UTL scenario are deemed to be sustainable thereby showing the impact of off-farm income in improving the welfare of farm households.

Figure 7.31. Vulnerability Assessment (%) by Age classification with DP, SCOTLAND



Irrespective of the age category of farm households, the contraction of off-farm income caused the incidence of incidence of economic vulnerability to increase. The highest incidence falls within age groups 45-54 and 55-64.

Figure 7.32. Vulnerability Assessment (%) by Age classification without DP, SCOTLAND



Across each scenario, most farm households within all age classifications would be economically vulnerable without direct payment, this connotes that the incidence of vulnerability increase without support payments.

7.5 Conclusion

The three broad groups applied to classify farm population are viability, sustianabilty and vulnerability which are referred to as Via-Sus-Vul. Farm income are important for farm viabilty while off-farm income are important for sustainabilty. Vulnerabilty being the extreme case is when a farm household lacks both farm and off-farm income. Studies of farm viability have attempted to understand the criteria for vulnerabilty cases at the farm level and identify factors which determine a switch from being viable to non-viable as well as the subsequent consequences for underperformance within farm households. Vrolijk et al 2010 opined that viability is determined by the level of farm husehold income and the ability for the farm households to cover capital investment. The findings in this report explores the impacts of brexit scenarios on the Via-Sus-Vul ratings of England, Wales, Scotland and Northern Ireland and consequently investigated the impact of these scenarios by farm types and age.

The viability general model (as described in this chapter) is used to estimate the effects of various policy scenarios across different farm types and age categories in different parts of the UK and our findings are consistent with the Baseline results of other studies such as O'Donoghue *et al.*, 2016, Hennessy and Moran, 2015 and Vrolijk *et al.*, 2010. Considering the regional classification, large differences in the viability ratings of farms exist across the regions in the UK. Under the Baseline Scenario, only 29% of the farms in England are viable, 21% in Wales, 14% in Scotland and 22% in NI. In each of these countries, the scenario with income support have more significant impact on farm viabilities while scenarios without support leaves most farms in a vulnerable state. However, the presence of off-farm incomes improves the economic situation of some farm households since off-farm income is critical in safe-guarding the economic wellbeing of a large proportion of farm households. This means that in England for example nearly two-thirds of the farms would be vulnerable, if it were not for off-farm income.

Via-Sus-Vul assessment varies substantially by farm types which are driven by farm and off-farm factors. Due to the increase in milk prices, viability rates for dairy farm businesses remain high with 42% of the farms being viable. This increased to 89% under WTO+, 43% under FTA+ and reduced to 11% UTL+. In the same vein, the increases in pig prices influenced the viability ratings of pig farms in each of the scenario. 38% of the pig farms are viable under the Baseline scenario, 57% under WTO+, 37% under FTA+ and 20% under UTL+. On the other hand, it is obvious that certain farm types are more vulnerable to farmgate price reductions than others. For example, if pillar 1 remains, the viability of sheep farms (Baseline 19%, FTA+ 18%, WTO+ 12% and UTL+ 10%) would be adversely affected due to price reductions under WTO+ and UTL+ while the number of viable (Baseline 11%, FTA+ 11%, WTO+ 20% and UTL+ 1%) beef farms would be adversely affected by price reductions under UTL+. It is important to mention that some farms would experience higher viability ratings through higher beef, milk and wheat prices under the WTO+ scenarios. The UTL+ scenario leaves most farm households in highly devastating and vulnerable conditions. Conversely, if support payment is abolished, most livestock farms would be out of business because of the reductions in beef cattle and sheep numbers. This suggests that very few viable farms would be able to produce profit that is sufficient to reward the labour and capital invested. Off-farm income would therefore be critical in safe guarding the economic well-being of a large proportion of farm households since just over one third of farm households can be considered economically vulnerable (the farm business is not viable and there is no off-farm income present in the household). Off-farm remains very important especially for beef and sheep sectors.

The viability assessment by demographic classifications shows that with income support, young farmers (35-44 years) have higher viability ratings under WTO+ scenario in each of the countries while the old farm households (64 years and above) have poor viability ratings. However, since the presence of off-farm income improves the welfare of farm households, its reliance is particularly pronounced for farmers' in the older age categories.

Without support payment, it is clear that most farms especially in Wales and Scotland would be out of business particularly under the UTL+ scenario. In England and Northern Ireland, younger farm households have viability ratings than their older counterparts not minding the scenario. Due to large differences occuring across regions, systems and demographic characteristics, the future viability and sustainabilty of a large number of farm households is dependent on farmers and their spouse's ability to secure employment off the farm. Finally, price projections, direct payments and off-farm income, largely influence variability in the levels of viability, sustainability and vulnerability across UK countries, farm types and demographic characteristics. Overall, the results show that the economic welfare of farm households in the UK is influenced markedly by farmers' accessibility to off-farm income, but the shape of the future domestic agriculture (e.g. retaining/eliminating direct payments) and the trade relations with the EU and the rest of the world cannot be ignored, and their farm impact will be far from uniform.

8. Model Reconciliation and Modelling Issues[34]

8.1. Macro (CGE) and Sector (FAPRI) Models

This Chapter seeks to reconcile the results and projections of the macro (Chapter 3) and the sector (Chapter 4) models between themselves and with the farm level analysis (Chapter 5, and 6). This may be understood as the difference in effect on the whole of the agricultural sector, as compared with how changes are experienced by individual farms.

As with any models, those deployed for this project necessarily invoke a number of simplifying assumptions. These include presumed production objectives (i.e. profit maximisation), consistent consumer preferences (e.g., own and cross-price elasticities; Armington origin effects) and domestic and international supply-responsiveness (e.g., capacities to meet increased demand). Although these assumptions are common to most agricultural production and trade modelling exercises, they will influence the model results under different scenarios, hence different modelling frameworks inevitably lead to different projected impacts. Nevertheless, the broad policy conclusions arising from the differing modelling systems (CGE and PE) employed in this analysis are similar, i.e. a UK-EU FTA results in modest market changes, following the loss of access to Single Market (hence the imposed trade facilitation costs), while the imposition of WTO tariffs depends on the UK's net trading position (net importer vs net exporter). The impact of trade liberalisation hinges on the degree of trade openness of and competitiveness of the UK sectors compared to their international competitors. In addition, both models indicate that any depreciation of the pound has a strong inflationary impact on output prices but limited production impacts due to offsetting increases in input prices.

A strength of the CGE model is its ability to capture general macroeconomic feedback effects and provide detail on the impact on agricultural factor markets, e.g. decline in wages and land rents following removal of Pillar 1 direct payments. It also provides some estimates for the food processing sector and changes for food prices (at retail level). In contrast, the PE model provides a more detailed subsector assessment within the agricultural sector, for example, sheep versus beef. Nonetheless, the supply and demand responses of the agricultural system are modelled somewhat differently in PE and CGE. The former makes use of relatively familiar supply and demand functions, typically based on estimation from historic data, which may or may not reflect future circumstances and conditions (e.g. those representing substantial departure from Baseline, such as the ULT and WTO scenarios). The CGE model, on the other hand, uses the framework of production possibility frontiers, based on the availability of factors of production, i.e. labour, land and capital (which generate the implicit supply responses), and consumer preferences and responses as reflected in utility functions which generate the implicit demand responses to both incomes and prices.

As a consequence, although both models are based on very similar assumptions about the 'present' condition of the economies and markets, and their supposed development in the future, they generate somewhat different projections of the impacts of trade and policy changes. A brief review of the major differences between the two models (PE and CGE) under the six scenarios highlights the differences and provides a basis for discussion of the potential implications.

[34] This chapter was written by Myles Patton, George Philippidis and Andrew Moxey.

We first discuss the effects of changing trade relations, while maintaining current direct payments, and then consider the effects of removing CAP Pillar 1 direct support.

8.1.1. Trade Scenarios with Direct Payments: FTA+ (1), UTL+ (3) and WTO+ (5)

UK-EU FTA: Both models show modest price impacts due to higher trade costs, with additional trade facilitation costs for UK exports to the EU and imports from the EU broadly cancelling each other. We should note, however, that neither of our models deals in any detail with non-tariff barriers, which would exist under most FTAs. We justify their exclusion on at least two grounds. The uncertainty concerning the extent to which non-tariff barriers may inhibit trade, and the unavailability of robust data. Hence, our representation of these measures is restricted to imposing relatively modest but arbitrary trade facilitation costs, which do not and cannot include all the issues associated with non-tariff barriers (e.g. sanitary and phytosanitary rules, labelling, compliance with different regulatory regimes, custom checks and rules of origin). Some observers (e.g. House of Lords, 2017) have suggested that non-tariff barriers will add to farmers' cost and these might be higher than tariffs. However, care needs to be taken about making generalisations based on specific barriers between individual pairs of countries. For example, while there may be specific issues concerning non-tariff barriers between the EU and the US (*e.g.* chlorine-washed chicken and hormone-fed beef), Mercosur countries already export significant volumes of agriculture produce to the EU through tariff rate quotas. These exports already comply with UK/EU requirements and production standards.

Unilateral Free Trade: The major difference between the two models is that in the PE model consumers do not differentiate between products from the domestic market and those from the rest of the world (as the PE model assumes perfect substitutability between domestic produce and imports). In contrast, the CGE model allows for imperfect substitutability (e.g. apple from Spain versus apple from Brazil) using the conventional Armington assumption, which incorporates, to some extent, a reflection of domestic consumers' preferences for products from different sources (different varieties). The Armington assumption is a form of product differentiation explicitly linked to country/region of origin, hence it exogenously differentiates products either based on their physical properties or on consumers' perceptions attached to products from a particular region (e.g., ethnocentric attitudes ('Buy British'); brand quality (PDO/PDI wines from France or Spain)). These are also considered as non-tariff measures, and their presence varies dramatically depending on the product under consideration. The resulting quantity and price impacts are therefore very difficult to ascertain, a priori, and hence are not modelled here.

Both models show a significant price decline for 'red meat'. The CGE generates an 11% fall for 'red meat' at the retail level, while the PE model shows falls of 42% and 19% in beef and sheep producer prices, respectively. An attempt to transform retail prices into producer prices implies larger price declines using the PE model. The price falls from both models reflect the current price differences between the UK and elsewhere in the world, especially the most competitive world producers.

The CGE model also yields a marked decline in 'red meat' production under UTL (-27%). This compares to more modest decreases in production projected by the PE model (-12% for beef and -5% for sheep). This is partly attributable to dynamic effects, which mean that the declines in production are not fully captured at the end of the projection period by the PE model, for example illustrated by the marked

decline in suckler cow numbers. Our models generally assume that there is sufficient capacity within the rest of the world to meet the expansion in UK imports in the beef and sheep sectors under this trade liberalisation scenario. Within the beef sector this assumption is regarded as plausible since the increase in the level of imports to the UK is relatively small compared to the global level of trade, and imports are sourced from various countries. In contrast, the potential of the rest of the world to meet the expansion in UK imports in the sheep sector is questionable, hence a sensitivity analysis was undertaken to explore the importance of this assumption (see Chapter 4). The CGE model structure is, however, centred on the availability of land, labour and capital to meet consumer (market) demands through the production possibility frontier, therefore the supply functions are implicit rather than explicit.

CGE yields a negligible fall in the price of 'white meat' (-0.1% - pork and poultry are grouped together within this category). Similarly, the PE model yields modest declines for pig meat and poultry (-3% and -4% respectively).

There are some divergent price impacts in the dairy sector. The CGE model yields an overall price increase for the dairy sector, while the FAPRI PE model yields price declines for cheese and butter. The projected price increases arising from the CGE model result from the combined impact of trade facilitation costs and increased access to non-EU markets. The part-worth results from the CGE model suggest that the elimination of tariffs on imports for the rest of the world does not fully offset these other effects. In contrast, within the FAPRI analysis the elimination of tariffs dominates the other policy changes since the increased inflow of imports from the rest of the world results in market prices falling to world levels. It should also be noted that these results depend on the definition and specification of the base line for 'world prices', which cannot easily be fully reconciled between the two models. Within the beef sector the Brazilian price is used as the reference world price in the PE model, as it is the most competitive. The differential between the UK and Brazilian beef prices within the PE modelling system is reasonably consistent with Irish Bord Bia international datasets. It should, however, be borne in mind that the magnitude of the estimated policy changes is dependent on the evolution of world markets and exchange rates. Both models show similar price impacts for wheat, while the PE model shows a specific negative impact for barley.

A fall back to WTO MFN tariff schedule

Both models show differential impacts across sectors depending on import trade dependency.

The CGE model yields a 7% increase for 'red meat' at the retail level, while the PE model shows a 17% increase for the beef producer price and a 23% decrease for sheepmeat producer price at the farm gate. The aggregate price impact for beef and sheepmeat is similar, although the PE projections identify the particular vulnerability of the sheep sector to both WTO and UTL.

Both models show a price increase for 'white meat', with a strong production response in these sectors reflecting the significant output price increases but limited input price increases.

Both models yield price increases in the dairy sector, which are primarily driven by high tariffs on imports from the EU. The disaggregation of the PE model across the devolved administrations demonstrates different price impacts for milk producers, particularly for Northern Ireland.

Both models yield equivalent price impacts for wheat (+1%). The PE model provides specific projections for barley, with the price declining by 5% due to surplus net exports in the Baseline.

8.1.2. Trade scenarios with the Direct Payments Removed: FTA- (2), UTL- (4) and WTO- (6)

Despite different modelling frameworks both models show fairly modest declines in production following the removal of CAP direct payments. These results are especially sensitive to the assumptions made about the extent to which decoupled payments actually increase domestic production from what it otherwise would have been. Although direct payments (officially decoupled from production) are considered as non-trade distorting (included in the Green Box) by the WTO, there is still considerable debate regarding their effects on production. While the negative livestock production impact is slightly more marked in the CGE model, this reflects the fact that the PE model does not capture the full production impact. This is mainly due to livestock dynamics as indicated by the significant falls in livestock numbers, the implications of which are not fully worked through within the time period of the analysis.

The additional positive impact of the removal of Pillar 1 direct payments on price arising from the CGE model is similar across the different trade arrangements. This reflects the equivalent per unit cost increase to the farmer resulting from the elimination of per unit (direct) subsidies on agricultural land, capital and labour factors. In contrast, the removal of direct payments within the PE model has a positive impact on price under the FTA scenario, but not under the other two trade scenarios. In both, UTL and WTO scenarios, the UK domestic prices are essentially bounded by world prices (with added tariff in the case of WTO) and therefore there is no price response from the removal of direct payments. Again, the differential trade effects in the CGE versus the PE model reflect that lack of consumers' preferences as well as the differential effects of world prices and exchange rates.

In addition, it is important to recognise that the assumed extreme policy changes (i.e. UTL-) represent significant shifts from existing policies. For example, price changes go beyond the variation experienced historically, upon which the models are calibrated. Furthermore, the strong reliance on direct payments within some sectors means that the elimination of direct payments may lead to major structural changes (e.g. rationalisation and potential concentration of farms, and changes in land use and production patterns) that are difficult to capture in our present models. Neither of our models (PE or CGE) capture the frictions and dynamic adjustment costs likely to be associated with these changes, including the calibration of adjustment rates to historic data.

8.1.3. Concluding remarks on the CGE and PE modelling assumptions

The critical issue in the modelling of agriculture's ability to cope with policy changes and thrive after Brexit is the effect of direct payments (DPs). The macro (CGE) and sector (FAPRI PE) models assume that these payments have some effects on production, enabling the domestic farm sector to produce more than otherwise would, hence their elimination would reduce domestic production. This will also exert some upward pressure on domestic producer prices, which might or might not offset any downward pressure resulting from the changes in trade conditions.

Legitimate questions have been raised in workshop discussions of our results about the reflection of the effects of direct payments, especially in the CGE model. In particular, the assumption used in the present version of the CGE model is that only 8% of direct payments are 'capitalised in farm land rents. This assumption is based on earlier and independent research (Michalek *et al.*, 2014) which looked at rents paid by farmers as recorded in farm business survey (FADN) data over the period 2004 – 2007 (spanning the introduction of the current direct payment regime). Without any more reliable estimates available, this assumption was retained for the analysis we report in this study. However, there are good reasons to suppose that the estimate of the effects of direct payments on land rents is too small. In particular, the single payment scheme (SPS) introduced in 2004 (or 2005 in some EU countries) replaced a set of area payments (also considered effectively de-coupled) which already had some effects on land rents which are not included in the Michalek *et al.* (2014) estimates. More importantly, land rents do not adjust immediately to changes in expected revenue streams, while the mechanics of the transition to the SPS itself also mean that the effects of the scheme on actual (or estimated) farm rents in the farm survey data will not have been fully realised over this time period. Our conclusion is that the price effects of policy and trade changes following Brexit are probably more robustly projected by the FAPRI PE model, and these are the changes used in the farm level analysis, although we do make use of the projected changes in input costs and factor prices from the CGE results, with the caveat that these are indications of direction rather than robust estimates of probable effects.

8.2. Farm-level modelling Key Issues

Although the ScotFarm model allows for some dynamic optimisation under different scenarios, the production possibility frontier is restricted to that already observed on a farm. That is, the model can change the level and mix of activities, but not introduce new ones. This reflects practical constraints imposed on farms by, for example, the suitability of land or credit availability which limit opportunities to adopt new enterprises. However, whilst such constraints may be binding for some farms, they will not be for all farms. Consequently, ScotFarm results under-estimate the longer-term scope for adjustment to farming systems. This explains to some extent why the ScotFarm results are bleaker than the national or sectoral results. However, beyond splitting the UK into four parts, the national and sectoral results are non-spatial *per se*. Yet farming activities and structures display considerable spatial heterogeneity, with local conditions and markets exerting significant influence on farming practices. Hence, the national and sectoral models may misrepresent the ease with which resources can be transferred between different agricultural uses (or indeed the wider economy), and consequent adjustment. For example, rough grazing land released by cessation of extensive sheep grazing is unlikely to be utilised for other agricultural activities; an eastern arable farming looking to expand will have no interest in redundant western grazing land. On the other hand, the macro and sector level models do assume substantial structural adjustment, which cannot be included in existing farm level models.

Spatial heterogeneity of land quality also means that land prices and rental values vary considerably. Moreover, price and land rents also vary with size and location/accessibility and whether it comes with buildings and equipment. Consequently, whilst reductions in (especially) rental values may be anticipated, the use of averages estimated across the UK, or even across each of the four devolved administrations will misrepresent local conditions. Unfortunately, addressing such modelling weaknesses

would require better data plus explicit linkages between the different modelling levels – neither of which were available within this project, nor yet to the analytical community in the UK.

The ScotFarm results presented here also reflect fixed efficiency levels[35] rather than allowing for productivity improvements. Again, this is likely to under-estimate the scope for adjustments to offset some of the impact of removing direct payments. However, the Simulated Income Distribution analysis has explored efficiency gains to some extent (through sensitivity analysis), revealing that even ambitious target improvements were insufficient to mitigate farm income loss impacts in many cases. The same applied to reductions in land rental values.

8.3. Overall Modelling Concluding Remarks

There is a clear and substantial disconnect between the projections of the macro (CGE) and sector (PE-FAPRI) models and the farm level analysis. Both the CGE and PE estimates imply that UK Agriculture and its sectors can certainly survive, and in some cases clearly prosper under Brexit, even under the harshest (WTO) conditions. However, we should note that they do not model any short-run adjustment and adaptation costs; rather they reflect the effects of these changes on an on-going and more or less fully adjusted basis (with the *caveats* noted above). On the other hand, the farm level analysis clearly demonstrates that Brexit, especially the removal of direct payments, would be harmful for many farms, especially beef and sheep. The principal explanation of this critical difference is that the macro and sector level models reflect the major elements of structural adjustment within the industry (PE) and between the industry and the rest of the economy (CGE). In contrast, the farm level analysis ignores this structural adjustment and focuses on the impacts on existing farms. It is a critical shortfall in the analytic and simulation capacity of the applied economics profession, especially in the UK, that we do not have any computable models to bridge this gap, i.e. directly incorporating farm level impacts with consequent adjustment and structural changes in regional and national markets, both for factors of production (land, labour, management and capital), and inputs and outputs.[36] As a consequence, we are obliged to use a more traditional discursive approach to identifying and interpreting the implications, as in the following Chapter.

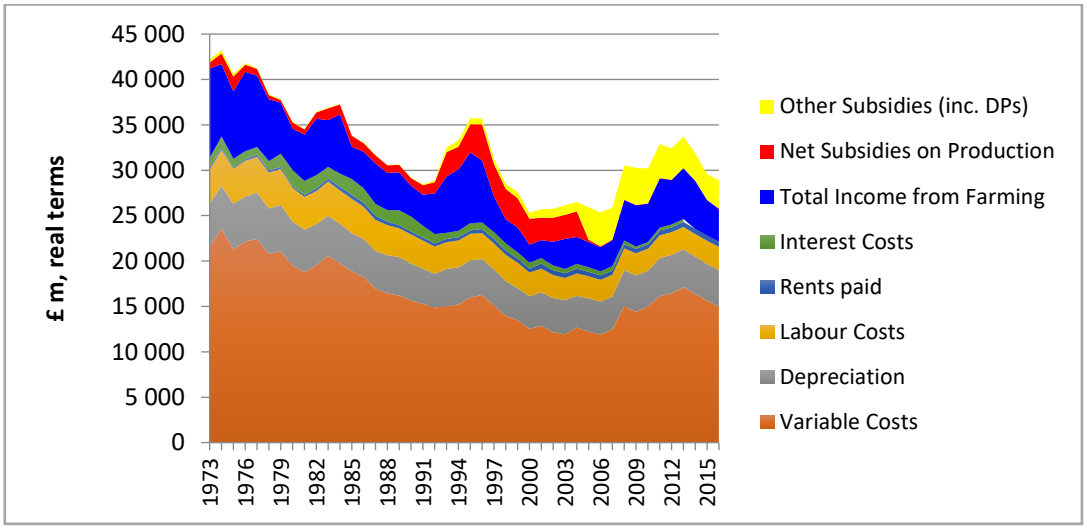
[35] Relaxation of this assumption is possible, but not within the life time of this project.

[36] At the EU level, the CAPRI model does attempt this bridge, capable of further development to include agent-based modeling approaches.

9. Historical changes in the UK Agriculture's Aggregate Accounts[37]

As a background to considering both the robustness and implications of our results for the development of future UK and devolved policies, it is instructive to remember the extent to which technical and structural change in UK agriculture (during our membership of the EEC/EU), and the outcomes (production revenues and returns) have shown substantial variations in the past. Figure 9.1 focuses on the economic accounts for UK agriculture as a whole, and shows the constituent parts of UK Agriculture's total revenues in real terms (Defra, Table 4.1 Production and income account in real terms; United Kingdom).

Figure 9.1: UK Agriculture's Total revenues and disposition, 1974-2016

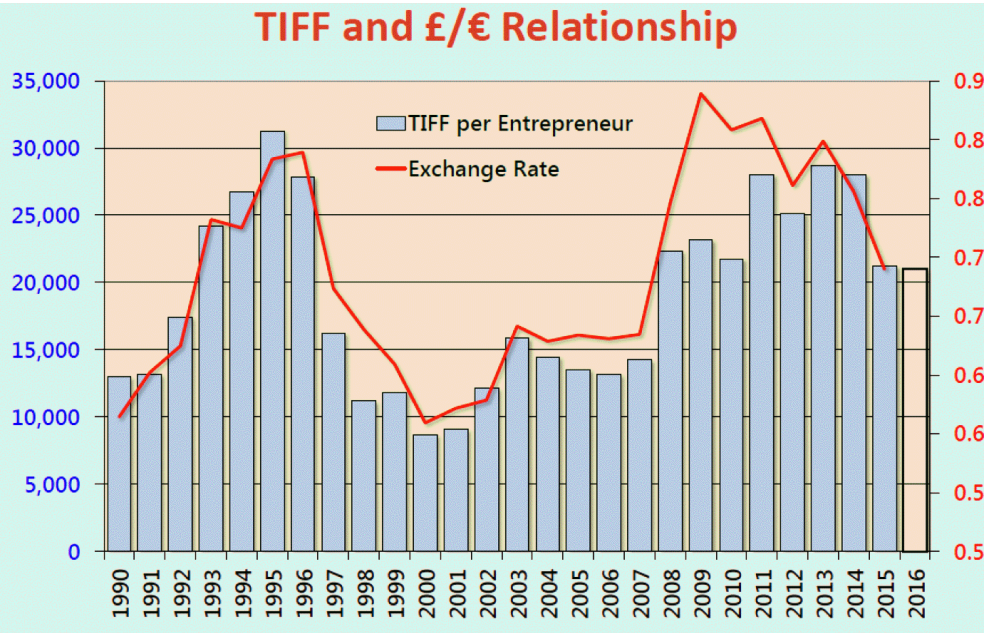


Two obvious features of this history stand out. First, the substantial variation in the real value of total revenues, and thus, to a lesser extent, the constituent parts, but exaggerated in the residual 'total income from farming' (TIFF). Second, an apparent general downward trend in total revenues, albeit with more or less erratic peaks and troughs, which again tends to be exaggerated in the trend in TIFF. However, this trend is also exaggerated by the starting date as 1973 was not only the beginning of the UK's accession to the EEC and the CAP, but also a period of unprecedentedly high world prices. These spiked massively as a consequence of the coincidence of several compounding events: the breakdown of the Bretton Woods fixed exchange rate regime in 1971 and the collapse of the $ (and £); the spike in world grain prices following unexpectedly large USSR purchases of grain from North America in 1972; the OPEC oil crisis in 1973. In real terms, 1973 saw the post war record in UK agriculture's total revenues. The coincidence of the UK's entry to the EEC in the same year arguably led to an over intensification and capitalisation in the agricultural industry, which may still be unwinding.

[37] This section was written by David Harvey.

At least more recently, one of the key factors explaining the variation in total revenues, exaggerated in TIFF, is the exchange rate. In particular, the notable spike in the real value of revenues and TIFF in the mid-1990s coincides with the (temporary) collapse of sterling following its exit from the European Monetary Union (EMU) in September 1992. Figure 9.2, shows how TIFF per farmer, accounting for the change in farmer numbers as well as changes in the overall total, has varied with the £/€ exchange rate since the 1990.[38]

Figure 9.2



The exchange rate conditions both input and output prices, since the UK is completely open to product and input trade influences from the EU over this period, while the protection afforded by EU tariffs on trade with the rest of the world has also been declining to relatively low levels over this period. The exchange rate also conditions the value of the DPs, albeit with a lag, since the total value of the DPs is set in €, but paid in sterling. While there are also variations in both yields and quality of products, as well as in the real costs of producing and marketing, which also contribute to the variations in revenues and costs, and hence in exaggerated form, in TIFF, these tend to be of second order to the variation in world prices, as reflected through the exchange rate, especially since the removal of many of the CAP's product tariffs and replacement with, first area and headage payments in 1994/5, and subsequently with DPs in 2004/5. As Figure 9.1 illustrates, the real value of subsidies under the CAP increased substantially in the 1990s, mostly reflecting the exchange rate. The import protection offered by substantial EU import levies was largely removed in 1994 under the MacSharry reforms (except, notably, for dairy products and beef, albeit that these are also subject to considerable TRQs, allowing preferential imports without tariff protection).

[38] Redman, G. (2016), the Andersons Centre, available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/536626/AUK2016_presentationsam11jul16.pdf,

These early CAP reforms coincided with the eventual conclusion of the Uruguay Round of GATT negotiations, to be largely replaced with fixed area and headage payments, subsequently replaced with the Single Payment Scheme (DPs) in 2003/4. The history of the development of UK Agriculture, encapsulated in Figure 9.1, is instructive in considering the consequences of the removal of Direct Payments (DPs). However, the period between 2007 and 2016 may be taken as reasonably representative of the current condition of the industry (Table 9.1).

Table 9.1. Relative levels and variations in UK Agriculture's Revenues & Disposition 2007-16

	2007/16 average (£bn, real)	St. Dev
Total Output	24.00	2.4 (10%)
Variable Costs	15.36	1.3 (9%)
Gross Value Added	8.45	1.1 (13%)
Subsidies	*3.48*	*0.4 (11%)*
GVA at Factor cost	**11.93**	**1.0 (9%)**
Depreciation	4.00	0.2 (5%)
Labour Costs	2.47	0.06 (2%)
Rents paid	0.52	0.04 (9%)
Interest Charges	0.36	0.08 (22%)
Total Income from Farming (TIFF)	**4.48**	**0.8719%)**

The GVA at factor cost (including subsidies) is, in effect, the realised gross margin of the UK farm, which over this 10 year-period has varied by +/- 9%. The average real value of subsidies over this period is £3.5bn, +/- £0.4bn, (of which £2.5bn Direct Payments). Notice that the value of the direct payments is practically equivalent to the variation in the value of total output over this period, at +/- £2.4bn, which might suggest that UK agriculture is already well able to cope with removal of these payments. However, there is a considerable difference between plus **or** minus and simply minus (which is what removal of DPs means). Nevertheless, it is apparent that UK agriculture has managed to cope with, if not thrive, in the face of very substantial variations, and reductions in total gross margins over time, which needs to be borne in mind when considering the possible effects of the removal of DPs. In particular, while the claims on the industry's gross margin from hired labour, landlords and creditors have to be settled immediately, the capital depreciation charges are more notional than actual. The depreciation figure in Table 9.1. is estimated on the basis of 'normal' replacement periods for the different forms of physical capital and breeding livestock. While some of these costs need to be met on a regular basis for the survival of the business, many can be postponed until financial conditions are better. The depreciation charge of £4bn is more than enough to cope with swings in the gross margin of +/-£1.1bn.

Furthermore, we also need to consider the extent to which UK agriculture is already under pressure to adapt, adjust and innovate to meet future market conditions. The total income from farming at an average of £4.5bn (+/- 19%) is what remains after allowance for the replacement of live and deadstock capital (depreciation), after paying for hired labour, paying rents and interest charges. As such, it represents returns to farmers' own labour and management, owned (rather than borrowed) capital and owned (rather than rented) land. But is it enough?

The industry's labour cost of £2.47bn is paid to 72k full time, 42k part time and 63k casual or seasonal workers[39]. Assuming that part-time means half time, and casual averages 20%, average annual wages per worker are £23,300. On the same basis, there are 217,000 full time equivalent farmers (including partners) trying to earn a living from farming, which implies that they need in total just over £5bn to earn as much as their own workers, cf. £4.5bn as their total income from farming, without considering any return to management. In effect, farmers' own equity capital, excluding land, which should earn about £6bn if it is to match the interest payments on borrowed non-land capital, is earning nothing. Owned land, which should also be earning rents equivalent to those being paid to landlords (approximately £1.2bn) is also being farmed for nothing, apart from any capital gains.

In other words, UK Agriculture is currently running at a substantial economic loss, of the order of £7.7bn a year, 65% of its gross margin (gross value added), even with the current level of subsidy. This is not sustainable, and is already resulting in substantial structural and technical change as farmers and their households seek to secure their own futures. Hence, fewer people will be able to earn a full time living from farming in the future, whatever happens to policy or markets, and that structural change will continue to occur.

Removal of direct payments, and increased opportunities to provide and be paid for environmental management will reinforce existing competitive pressures on the industry and redirect its efforts towards products and services demanded by both the public and private sectors. Indeed, it is probable that farmers' support for Brexit, despite the apparent levels of support provided by the EU's CAP, stems for the realisation that both the level and the mechanism for support (the DPs) are frustrating plans for improving the viability and prosperity of their business. Not only do these payments encourage some to remain in farming rather than seek other ways of making a living, but they also encourage landlords, suppliers of capital goods and inputs and others to take advantage of the apparent 'cushion' that these payments provide, while also reducing the pressure on the marketing chains to ensure a sustainable living and business returns to their suppliers (the farmers).

In short, pumping £2.5bn a year into a competitive agricultural sector inevitably results in these payments being dissipated up and down the supply and marketing chains, rather than remaining in farmers' pockets. Adjustment and adaptation to the removal of these payments will similarly be dissipated up and down the supply and marketing chains. While comparing the total payments to the total income from farming suggests that their removal will be a traumatic 'hit' of 50%, a more appropriate comparison is with the total output, where a 10% reduction is well within the 'normal' variation in revenues.

It is often supposed that exposing the agricultural industry to purely competitive forces, without any protection and support (as an extreme Brexit scenario approximated here as the unilateral free trade without any DPs) would necessarily lead, on one hand, to concentration in fewer and much larger farms, intensification and industrialisation or, in more remote and less favourable areas, either ranching or abandonment, with a residual of hobby farms on the other hand.

[39] Average numbers from 2010 to 2015, from: https://www.gov.uk/government/statistical-data-sets/agriculture-in-the-united-kingdom

10. Policy Implications and Conclusion[40]

10.1 Key implications of selected trade and domestic policy scenarios

1. Brexit would have significant implications for UK agriculture, a sector with strong trade links to the EU and reliance on CAP income support. Moreover, the impact will be far from uniform, with large variation across the sectors and the devolved administrations.

2. The consequences of Brexit for UK agriculture will depend upon (at least) two major factors: trade agreements or the lack of them and changes in domestic policy agricultural policy, i.e. changes in domestic agricultural policy, i.e. retaining or maintaining of direct payments.

3. Trade negotiations with the EU and the RoW will be paramount, and the impact of trade agreements on the sector is conditioned by the degree of trade competitiveness (i.e. relative tariffs) and trade openness. It also depends on the status of the sub-sector concerned (e.g., beef, sheep, dairy, pigs, poultry, wheat and barley) and whether the UK is a net importer or net exporter of specific commodities.

4. The trade effects, however, might be overshadowed by the exchange rate and possible labour market changes and other non-tariff barriers (not addressed here). However, the lack of concrete policy decisions and the uncertainty that surrounds the terms of negotiations with the EU (at the time of writing this report) make it very difficult for farm business planning.

5. Across all the scenarios considered Brexit has a negative impact on UK Gross Domestic Product. A reversion to WTO under most favoured nation (MFN) tariff schedules reduces it the most, circa 0.4 percent per annum on average, whereas UTL reduces it the least, 0.22 percent per annum on average. The removal of direct payments is beneficial to the UK economic growth, although negligible.

6. In macroeconomic terms the impacts that arise from the scenarios are relatively small. This is because average tariffs in the wider economy between the UK and EU, as well as the assumed trade cost increases, are only moderate for the majority of UK economic activities. In those scenarios where larger tariffs and/or trade cost shocks occur, these effects are typically restricted to agrifood industries, which constitute only a small share of the UK GDP.

7. At the sector level, different sectors will be affected in various ways according to the different trade scenarios. Even a relatively 'soft' Brexit, a free trade agreement with the EU close to current arrangements (i.e. *FTA+*), would create some disruption to trade flows, albeit with estimated market impacts that are relatively small. The market impacts are mainly due to the introduction of an assumed increase in UK and EU trade facilitation costs (to capture the UK's loss of access to the single market), which leads to changes in the UK terms of trade.

[40] This chapter was written by Andrew Moxey, David Harvey and Carmen Hubbard.

8. These are, however, mitigated by the removal of UK-RoW tariffs (UTL scenario) or amplified by the adoption of the current EU schedule of WTO MFN tariffs (WTO scenario). In the case of products where the UK is a net importer (e.g. beef) the imposition of tariffs reduces the competitiveness of the imported product resulting in higher domestic producer prices in the UK. The converse applies for products where the UK is a net exporter (e.g. lamb) to the EU.

9. Given the dependence of many UK farms on direct payments, their removal, predictably, worsens the negative impacts of new trade arrangements and off-sets positive impacts. The elimination of direct payments will affect most farm businesses but the magnitude varies by farm type and devolved administration.

10. The negative impact on farm business income is reflected across all trade scenarios, especially UTL *with or without* direct payments. Average farm income varies significantly across the devolved administrations and by farm type, with most farms worse off (relative to the Baseline) under all scenarios but one, *WTO+*. Noticeably, under this scenario dairy farms will particularly benefit as their average farm income could almost triple as compared to the Baseline scenario. Beef and sheep farms will be the most affected under *UTL-*.

11. Our extreme free trade scenario (UTL) leads to some striking results regarding farm income distribution. Whereas 15-20 percent of the farms were not making any money at all (even in the Baseline scenario), this rises to 45 percent under the UTL scenario with direct payments still in place (*UTL+*). The elimination of direct payments further increases this figure to 70 percent under *UTL-*.

12. Subsidies are a crucial component of farm business income across the UK and removal of direct payments could have significant implications for the sector as a whole. For example, there could be land use changes and restructuring, involving some farms, particularly smaller enterprises, going out of business. There may be particularly significant effects for upland farms which depend on subsidies to a greater extent.

13. Price projections, direct payments and off-farm income, largely influence variability in the levels of viability, sustainability and vulnerability across farm types and between the devolved administrations. Especially, given the substantial contribution of CAP direct payments to farm income, their removal amplifies farm vulnerability. Furthermore, the combination of trade liberalisation and removal of Pillar 1 direct payments increases the proportion of vulnerable farms. Hence, the presence of off-farm income is critical in safe-guarding the economic welfare of most UK farm households.

14. Brexit, under any scenario, could have significant effects for UK agricultural producers, exporters and consumers.

15. For producers, removal of agricultural subsidies will affect most farm businesses, but effects will vary by sector, region and devolved governments. Arable and dairy farms may be relatively unaffected whereas sheep and beef producers in more remote locations such as the Scottish uplands most likely to be affected and many may struggle to survive. Under Free Trade

Agreement with the EU agricultural impacts are modest but by contrast under UTL there are significant. Adoption of the World Trade Agreement tariff schedule favours some net importer sectors such as dairy.

16. For exporters, any exports from the UK to the EU and Rest of the World would be required to meet the product and provenance standards of the importing country. Adoption of the WTO current EU tariff schedule harms some export sectors such as sheep.

17. For consumers, prices will depend not only on the tariff schedule put in place in the UK, but also the value of the pound in foreign exchange markets. A fall back to WTO MFN terms would increase significantly domestic food prices which would particularly affect those with least disposable income. For example, under *WTO+,* estimates for the meat sector and food processing are particularly high compared with the Baseline, e.g. 7.3 percent and 3.7 percent increase in retail prices, respectively. Lower (or no) tariffs could leave food prices unchanged or lower, so benefiting consumers, at least in the short term. While the UK would be free to negotiate new trade deals worldwide this is a complex process that could be a lengthy and disruptive.

10.2. Overarching Policy Implications and Conclusions

18. British farming has been shaped by policy interventions since well before joining the CAP in 1973. Measures have included various forms of price support and input subsides plus knowledge transfer and public research and development activities. As a result, the diverse patterns of resource allocation, production and countryside management are different from what they would have otherwise been. Critics have frequently cited, on the one hand, poor productivity/competitiveness and low farm incomes, and on the other hand, environmental degradation, as evidence of market distortions and perverse policy outcomes.

19. Continuing reform of the CAP, typically with strong support from the UK, has gone some way towards addressing such criticisms. However, the UK's position on CAP reform has generally been that these reforms have not gone nearly far enough. Brexit provides a great opportunity for change. This is reflected in policy consultations and statements from each agricultural administration across the UK, albeit with some differences of emphasis. Cardiff and London have signalled a clear intent to abolish direct payments and instead to focus attention on raising productivity (on-farm but also along supply-chains) and enhancing the delivery of wider ecosystem services, by rewarding farmers for the provision of 'public goods'. Belfast and Edinburgh also seek to enhance competitiveness and environmental performance, but are more cautious about completely and rapidly abandoning direct payments.

20. To a certain extent, these differences in emphasis reflect geographical variation in the structure, composition and relative importance of agriculture and associated supply-chains. For example: agriculture and food manufacturing account for lower shares of GVA and employment in England than elsewhere; arable farming is more prevalent in England than elsewhere; Scotland has more extensive rough grazing land than elsewhere.

21. These differences also reflect variation in the perceived effectiveness of policy instruments and/or what is regarded as tolerable transitional disruption between current and future positions. For example, removal of direct payments will expose farm incomes to full market pressures, which may encourage structural adjustment. However, if too rapid or unassisted, such adjustments may cause unwelcome volatility in supply-chains, discontinuity in environmental land management, undesirable changes across rural communities, and unnecessary, perhaps even inefficient, structural change. Any choice of policy instruments among the devolved administrations will also be constrained by available budgets and acceptability to trading partners.

22. Indeed, the EU represents all member states in all WTO affairs. However, the UK is a member of the WTO and does not have to renegotiate its membership once outside the EU. But it will need to negotiate its "own commitments" (e.g. access to imports of goods and services from other WTO members and farm subsidies) which currently are embodied within the EU as a whole.[41] However, this process provides an opportunity for other WTO members to exert pressure on the UK to adjust domestic and trade policies – as a precursor to bilateral negotiations for any subsequent free-trade agreements. Likely points of concern include the allocation and treatment of TRQs for agricultural products, and also the applicability and size of the UK's Amber, Blue and Green boxes[42].

23. Governing the budgetary size of Amber box policies in particular will be crucial. For example, whilst it is possible that the UK will be granted an Amber Box proportionate to its share of the current EU level, this is not guaranteed. Nor indeed is the willingness of other WTO members to accept an increase in coupled support even if still within Amber box levels, since this would not be in the spirit of the Agreement on Agriculture (AoA).

24. The WTO focus is on reducing trade distortions.[43] Consequently, even if any part of the UK wanted to, the scope for using coupled support may well be constrained by WTO, with even the split of the present implicit UK ceiling between the four administrations possibly proving controversial.

25. Significant use of the Amber Box has not been proposed by any part of the UK, but could nonetheless be required if policy instruments are viewed by other WTO members as incompatible with Green Box classification. However, given evidence that they are not entirely decoupled, the UK's use of continued Pillar 1-type direct payments could be subject to challenge. This may well

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[41] Ungphakorn, P (2018), Chapter 2: In the event of a no deal Brexit, can the UK just fall back on WTO terms? in UK in Changing Europe's Report on ' What would 'trading on WTO terms' mean for the UK?, available at https://ukandeu.ac.uk/new-report-explains-what-trading-on-wto-terms-would-mean/, last accessed 24th February 2019.

[42] Amber Box includes support measures (e.g. price support, input subsidies and export subsidies) that are production and trade distortive. They are subject to limits: '*de minimis*' or minimal supports are allowed, generally 5% of agricultural production for developed countries, 10% for developing countries. The Blue Box includes amber-type support measures that distort production (e.g. payments per unit of land or number of animals). The Green Box includes subsidies that do not distort trade and are decoupled from production, e.g. direct income support for farmers and environmental payments; https://www.wto.org/english/tratop_e/agric_e/agboxes_e.htm, last accessed 26th February, 2019.

[43] Whilst intra-EU trade flows are beyond WTO scrutiny, once the UK has left, the volume of some trade flows (e.g. sheep and beef) between the UK and EU27 could become viewed as trade distortionary, hence attracting challenges from other WTO members.

be encouraged by the reduced heft of an independent country relative to that of the EU, with an independent UK being an inviting 'stalking horse' for WTO members to pursue in their continued efforts to change the CAP and associated support systems and continued trade protection. Similarly, the Green Box eligibility of agri-environmental schemes may also be questioned.

26. Under AoA, payments for agri-environmental schemes are restricted to cover costs incurred or income foregone, and schemes cannot be trade distorting. Release from the CAP does not remove the need to comply with these obligations. Yet policy statements (especially from Cardiff and London) suggest that these payment rates will be increased beyond those currently used. Whilst it is possible that some payment inflation might be achieved through more creative interpretation[44] of AoA rules, demonstrably moving beyond income foregone or costs incurred will attract challenges, particularly if a significant degree of joint agricultural production is involved.

27. Moreover, examples of existing schemes with relatively high payment rates may not necessarily signal scope for the expansion of such an approach. For instance, schemes under the CAP may have been protected from challenge by the EU's negotiating weight in the WTO. Equally, existing generous schemes (mainly under the new payment-by-results (PBR) model) are relatively small-scale and may not have attracted the attention of WTO members, or if they did have been judged too small to be trade distortionary: scaling them up across the UK could well alter their perceived relevance.

28. If Green Box eligibility was challenged, deployment of stated policy support might need to fall wholly or partially under the Amber Box. For example, agri-environmental payments might comprise a basic payment calculated under AoA rules, but with an area[45] or headage top-up under the Amber Box. If use of the Amber Box is constrained, the Blue Box could possibly be utilised through imposing some form of scheme membership quota. The current UK share of the EU's '*de minimis'* WTO provisions (on Amber Box) seems sufficient for covering future spending on agriculture at levels currently envisaged. Ungphakorn (2018:28) points out that for its 'own separate WTO commitments on goods, the UK is proposing a trade-distorting limit of support of €5.9 billion'.

29. Within the UK, agriculture is a devolved policy area. Consequently, despite currently all being under the CAP, the four UK constituent nations have adopted slightly different policy approaches. This applies both to how Pillar 1 support (e.g. direct payments) have been implemented but also to how Pillar 2 support (e.g. environment, structural support and rural development) has been distributed. For example, decoupled area payment rates and the use of capping/tiering vary, as do compliance requirements, whilst the level and focus of agri-environmental funding differs. This reflects variation in available budgets but also differences in regional priorities. For example, Scotland has retained Less Favoured Area funding and has deployed coupled headage payments.

[44] For example, whole-farm costs or transfer wages from off-farm employment, or simply just more generous allowances for materials, effort and displaced output; again, however, WTO acceptance of such creativity would probably have been easier as part of the EU than in isolation.

[45] An area payment might remain Green Box, depending on what WTO members choose to challenge and what the EU chooses to defend alongside the UK.

30. Different political priorities and visions are apparent in published policy statements and consultation documents, but the extent to which responsibility will continue to be devolved remains unclear. In particular, at least in the first instance, the allocation of funding and the scope for deploying particular forms of support (e.g. coupled payments) may be determined centrally by London in an attempt to retain a common framework (level playing field) across the UK. This may well be necessary to avoid possible internal market distortions conferring competitive advantage to one region.

31. The UK Agriculture Bill provides little detail on the common framework, but the continuing standoff between Edinburgh and London over how devolved powers should be repatriated from Brussels means that these issues add a further layer of uncertainty to policy formulation (as illustrated by Scotland's absence from the UK Agriculture Bill).

32. Irrespective of the international or domestic constraints on their adoption, our modelling results suggest that different policy options raise a number of issues. In particular, our farm-level analysis implies significant pressure for structural adjustment as and when direct payments are eliminated. The immediate impacts on farm income are such that farm businesses and households would be expected to react by seeking to improve on-farm efficiency and/or search for alternative income sources, in some cases by leaving farming.

33. Although our models do not provide any explicit outcomes about the likely nature of structural change, the national (CGE) and sectoral (FAPRI) models imply that structural adjustment will continue to occur, leading to resource reallocations and changes in the level and composition of output. Such structural adjustment has implications in terms of the availability of raw materials for food manufacturing, levels of local economic activity and environmental impacts, all of which may lead to demands for further policy responses.

34. For example, reduced volumes of sheep and beef cattle might undermine the viability of the red meat processing sector. Conversely, increased dairying, or an increased availability of cheaper imported raw materials, may enhance opportunities in other sectors. In either case, the process of shifting resources between uses may require policy action to mitigate (social) disruption and encourage new development (both of which extend beyond the reach of agri-environmental policy alone).

35. Similarly, changes in agricultural land use may relieve environmental pressures, such as over-grazing, in some locations whilst increasing pressures, such as air and water pollution, in others. Again, this suggests that policy action may be needed to manage such transitions. Indeed, the theme of "public money for public goods" in the Agriculture Bill implies that (agri-environmental) policy might be expected to guide change processes (but, as noted above, this may be constrained by WTO rules).

36. The demand (and supply) for agricultural labour will change, possibly increasing in some sectors under a WTO scenario but declining overall under a unilateral scenario. Given that the capacity of farmers and farm workers to switch between different agricultural enterprises or into non-

farm activities may be constrained by skills and location-specific opportunities, there may be a policy need to assist labour reallocations and restructuring, for example, through advice and training or assistance with commuting/relocation or retirement. Again, this extends beyond the remit of agricultural policy alone.

37. However, the dynamics of how adjustment might be achieved have not been modelled explicitly in this research. That is, whilst the national and sectoral results reflect changes to resource allocation and production patterns, the processes by which change comes about are not considered. The implicit changes in allocation (structural adjustment) are reflected in these macro and sector level models by their internal logical specification and trend responses based on historical data. Similarly, although ScotFarm allows for some resource adjustment at the farm level, and some of our income-distribution analysis includes changes in efficiency and factor prices, the farm-level analysis takes no account of (local) availability of resources or markets.

38. Yet, in addition to the ease with which labour can be redeployed, structural adjustment also depends upon the ease with which other resources, such as land, can switch between uses and, again, encouragement may be required from wider policy support. For example, planning regulations may slow land transfers out of agriculture and the availability of land to farmers wishing to expand their operations may be impeded by other influences on land markets, such as taxation regimes and tenancy laws.

39. It is also the case that land varies considerably in terms of its suitability for different uses (agricultural or otherwise) and hence the opportunity for redeployment varies. This highlights the importance of the uneven geographical distribution of impacts, both between and within the four nations of the UK, and the associated implications for rural communities in different locations.

40. Raising agricultural productivity closer to the all-economy average will require reallocating less productive resources (e.g., poor quality land, unskilled labour) to other uses including provision of public goods) and utilising remaining resources more effectively. Our sensitivity analysis at the farm level shows that, for example, by increasing productivity by 10 percent across beef and sheep will indeed lead to a sizeable increase to in farm business income under all trade scenarios. However, this improvement in productivity would not be sufficient to offset the removal of direct payments nor the projected price decline under UTL.

41. Nevertheless, the capacity of the farming industry to adjust depends critically on both the confidence and the capability of farmers and their businesses to adapt and innovate. Confidence depends on expectations about the future, which ongoing Brexit negotiations currently seriously undermine. While the future direction of domestic policy has been reasonably signalled with the publication and current parliamentary and public scrutiny of the Agriculture Bill, the UK agriculture and food sectors' future trading relations remain highly uncertain.

42. The Environment, Food and Rural Affairs Committee of the House of Commons (EFRA) has also been scrutinising the Agriculture Bill, in parallel with the Committee stage of the Bill through Parliament. EFRA's report echoes and amplifies the concerns that phased reduction of DPs should not begin until both trade arrangements and future Environmental Land Management Schemes

are in place, in order to establish the necessary confidence to adjust and adapt, and stresses the need for a multiannual financial framework to further assist in confidence building.

43. The EFRA report also notes that insufficient attention has yet been paid to the balance between agricultural production and the environment, and that the prioritisation of the several and various public goods to be supplied with the payment of public money is not either specified or provided with clear 'control' mechanisms, which reduces both the confidence and capability of the industry to respond appropriately. EFRA, echoing the NFU, is also concerned that the Bill makes no reference to the defence of current UK quality and production standards in any future trade agreements, especially since this is not (yet) incorporated in the Trade Bill.

44. Similarly, EFRA notes that the intention to ensure fairness along the food supply chains is welcome, but strongly suggests that this should be entrusted to the existing Groceries Code Adjudicator (with sufficiently widened remit, resources and powers), rather than, as in the Bill, to the Rural Payments Agency, whose competence and reliability does not claim any confidence amongst producers.

45. There is an obvious contrast between our farm level analysis and the analysis at the sector and macro level. The former implies considerable hardship for many farm families and their rural communities, especially from the discontinuation of direct payment support without any offsetting payments for public goods (or penalties for public bads). The impacts of removal of DPs is also, in some cases, exaggerated by the projected price changes arising from changes in trade relations following Brexit. The latter, however, notwithstanding rather modest differences between the sector (PE) and industry/macro (CGE) projections.

46. As noted above, the explanation of this critical difference is that the sector and macro models include some reflection of structural adjustment, based on historic patterns and calibration to historic trends, while the farm level analysis ignores structural adjustment and adaptation. Many of these adjustments are difficult to identify, though agricultural rents are often advanced as a salient example of the potential effect of removal of direct payments. As also noted above, there is considerable debate, and hence uncertainty, about the extent to which DPs have already been 'capitalised' in farm rents, though this has probably been underestimated in our CGE model specification.

47. It is often supposed that exposing the agricultural industry to purely competitive forces, without any protection and support (as an extreme Brexit scenario approximated here as the unilateral free trade without any DPs) would necessarily lead, on one hand, to concentration in fewer and much larger farms, intensification and industrialisation or, in more remote and less favourable areas, either ranching or abandonment, with a residual of hobby farms on the other hand.

48. This, indeed, tends to be the outcome of textbook economic models of maximising profits in purely competitive markets, where all products are essentially homogeneous (as commodities) and more or less perfectly substitutable from whatever source of provenance, supplemented by a recognition that farming lifestyle is sufficiently attractive that some people are content to be 'farmers' as a way of life, rather than a way of making a living. Our CGE model, through its

Armington assumption, recognises that the domestic demand for commodities exhibits some differentiated preferences for one source over another, at least at the international level. Nevertheless, within the domestic economy, no allowance is made for the differentiation of commodities into products.

49. However, there are other areas that cannot be fixed by increased spending from the UK government, e.g. rules of origin, organic certification, geographical indications, if the UK will fall back on WTO terms. For example, a certification black hole is a key problem for UK farming flagged up by the first tranche of the Government's technical papers. Only organic food and drink exporters certified by an organic control body approved by the European Commission would be legally allowed to export to EU countries. But a certification process usually takes up to nine months to complete. This disruption could be substantial and, for some export businesses heavily reliant on trade with the EU, potentially existential. Regarding geographical indications, UK producers were warned that they may have to re-apply for protection if the EU requires, but there is no guarantee that this will be an easy and straightforward process. These topics were beyond the remit of this research.

50. We are confident that UK Agriculture can and will generally survive, and that parts of it will be able to thrive after Brexit. But we are also certain that Brexit and taking back control of UK (and devolved administrations) agricultural, food and rural environment policies presents major challenges to our policy making machinery and procedures, and to the research communities responsible for generating the necessary evidence on which to base sustainable policies.

11. References

Boulanger, P. and Philippidis, G. (2015) The EU Budget Battle: Assessing the Trade and Welfare Impacts of CAP Budgetary Reform, *Food Policy,* 51, pp119-130.

Boulanger, P. and Philippidis, G. (2015). The End of a Romance? A Note on the Quantitative Impacts of a 'Brexit' from the EU. *Journal of Agricultural Economics,* 66 (3), 832-842.

Boulanger, P., Philippidis, G. and Urban, K. (2017) Assessing potential coupling factors of European decoupled payments with the Modular Agricultural GeNeral Equilibrium Tool (MAGNET), Joint Research Centre Technical Report, EUR 28626 EN. Luxembourg (Luxembourg): Publications Office of the European Union; 2017. JRC104276 https://ec.europa.eu/jrc/en/publication/assessing-potential-coupling-factors-european-decoupled-payments-modular-agricultural-general

Bradley, D. and Hill, B. (2017). Quantitative modelling for post-Brexit scenarios. Final report for AHDB, Agribusiness Consulting | Informa. Available at https://ahdb.org.uk/brexit/documents/Quantitative_Modelling_For_Post_Brexit_Scenarios-12oct17.pdf, last accessed 28 March 2018.

Bryne, R.(2018) The migrant labour shortage is already here, and agri-tech can't yet fill the gap, https://blogs.lse.ac.uk/brexit/2018/01/05/the-migrant-labour-shortage-is-already-here-and-agri-tech-cant-yet-fill-the-gap/, last accessed 10 December 2018.

Davis, J., Feng, S. and Patton, M. (2017). Impacts of Alternative Post-Brexit Trade Agreements on UK Agriculture: Sector Analysis using the FAPRI-UK Model, FAPRI – UK Project

Defra (2017). Government response to the House of Lords EU Energy and Environment Sub- Committee report into Brexit, Environment and Climate Change Policy, available at https://www.parliament.uk/documents/lords-committees/eu-energy-environment-subcommittee/Brexit-environment-climate-change/Gov-response-Brexit-env-climate.pdf, last accessed 30 April 2018.

Feng, S., Patton, M., Binfield, J., Davis, J. (2017). 'Deal' or 'No Deal'? Impacts of Alternative Post-Brexit Trade Agreements on UK Agriculture. *EuroChoices* 16 (3), 27-33.

Frawley, J.P., Commins, P. (1996). The changing structure of Irish farming: trends and prospects. Teagasc Dublin.

Gove, M. (2018) 'Farming for the next generation', speech at the Oxford Farming Conference, 4th January 2018, available at: https://www.ofc.org.uk/sites/ofc/files/papers/Farmingpercent20forpercent20thepercent20nextpercent20generationpercent20-percent20GOV.UK_.pdf; last accessed 28 March 2018.

House of Lords (2017). Brexit and Agriculture, the European Union Committee, HL Paper 169 https://publications.parliament.uk/pa/ld201617/ldselect/ldeucom/169/16902.htm, last accessed May 2017

Hazell, P. and Norton, R. (1986). Mathematical Programming for Economic Analysis in Agriculture. Macmillan, London.

Hennessy, T., Hynes, S. and Shrestha, S. (2008) The CAP Health Check: a potential reform of the Single Farm Payment? Research, 3 (2): 50-53.

Hennessy, T. and Moran, B. (2015). The viability of the Irish farming sector in 2015. Carlow, Ireland: Teagasc.

Harrison, W. J., Horridge, J. M., and Pearson, K. R. (2000) Decomposing Simulation Results with Respect to Exogenous Shocks, *Computational Economics*, Vol.15(3), pp. 227-249.

Kitou, E. and Philippidis, G. (2010) A Euro-Mediterranean Deal in Agro-Food and Fisheries Trade: Long Run Impacts in Greece, *Agricultural Economics Review*, v11(1), pp5-16.

Mishra, A.K., Sandretto, C.L. (2002). Stability of Farm Income and the Role of Nonfarm Income in U.S. Agriculture, *Applied Economic Perspectives and Policy 22*, 208–221.

Moss, J.E., Patton M., Zhang L., Kim In Seck, Binfield, J. and Westhoff, P. (2009) Impact of HM Treasury/Defra's Vision for the Common Agricultural Policy on Agriculture in the UK, UK-FAPRI Project, Working Paper No.16.

Narayanan, B., Aguiar, A. and McDougall, R. (2015). Global Trade, Assistance, and Production: The GTAP 9 Data Base, West Lafayette, Purdue University, available at: https://www.gtap.agecon.purdue.edu/databases/v9/v9_doco.asp

O'Donoghue, C., Devisme, S., Ryan, M., Conneely, R., Gillespie, P., Vrolijk, H. (2016). Farm economic sustainability in the European Union: A pilot study. *Studies in Agricultural Economics,* 118, 163-171

Philippidis, G., Renwick, A., Sanjuán, A.I. (2007) *Defra-TAP Tailoring the GTAP Model for Defra Project EPES 0607/08,* Technical Book for the Department of Environment, Food and Rural Affairs (DEFRA), UK Government.

Philippidis, G. & Karaca, O. (2009) The Economic Impacts of Turkish Accession to the European Union, *World Economy*, 32(12), pp1706-1729

Philippidis, G. and Kitou, E. (2012) Quantifying Opportunities and Threats: Examining the Canada-EU Trade Negotiations, *Journal of Economic Policy Reform*, **15** (4), 301-320.

Shrestha, S., Hennessy, T. & Hynes, S. (2007) The effect of decoupling on farming in Ireland: a regional analysis. Irish Journal of Agriculture and Food Research. 46, 1-13.

Shrestha, S., Gibbons, J. & Ramsden, S. (2004) Dairy farms in central England under climate change in 2050s: do they need to change? Abstract of Communications, Journal of Agricultural Science. 142: 246-247

Shrestha, S. (2017) ScotFarm – a farm level optimising model. Policy Analysis, Behaviour and Innovation Team (PABIT), Land economy, environment and society research group, Scotland's Rural College (SRUC). https://www.sruc.ac.uk/download/downloads/id/3513/scotfarm_%E2%80%93_a_farm_level_optimising_model.pdf

Shrestha, S., Thomson, S., Ahmadi, B. V & Barnes, A. (2018) Assessing the impacts of alternative post-Brexit trade and agricultural support policy scenarios on Scottish farming systems. Policy Analysis, Behaviour

and Innovation Team (PABIT), Land economy, environment and society research group, Scotland's Rural College (SRUC). ScotFarm Policy Report 1. https://www.sruc.ac.uk/downloads/file/3606/assessing_the_impacts_of_alternative_post-brexit_trade_and_agricultural_support_policy_scenarios_on_scottish_farming_systems

Swales, D., Macleod, J., Ashworth, S., Bell, J. & Bradley, D. (2017) Exploring the implications of Brexit for agriculture and horticulture in Scotland. AHDB. https://ahdb.org.uk/documents/Horizon_November2017.pdf

Ungphakorn, P (2018). 'In the event of a no deal Brexit, can the UK just fall back on WTO terms?', Chapter 2 in UK in Changing Europe's Report on ' What would 'trading on WTO terms' mean for the UK?, available at https://ukandeu.ac.uk/new-report-explains-what-trading-on-wto-terms-would-mean/, last accessed 24th February 2019.

van Berkum, R.A., Jongeneel, H.C.J., Vrolijk, M.G.A., van Leeuwen and Jager, J.H. (2016). *Implications of A UK Exit from the EU for UK Agriculture*, LEI Report 2016-046b (Study for the National Farmers' Union (NFU), Warwickshire, UK), LEI-Wageningen UR, The Hague. Available at https://www.nfuonline.com/assets/61142, last accessed 23 May 2018.

Vrolijk, H.C.J., De Bont, C., Blokland, P., Soboh, R. (2010). Farm viability in the European Union: Assessment of the impact of changes in farm payments. LEI Wageningen UR.