Discussion Paper – Assessing options for estimating carbon offshoring impacts of UK trade agreements in agriculture

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Contributed Paper prepared for presentation at the 97th Annual Conference of the Agricultural Economics Society, University of Warwick, United Kingdom

27 – 29 March 2023

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Acknowledgements

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Abstract

The UK has signed significant Free Trade Agreements (FTAs) since leaving the European Union. In some cases, these FTAs have included liberalisation on UK agricultural products, notably beef. The UK Government's published assessment of these agreements demonstrates that it expects some UK consumption to shift from domestic production to imports. Given the emissions associated with this sector, there is likely to be some offshoring of carbon emissions. This paper sets out a variety of options to estimate and monetise the emissions impacts of this agri-food liberalisation on both the UK and partner countries. We attempt to fully capture the range of global emissions sources, including both domestic and international production and international transport emissions. A recommended approach is set out. We test this approach on the UK's FTAs with Australia and New Zealand.

Keywords Trade, Modelling, Climate Change, Carbon Leakage

JEL code Agriculture Q1, Trade F1, Environmental Economics Q – see: www.aeaweb.org/jel/guide/jel.php?class=Q

1. Introduction

The UK government has signed significant FTAs since leaving the European Union and negotiations are underway to agree further trade deals. There is a growing interest in the impact of trade policy on global carbon emissions. In this paper, we examine a mechanism known as 'carbon offshoring'. This involves liberalisation generating reduced domestic production and increased production abroad, thereby 'offshoring' carbon emissions to partner countries. This paper examines options for estimating these offshoring effects in UK agricultural sectors, for use in analysis of FTAs.

We set out potential methodologies for estimating changes in global and country-level emissions. We test this approach on the UK's FTAs with Australia and New Zealand, with a specific focus on the beef sector. We use the beef sector as modelling suggests both FTAs could generate significant new imports in this sector and thus new production in both countries. Also, beef production is highly emissions-intensive and has the potential for deforestation. As such, it is a sector of key environmental interest in both agreements.

This paper starts with our methodology used to generate trade and production changes from FTAs. We then discuss methodologies used to calculate changes in emissions in both production and international transport. We then present our results, testing the approach on the UK's FTAs with Australia and New Zealand. Finally, we contextualise these changes using multiple approaches to monetise the impacts.

2. Methodology

i. Trade Modelling

For this analysis we have used a partial equilibrium model of trade, Petra. This is one of several trade models used by analysts across the UK government. We used Petra in this work to estimate changes in trade flows, production and consumption. Results from Petra were published as part of the government's Impact Assessments of both the Australia[1] and New Zealand[2] FTAs.

Petra is a 'static comparative' model of international trade, so its results do not have an explicit time dimension. The model is sensitive to key parameters, including demand and supply elasticities, in particular the 'Armington' elasticity on the demand side.

ii. Trade Scenarios

The trade scenarios used as the basis for this work are the UK Free Trade Agreements with both Australia and New Zealand. The UK-Australia FTA was signed in December 2021 and involves full liberalisation in beef imports from Year 15. The UK-New Zealand FTA was signed in February 2022 and also involves full liberalisation in beef imports from Year 15. To simulate these agreements, we input the 'medium-term' scenario of full liberalisation on trade in beef between the UK and both partners. This involves reducing bilateral tariffs to 0% and reducing non-tariff barriers to trade.

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[1] https://www.gov.uk/government/publications/uk-australia-fta-impact-assessment
[2] https://www.gov.uk/government/publications/uk-new-zealand-fta-impact-assessment

There is significant uncertainty around the size of the impacts of these FTAs. To represent this, we generate a range of results. This range comes from varying one of our parameters to demand, the Armington elasticity. This elasticity captures the willingness of UK consumers to replace consumption of UK beef with beef from abroad.

iii. Production Emissions

To calculate changes in production emissions in each country, we require two pieces of data. We combine estimates of changing production levels in each country from our trade modelling results, with estimates on emissions intensities to production in each country.

$$\Delta\ Production\ Emissions_i = \Delta\ Production_i \ .\ Intensity_i$$

Where:

- *Production emissions$_i$: tonnes of CO2e produced by country i*
- *Production: tonnes of production in country i*
- *Intensity: emissions intensity factor for country i, tonnes of CO2e per tonne of production*

We identified a range of estimates on emissions intensities for each region. Our recommended approach involves using farm-level emissions data, produced by the United Nations Food and Agriculture Organisation (FAO STAT)[3], and deforestation emissions intensity data produced by the Joint Nature Conservation Commission (JNCC)[4]. We consider each of these datasets to be the best available to cover their respective emission types for beef. By combining farm-level and deforestation emissions, we should be able to estimate the production and land-use emissions associated with rising production globally.

However, there are important caveats to this approach on production emissions. In particular, these estimates do not include full supply-chain emissions. For this, the FAO GLEAM dataset can provide further insight. This captures feed, internal transport, fertiliser and other emissions left out of the FAO STAT data. As such, we also produce alternative estimates of emissions changes using FAO Global Livestock Environmental Assessment Model (GLEAM[5]) intensity values. This data has its own caveats, in particular a lack of geographic granularity. As such, FAO GLEAM results are presented as an additional alternative perspective to the FAO STAT & JNCC approach.

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[3] https://www.fao.org/faostat/en/#data
[4] https://commodityfootprints.earth/
[5] https://www.fao.org/gleam/en/

Table 1: Beef production emissions for each country. Estimates shown for 3 datasets covering 3 different approaches and scopes. Units are tonnes of CO2-equivalent per tonne of beef.

Country	**On-Farm (FAOSTAT)** *2015-17 average*	**Lifecycle (FAO GLEAM)** *2017*	**Deforestation (JNCC)** *2016-18 average*
Australia	21.6	41.6	12.0
Brazil	34.9	87.3	33.3
EU	15.4	26.6	0
Mexico	27.1	87.3	4.0
New Zealand	15.2	41.6	0
UK	16.4	27	0
USA	12.2	31.2	0

These estimates indicate that a key difference in emissions intensities between these countries is that additional beef production is associated with deforestation in Australia, unlike in the UK, EU and New Zealand. The differences in 'on-farm' emission intensities also suggest that some extra emissions are generated within the farm gate, such as manure management system and enteric fermentation. However, the crucial difference for this analysis lies in the additional deforestation in Australian production.

iv. Consumption emissions

To calculate the change in UK consumption emissions, we use the quantity of UK consumption from each exporter before and after the FTA, produced in our trade modelling analysis. We combine these with each exporter's emission intensities to estimate consumption emissions from production & deforestation, and then add on estimates of international transport emissions on those trade flows.

$$\text{Consumption emissions}_{UK} = \sum \text{Imports}_{UK,j} \,.\, \text{Intensity}_{j} + \sum \text{International transport emissions}_{UK,j}$$

Where:

- *Consumption emissions: UK, tonnes of CO2e*
- *Imports: UK imports from country j, tonnes*
- *Intensity: emission intensities for country j, tonnes of CO2e per tonne of production*
- *International transport emissions: between UK and country j, tonnes of CO2e*

We compare the changes in UK consumption emissions with the changes in UK production emissions. This allows us to examine how much any reduction in UK production emissions are 'offshored' to Australia and New Zealand.

v. International transport emissions

For the transport of beef, the vast majority of additional exports from Australia and New Zealand to the UK are likely to be sea-freighted. However, a small minority of exports will likely be air freighted, which is significantly more emissions-intensive. As such, we estimate changes in transport emissions by both modes, where we assume that past trends on the share of air vs. sea-freighting on bilateral routes is maintained.

Table 2: Share of UK beef imports by source that are transported by air vs. sea. 2019-21 average.

Trade flow	Share of trade air-freighted	Share of trade sea-freighted
Australia to UK	5.4%	94.6%
New Zealand to UK	1.3%	98.7%

For estimating UK consumption emissions, we simply calculate the additional transport emissions on UK trade with Australia and New Zealand, minus the reduction in transport emissions with the EU. For calculating global beef emissions, we also incorporate the knock-on impacts of these FTAs on international transport emissions on routes with third-party countries.

We have not estimated changes in domestic transport emissions. These may be non-negligible for a large country such as Australia.

a. Sea-freight emissions

We have taken a micro approach to calculate the sea-freight emissions. We calculate the number of additional shipping containers and combine this with the distance they travel and the emissions factor of each container. The CERDI sea distance database[6] was used for the distances between countries, and an additional 15% was added to journey distance to account for detours. To calculate the number of additional containers, a 'stowage factor' was used to estimate the quantity of beef that fits into a shipping container.

We combine our trade flow changes with these values to give the number of additional containers. We then multiply this value by the adjusted distance and the respective Clean Cargo Working Group CO2e emissions factor.

b. Air freight emissions

We use the UK government's international freight flights emissions factor[7] to estimate air-freight emissions. We combine this with the air distance between trading partners[8] and the modelled change in trade that will be transported via air freight.

vi. Monetisation of CO2-equivalent emissions

Finally, we convert these CO2-equivalent[9] (CO2e) results into monetary values (£m), using two options for carbon valuation. Our lower bound estimate uses the OECD's carbon values

[6] https://ferdi.fr/en/indicators/the-cerdi-seadistance-database
[7] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022
[8] https://www.greatcirclemapper.net/en/great-circle-mapper.html?route=EGLL-YSSY&aircraft=&speed=
[9] Carbon dioxide equivalent or CO2e is defined as the number of metric tons of CO2 emissions with the same global warming potential as one metric ton of another Greenhouse Gas.

for 2030 of £100 per tonne of CO_2e[10]. Our upper bound estimate uses the UK government's Green Book central estimate for 2030 of carbon values of £280 per tonne of CO_2e[11]. The discrepancy reflects that these values are capturing different estimates. The OECD value is an estimate of the price of carbon that, if implemented globally by 2030, should have countries on track to reach the Paris Agreement's goals. This estimate only indirectly applies to agricultural products, as it is used across all economic sectors. The Green Book estimates are instead tailored to the UK's net zero target and non-traded sectors[12] such as agriculture. There is uncertainty over the trust cost of carbon, so using these two figures captures a range of this uncertainty. For simplicity, final results emphasise the 'upper bound' estimates as they are more specific to analysis of UK agriculture.

vii. Caveats to analysis

This analysis is uncertain. There are many limitations and caveats to these estimates, and so results should be interpreted as reflecting a broad direction of impact. One key uncertainty is the trade modelling, which struggles to simulate changes when the reduction in tariffs is so substantial and when existing trade is so low. A further uncertainty is in the production response in partner countries. The supply elasticities in our trade modelling are assumed at highly elastic levels, and these may not accurately represent the characteristics of domestic beef sectors. A further uncertainty is the emissions intensity of production in each country, as estimates vary substantially from year to year.

Also, the treatment of land use is overly simplistic, as we do not model land use change. To fully capture this, we would attempt to model the type of land that is brought into production in Australia and New Zealand, and the type of land taken out of production in the UK. We would then attempt to estimate the carbon impacts of the changing uses of this land. Instead, we calculate emissions using estimates of deforestation emissions associated with each additional tonne of beef production in each country.

Finally, carbon pricing estimates are uncertain. It is difficult to estimate the true social cost of emissions. However, we use two different prices at quite different levels from reputable sources to mitigate this uncertainty.

3. Results

i. Import changes

Our analysis using Petra shows that imports of beef are expected to rise from both Australia and New Zealand. The exact magnitude of this is uncertain, but our estimates vary from 28kt-132kt from Australia and 6kt-27kt from New Zealand. A significant amount of these rising imports will displace existing imports from the EU, which currently constitute almost all UK

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[10] https://www.oecd.org/tax/tax-policy/effective-carbon-rates-2021-0e8e24f5-en.htm

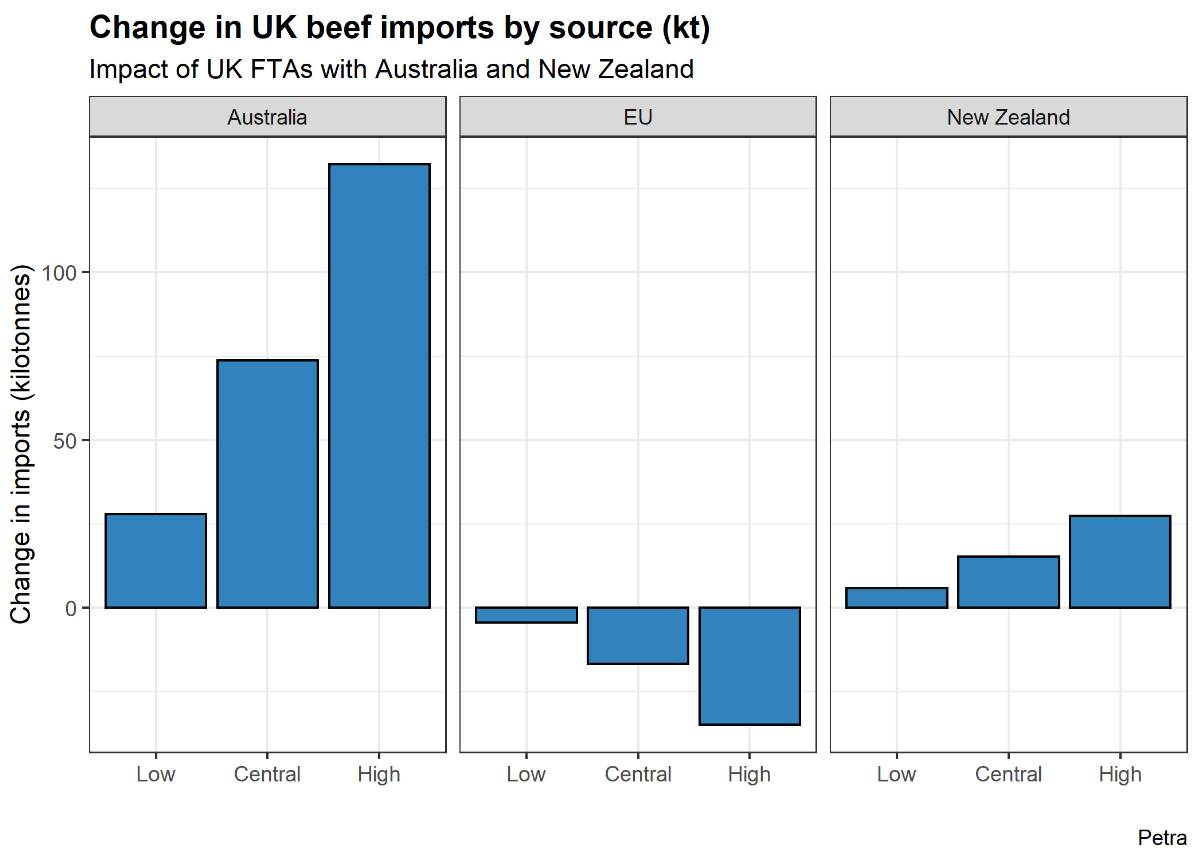
[11] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

[12] Sectors can be categorised into 'traded' and 'non-traded'. 'Traded' emissions capture those that come from sectors covered by a 'cap and trade' scheme.

beef imports. We estimate imports from the EU to fall by 4kt-35kt. Overall, total UK imports are expected to rise, with our range indicating this could be between 29kt-122kt.

Whilst the upper limits to these ranges are large, they do not represent the full range of possible outcomes. The quotas agreed in both agreements exceed the upper bound estimates identified here, at combined levels of 230kt in Year 15, so actual trade could exceed these ranges. Imports beyond the ranges shown here are possible, although we don't consider this outcome to be particularly likely.

Figure 1: Modelled changes in UK beef imports by source following FTAs. Changes in kilotonnes.

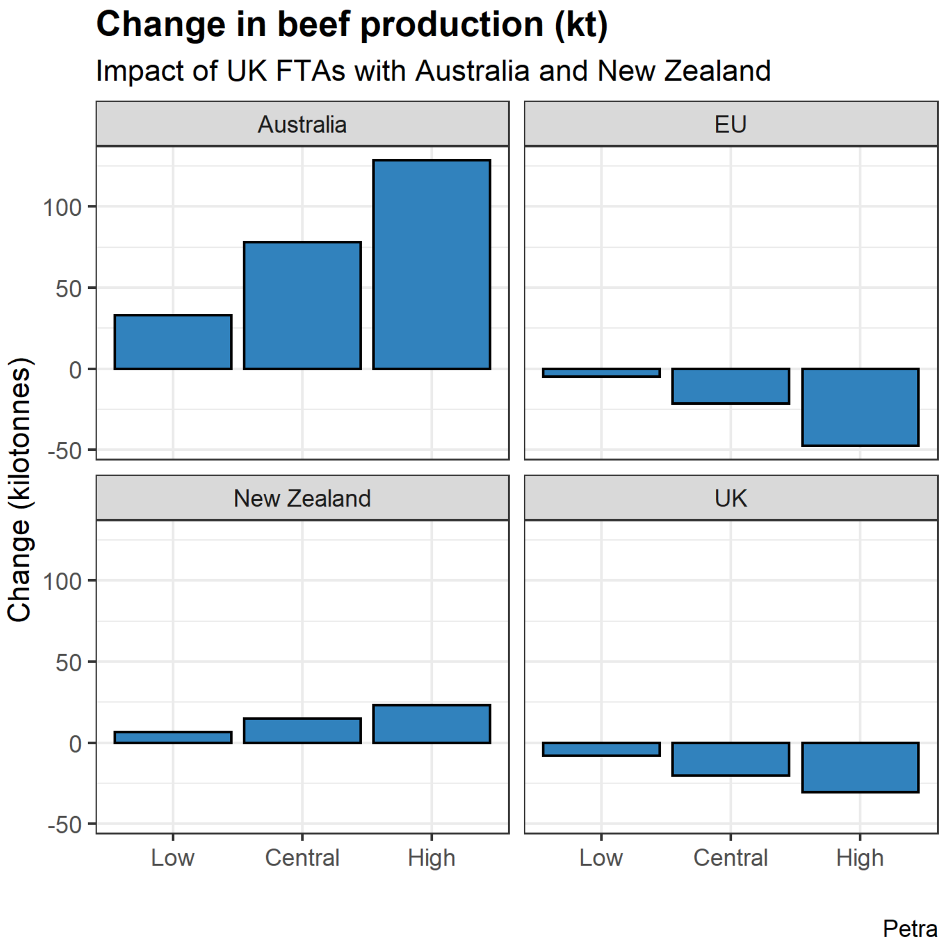


ii. Production changes

Our estimated changes in production closely track the changes in trade. Both Australia and New Zealand are expected to increase their output of beef to meet UK demand, although more significantly in Australia. We again find that the magnitude of this is uncertain and depends on various factors, including the level of UK demand for imported beef.

The analysis also shows that production is expected to fall in both the UK and EU. This reflects that UK consumption will be shifting away from almost-exclusively UK and EU beef to more diverse sources.

Figure 2: Modelled changes in beef production by relevant countries following FTAs. Changes in kilotonnes.



The changes in production quantities estimated here are large relative to the size of the trade being created. This is because Petra includes assumptions around key parameters, including the supply elasticity. Supply elasticities capture the responsiveness of production to changes in price, and in our model are assumed to be highly elastic (i.e. responsive). As such, changes in quantities of production tend to be significant in response to significant trade scenarios. If we assumed more inelastic supply, as econometric evidence indicates holds true especially in the UK, then production changes would be smaller and price impacts would increase.

iii. Emissions changes

We separate our estimates of emissions changes into 3 categories:

- on-farm & deforestation emissions
- international transport emissions
- total emissions

a. Country-level production & deforestation emissions

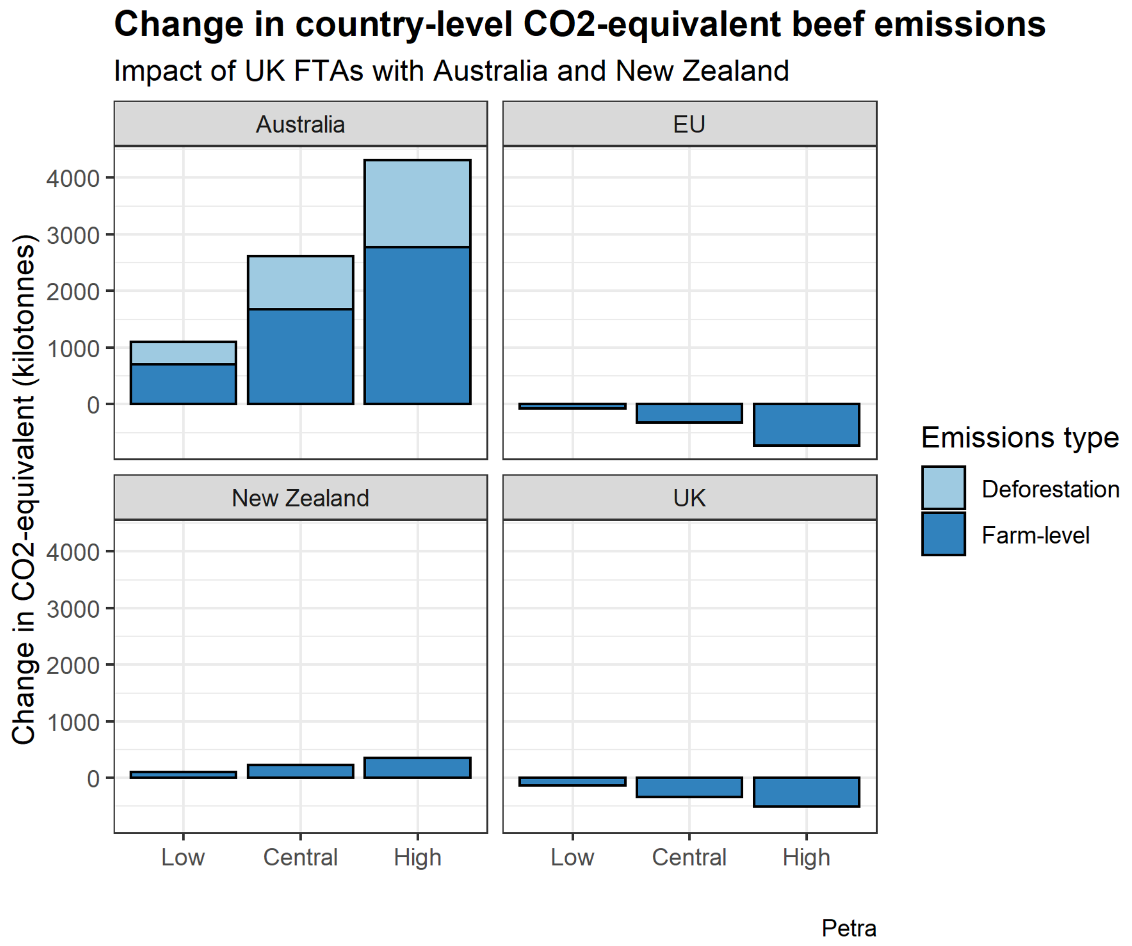
Our analysis shows that additional beef production in Australia could generate substantial additional greenhouse gases, through both on-farm and deforestation emissions. These additional emissions in Australia are estimated to be between 1,103kt – 4,310kt. This large impact is unsurprising, given our modelling projects a rise in production in Australia, and Australia's production is highly emissions-intensive. The combination of those two factors generates a large impact. We find that on-farm emissions generate most of the addition, but deforestation impacts are also substantial.

Rising emissions in New Zealand are much smaller, due to a lower expected production increase and less intensive production methods. CO2e emissions are estimated to rise by between 100kt – 353kt.

Emissions in the UK and EU are estimated to fall, in line with falling production. These emission decreases are much smaller than the changes in Australia, in part because of the lower emissions intensities in these regions than Australia.

Finally, it is worth noting that Australia has a legislated emissions reduction target of net zero by 2050. As such, while this analysis indicates Australia's beef production emissions may rise following these FTAs, it does not imply that global whole-economy emissions will rise by this much given wider governmental commitments on climate change.

Figure 3: Modelled changes in beef production and deforestation emissions for relevant countries following FTAs. Changes in kilotonnes of CO2-equivalent emissions (CO2e).

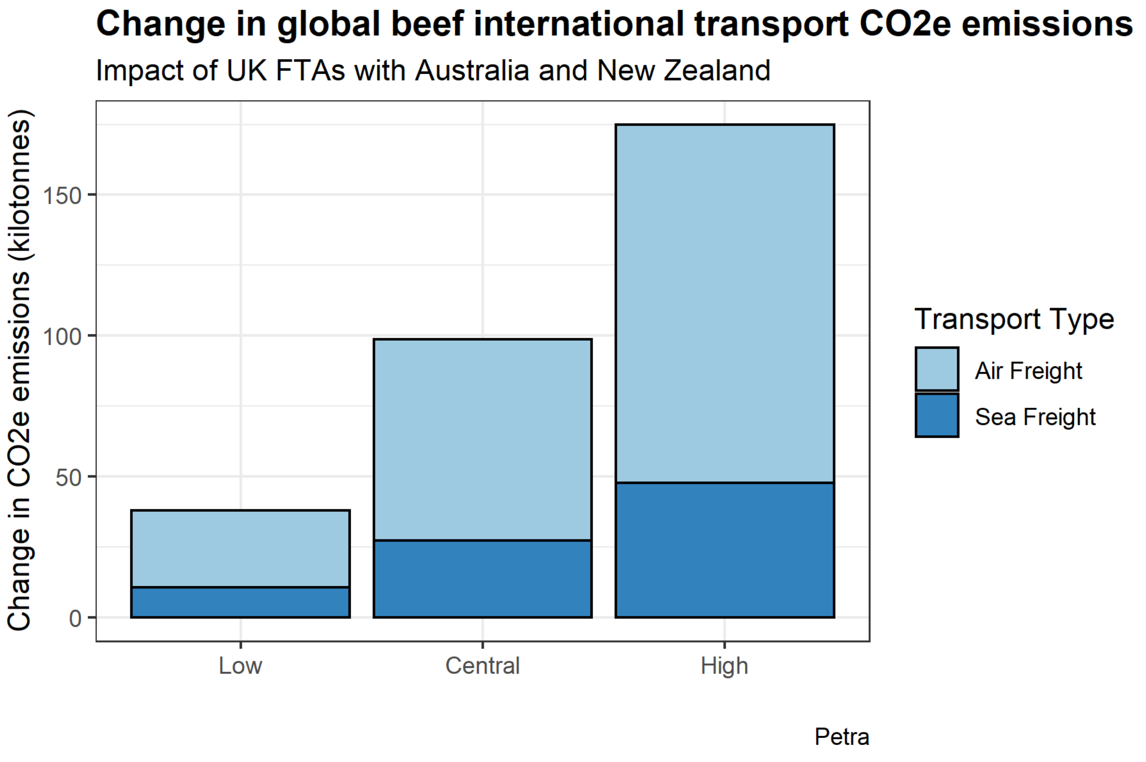


b. International transport emissions

We find that rising global trade generates rising international transport emissions. We estimate this to be worth 38kt – 174kt of CO_2e. Generally, international transport emissions tend to be only a small proportion of total agricultural emissions. We find this to be especially true in this case, given the high production emission intensity of beef – transport emissions represent only around 3-4% of total additional beef emissions from this FTA. However, these additional emissions are not negligible. The replacement of short distance trade between the UK and EU with long distance trade with Australia and New Zealand contributes to these figures. More significantly, the use of air freighting adds substantially to transport emissions. While representing only around 5% of additional trade, air freighting generates 60-70% of estimated international transport emissions.

Some of the rising transport emissions are offset by trade displacement. Our modelling indicates that rising exports from Australia to the UK will likely reduce exports from Australia to the USA. The figures presented below in Figure 4 show the change in total global international transport emissions, accounting for both rising and falling trade flows.

Figure 4: Modelled changes in global international transport emissions of beef. Changes in kilotonnes of CO2-equivalent emissions (CO2e).



c. Global emissions

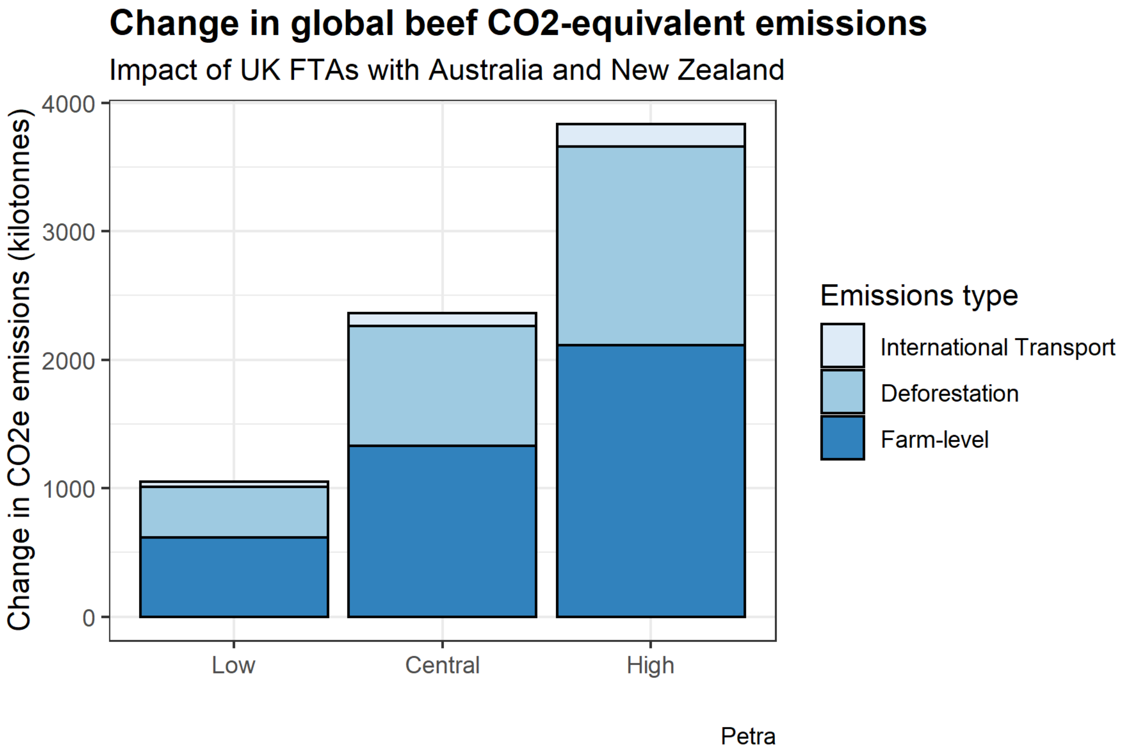
We aggregate the production, deforestation and international transport emissions together to estimate a change in global greenhouse gas emissions.

Combined, we expect a **rise in global emissions of between 1.1 and 4.6 million tonnes of CO2e per yea**r in the beef sector as a result of these FTAs. Most of these rising emissions come from on-farm production emissions, followed by deforestation, with a small amount added on top by international transport emissions. These impacts are almost entirely driven by Australia, with a small additional increase from New Zealand. Reduced production in the UK and EU offsets these impacts somewhat. We present a range as uncertainty in this analysis is high, but the direction of impacts is clear: we expect beef emissions to rise substantially.

If we instead use FAO GLEAM emissions intensity values, we find emissions could rise by between 1.6m and 6.7m tonnes of CO2e per year.

As discussed above, this analysis simply assesses the beef sector, in isolation from the rest of the economy. The UK, Australia and New Zealand all have net zero targets on emissions by 2050 and this paper does not seek to assess the wider trajectory of global emissions in relation to these targets.

Figure 5: Modelled changes in global beef emissions following FTAs. Changes in kilotonnes of CO2-equivalent emissions (CO2e).



d. UK production and consumption emissions

We have also estimated changes in UK production and consumption emissions. We find that UK production emissions are estimated to fall by between 131kt – 501kt of CO2e following these FTAs, as UK output falls in response to lower prices.

For consumption emissions, we find the reverse picture. Firstly, consumption emissions increase simply because consumption increases, due to the fall in prices generated by liberalisation. Our modelling suggests UK beef consumption could rise by between 1.7% and 5.6%. Secondly, consumption emissions rise due to a shift in the sources of consumption. Before the FTAs, Australia constitutes around 1% of UK beef consumption. After the FTA, we estimate this to be between 4% and 13% (see Annex). Given the higher emissions in Australian production, this adds substantially to UK consumption emissions. Estimates of these are shown in the table below.

Table 3: Change in UK production and consumption emissions of beef following FTAs. Changes in kilotonnes CO2e.

	UK production emissions	**UK consumption emissions**
Low	-131	+785
Central	-334	+1910
High	-501	+3308

We therefore find evidence that these FTAs will generate 'carbon offshoring'. The UK's production emissions of beef are estimated to fall by 1-3%, or 131kt – 501kt, following these FTAs. On the surface, this should help the UK meet its net zero ambitions. However, these emissions will likely be 'offshored' to FTA partners, especially Australia. We find that consumption emissions could rise by more, by between 4% and 19%, or 785kt – 3308kt. Around 5-6% of this rise is estimated to come from international transport emissions. The UK's greenhouse gas emissions associated with beef consumption are therefore expected to rise, even while its production emissions fall.

iv. Monetising emissions changes

These estimates in changes of CO2-equivalent emissions can be converted into monetary terms (£m) using values of carbon.

We use two alternative estimates of carbon values, provided by the OECD and by the UK Treasury's (HMT) Green Book. Using these values, we find that the rise in global beef emissions from these FTAs could be worth between £105m – £1,073m. We place a greater emphasis on the Green Book values, indicating impacts are estimated to be between £294m – £1,073m.

Table 4: Changes in global CO2e beef emissions following FTAs. Changes in £m.

Scenario	**Impacts, £m (OECD carbon values)**	**Impacts, £m (Green Book carbon values)**
Low	£ 105 m	£ 294 m
Central	£ 236 m	£ 662 m
High	£ 383 m	£ 1,073 m

We can also monetise our estimates of changes in UK production and consumption emissions. Using the Green Book carbon values, we find production emissions could fall by £37 – £140m, but this is more than offset by rising consumption emissions of £220m – £926m.

Table 5: Changes in UK production and consumption CO2e emissions of beef following FTAs. Changes in £m. Monetisation using Green Book carbon values.

Scenario	UK production emissions	UK consumption emissions
Low	-£37m	£220m
Central	-£94m	£535m
High	-£140m	£926m

4. Conclusion

This paper sets out a methodology to examine the 'carbon offshoring' impact of beef liberalisation in Free Trade Agreements. We test this approach on the UK's FTAs with Australia and New Zealand. We find that 'carbon offshoring' is likely in these FTAs. We estimate that while UK production emissions could fall by £40m – £140m per year in the medium term, UK consumption emissions could rise by £220m – £930m. This effect is driven partly by increased UK consumption and partly by shifting consumption from UK and EU beef towards higher-intensity Australian beef. A marginal additional impact comes from the increased international transport emissions.

5. Annex

Table 6: Changes in quantities of UK consumption and production of beef following FTAs. Changes in percentages.

Scenario	UK production	UK consumption
Low	-0.8%	1.7%
Central	-2.3%	3.5%
High	-3.4%	5.6%

Table 7: Share of UK consumption of beef from each country, before and after FTAs. Shares in percentages.

	Australia	New Zealand
Before FTAs	1.3%	0.2%
Low	3.8%	0.8%
Central	7.8%	1.6%
High	12.7%	2.6%

Table 8: Changes in UK production and consumption emissions of beef following FTAs. Changes in percentages.

	UK production emissions	UK consumption emissions
Low	-0.8%	+4.5%
Central	-2.3%	+10.8%
High	-3.4%	+18.8%

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