The impacts of Brexit on agricultural trade, food consumption, and diet-related mortality in the UK

Marco Springmann and Florian Freund

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Marco Springmann[1], Florian Freund[2]

[1] Oxford Martin Programme on the Future of Food, Centre on Population Approaches for Non-Communicable Disease Prevention, Nuffield Department of Population Health, University of Oxford. Address: Old Road Campus, Headington, Oxford, OX3 7LF, UK.
Email: marco.springmann@dph.ox.ac.uk; Tel: +44(0)7460202512.

[2] Johann Heinrich von Thünen Institute – Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute of Market Analysis. Address: Bundesallee 63, 38116 Braunschweig, Germany.
Email: florian.freund@thuenen.de; Tel: +49(0)5315965324.

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Abstract

Background: The British withdrawal from the EU is expected to lead to significant changes in the UK's trade relationships with the EU and with other countries who currently have trade agreements with the EU. This could have large impacts on the British food system and diet-related risk factors because the majority of the domestic demand, e.g. for fruits, vegetables, and some meats, is currently met by imports. Here we analyse the potential implications of Brexit for changes in agricultural trade, food consumption, and chronic disease mortality related to changes in dietary risk factors.

Methods: We used an economic-health modelling framework to analyse Brexit scenarios which include moderate increases in trade costs for a soft Brexit scenario and higher increases for a hard Brexit scenario. We used an agriculture-economic model to simulate the impacts that changes in tariffs and regulatory measures could have on the agricultural sector in the UK, and we used a national risk-disease model with eight dietary and weight-related risk factors and five disease endpoints to estimate the implications of the resulting dietary changes on diet-related disease mortality. Finally, we valued the health impacts associated with Brexit in terms of changes in healthcare-related expenditure and the value society places on reductions in the risk of mortality.

Results: In our simulations, Brexit led to high absolute reductions in the average per-capita consumption of fruits, vegetables, roots and dairy, ranging from reductions of half a serving per week each in the soft Brexit scenario to one serving per week each in the hard Brexit scenario. The consumption of foods such as beef, pork, poultry, sugar, and vegetable oils were reduced moderately, whilst other foods were relatively less affected. Changes in dietary and weight-related risk factors led to 5,600 (95% CI, 5,250-5,900) additional deaths for a hard Brexit, and to 2,700 (95% CI, 2,520-2,820) additional deaths for a soft Brexit, most of which were related to reduced consumption of fruits, vegetables, and nuts. The economic implications of these increases in mortality included additional healthcare-related expenditure of GBP 600 (560-630) million in the hard Brexit scenario, and of GBP 290 (270-300) million in the soft Brexit scenario. Valuing the changes in mortality by the willingness of society to pay for reductions in the risk of mortality resulted in costs of GBP 11.9 (11.2-12.6) billion and GBP 5.7 (5.4-6.0) billion, respectively, which increased losses of real GDP by 40-49%.

Interpretation: Whilst the precise conditions of Brexit and Britain's future trade regime are uncertain, we show that negative health impacts related to changes in agricultural trade and national food consumption can be expected under a range of possible future trade scenarios. The mechanisms behind these estimates reflect fundamental challenges to the British food system after Brexit. With its large import dependence, in particular of fruits and vegetables, any increase in trade costs can be expected to negatively impact the availability and consumption of foods that are critical components of healthy diets and chronic-disease prevention.

Introduction

In March 2017, the United Kingdom has formally entered negotiations for leaving the European Union, scheduled to be finalised by March 2019 and come into effect in the year thereafter. Since a 2016 referendum, narrowly won by the "Vote Leave" campaign, the British exit from the EU, or Brexit for short, has been varyingly portrayed as the most disastrous event in a generation, or as a great opportunity to cut EU 'red tape' and reform the governance of domains previously regulated by the EU. Whatever view one might take, the economies of the UK and other European countries, and the EU in general, have become strongly intertwined after almost half a century of UK membership of the European Union and its predecessor, the European Economic Community. Withdrawing from the set of common institutions and regulations can be expected to lead to changes across all sectors of the British economy [1,2], and will have implications for public and private life in the UK and Europe.

One major aspect that has received surprisingly little attention is the impact the British withdrawal from the EU could have on the food supply in the UK [3], and its implications for diets and diet-related health. Currently about one half of all food consumed in the UK, by value, is produced domestically, 30% is imported from the EU, and 20% imported from countries outside of the EU [4]. For particular commodities, the import dependence can be considerable higher. For example, more than 90% of fruits and vegetables and 50% of meat consumed in the UK, by value, are imported [4]. At the same time, dietary risks, including low consumption of fruits and vegetables and high consumption of red and processed meat, are the second biggest risk factor for mortality in the UK, after tobacco [5]. Any changes in the trade and regulatory regime between the UK on the one side, and the EU and its partners on the other side, will pose serious challenges to the British food system that will have consequences not only for agricultural trade and production, but also for dietary risks and diet-related health in the UK.

Here we provide what we think is the first quantitative estimate of the potential impacts that the British withdrawal from the EU could have on diet-related mortality in the UK as influenced by changes in agricultural trade and food consumption. Our analysis is based on a coupled modelling framework, consisting of an agriculture-economic model with which we simulated the impacts that changes in tariffs and regulatory measures could have on the agricultural sector in the UK, and a national risk-disease model with which we estimated the implications of the resulting dietary changes on diet-related disease mortality. We also provide an economic valuation of these Brexit-related health consequences and compare those to estimates of changes in the economic performance of the UK.

Brexit scenarios: hard vs soft vs remain

With only half a year left until the envisaged finalisation of the UK withdrawal agreement, it is still uncertain what the precise implications that Brexit could have for trade policy and regulation could be. However, there are several focal points around which the Brexit discussions evolve [1,2]. Those including an European Economic Area (EEA) option like Norway, a set of bilateral treaties like Switzerland, a Customs Union (CU) option like Turkey, a Trade Agreement option (TA) like the

Comprehensive Economic and Trade Agreement (CETA) between the EU and Canada, and a "no-deal" scenario where trade takes place under the WTO conditions such as with China. Some of these options may be dismissed because they are inconsistent with the red-lines that have been drawn by negotiation partners (e.g. the EEA option has been dismissed by Prime Minister May). For that reason, only a subset of these options is typically considered in quantitative analysis.

Most Brexit studies published so far have focused on, and included, at least two stylised scenarios that represent opposing visions of what Brexit might entail: a "hard" Brexit and a "soft" Brexit. The former implies trading on terms set out by the World Trade Organization (WTO) by imposing so-called Most Favoured Nations (MFN) tariffs on each other's imports. Those tariffs are especially high for sugar (51%) and beef and lamb (48%), followed by dairy (40%), pork and poultry (32%), and other commodities (19% or lower) (Table 1). In contrast, a soft Brexit usually implies some form of trade agreement without such tariffs, or substantially lower ones [6–12]. The two scenarios differ in how much trade costs increase due to Brexit. In the soft Brexit scenario, it is assumed that trade costs increase only due to non-tariff-measures (NTMs) that arise due to customs checks and possible regulatory divergences between UK and the EU. A hard Brexit, however, implies larger increases in trade costs, because new tariffs are imposed in addition to increasing NTMs.

A pending question concerns the UK's future status of trade agreements that have been negotiated between the EU and countries outside of the EU, usually referred to as Third Countries. Legally those contracts are only valid for EU members and leaving the EU while retaining the status quo enshrined in the trade agreements would contradict the WTO's MFN principle. This is true as long as the UK decides either to treat all WTO countries equally or ceases to be a WTO member. In order to retain the trade agreements, the UK will have to re-negotiate these trade deals - a difficult task given that the EU has negotiated 36 trade agreements with 58 different countries. In a similar vein the UK would also be legally excluded from the EU's Generalized System of Preferences (GSP), under which the EU unilaterally opens its markets for about 90 developing countries [13]. Incorporating the potential effects of a change in trade relations between the UK and Third Countries is an important factor for analysing the economic impacts of Brexit [6,11].

In our analysis, we combine an explicit treatment of Third-Country effects with the hard and soft Brexit options that determine the future trade relationship between the UK and the EU. We assess each scenario in comparison to a no-Brexit ("remain") baseline. In line with other analyses [6–12], we focus on a time horizon of ten years to account for the economic impacts and feedback effects that Brexit could have at a medium time scale. Our scenarios are defined as follows:

- ***No-Brexit baseline***: Our baseline projection consists of macroeconomic projections for GDP and population for the period of 2017-2027 in the absence of Brexit [14]. It includes all currently decided trade agreements of the EU, including CETA, which are sequentially introduced throughout the next decade.
- ***Hard Brexit***: In the Hard Brexit scenario, we assumed that trade between the UK and the EU is governed by WTO conditions such that MFN tariffs are levied on each other's imports, and that non-tariff measures will rise due to leaving the single market [10]. In addition, the UK loses its preferential access to Third Countries and does not take part in the EU's GSP.

- ***Soft Brexit***: In the Soft Brexit scenario, we assumed that a new trade agreement is negotiated between the UK and the EU, so that new MFN tariffs can be avoided. However, non-tariff measures are introduced, but at a lower rate than in the Hard Brexit scenario [10]. In addition, the UK loses its preferential access to Third Countries and does not take part in the EU's GSP.

In sensitivity analyses, we consider two additional scenarios in which the UK is able to negotiate trade agreements with Third Countries that would allow the UK to keep preferential access to Third Countries and the GSP.

Economic-health modelling framework

We used an economic-health modelling framework to estimate the potential impacts that Brexit could have an agricultural trade, food consumption, and diet-related health in the UK. The economic model consists of a computable general equilibrium (CGE) model of the global economy with a particular focus on agriculture in the EU. CGE models combine economic theory and empirical data according to which relative prices of commodities adjust so that supply matches demand across different sectors and regions. CGE models represent the whole economy, and include the agriculture sector, as well as industrial and service sectors. Due to its structure, the models allow for the identification of causal effects of policy experiments and other external factors on parameters, such as economic output per sector, inter-regional trade, and national consumption.

For this analysis, we used a computable general equilibrium model with agricultural detail, the Modular Applied General Equilibrium Tool (MAGNET), to estimate the potential impacts that changes in trade costs could have on agricultural trade, production and consumption in the UK. One of the main features of MAGNET is the comprehensive representation of land resources as a factor of production, as well as its representation of agricultural policies such as the EU's Common Agricultural Policy (CAP) and production quotas [15]. Due to its specific focus, MAGNET is regularly employed to inform policy makers and other stakeholders about the economic implications of various policies and other external factors related to agriculture [16–18]. A detailed model description is provided by Woltjer and colleagues [15].
We used a national risk-disease model to estimate the impacts that dietary changes related to Brexit could have on disease mortality in the UK. The model is based on the concept of comparative risk assessment which relates changes in risk factors, such as reductions in fruit and vegetables, to changes in cause-specific mortality, such as cancer and coronary heart disease [19]. The same concept forms the basis of the Global Burden of Disease project that tracks the impacts of different risk factors on mortality and morbidity in different regions and globally [5].

Our UK-based model included eight diet and weight-related risk factors and five disease endpoints. The risk factors were high consumption of red meat, low consumption of fruits, vegetables, nuts, and legumes, as well as being underweight, overweight, and obese, the latter of which are related to changes in energy intake. The disease endpoints were coronary heart disease (CHD), stroke, type-2 diabetes mellitus (T2DM), and cancer (in aggregate and as site-specific ones, such as colon and rectum cancers), and an aggregate of other diseases. We adopted the relative risk estimates that relate change in risk factors to changes in disease mortality from meta-analysis of prospective cohort

studies to minimise bias from individual studies [20–27]. The risk-disease relationships included here were responsible for three quarters of the deaths attributable to dietary risks, and for about a fifth all attributable deaths in the UK in 2016 [28]. A detailed model description is provided by Springmann and colleagues [29].

In addition to expressing the health impacts related to Brexit in terms of changes in mortality, we also provide an economic valuation and compare the economic value of the health impacts to the changes in economic performance related to Brexit as measured by changes in GDP. For that purpose, we used two different methods. First, we used disease-specific cost-of-illness (COI) estimates from the UK to calculate the healthcare-related costs associated with changes in mortality [30–32], e.g. how much additional healthcare-related costs would be spent on an additional death from cancer. Second, we followed a valuation method based on the value ascribed to changes in mortality. Those values are based on surveys that asked for the willingness to pay for small reductions in mortality which are then aggregated to a so-called value of prevented (statistical) fatality (VPF) [33]. The Department for Transport (DfT) and several other departments use a 2010-based VPF of GBP 1.64 million (for each case of averted death). We adjusted the VPF and COI estimates to our study horizon of 2027 by accounting for expected changes in real GDP, in line with governmental guidance for appraisals [34].

Results

Projections of agricultural trade and production

Along our baseline projections without Brexit, the UK continues to be highly dependent on imports (Table 1). The value of net import in 2027 was especially high for the category of vegetables, fruits, roots and legumes (GBP 5.9 billion), and for pork and poultry (GBP 4.0 billion). The value of imports from the EU constituted about half of the value of all imports for the category of vegetables, fruits, roots, and legumes, and 90% for the case of pork and poultry. The self-sufficiency ratio, i.e. the ratio of production to demand, for those commodities ranged from a third for vegetables, fruits, roots and legumes to one half for pork and poultry, which indicates that one half to two thirds of the national food demand for those commodities, by value, was met by imports. In contrast, self-sufficiency ratios were relatively high for beef and lamb (75%), dairy (87%), vegetable oil (96%), and wheat (99%) and other grains (90%).

Table 1. Overview of trade projections in the no-Brexit baseline, and of the tariff and non-tariff measures applied in the Brexit scenarios.

Food commodity	Total net imports (GBP million)	Net imports from the EU (GBP million)	Self-suffiency rate (%)	MFN tariffs (%)	Non-tariff measures (%)	
					hard	soft
Wheat	267	52	99	17	8	3
Other grains	176	38	90	19	8	3
Vegetables, fruits, roots, legumes	5,856	2,950	34	11	8	3
Vegetable oil	1,362	538	96	7	8	3
Sugar	348	202	70	51	8	3
Beef and lamb	725	333	75	48	8	3
Pork and poultry	4,024	3,630	49	32	8	3
Dairy	1,489	1,825	87	40	8	3

In our analysis, the changes in trade costs in the Brexit scenarios had a large influence on agricultural trade and production (Table 2). In the Hard Brexit scenario, imports declined by about two thirds for pork and poultry (64%) and dairy (66%), by a third for beef and lamb (36%), sugar (39%), and wheat (29%), and by almost a tenth (8%) for vegetables, fruits, legumes, nuts, and roots, and vegetable oils. Changes in exports and production mitigated some of the declines in imports. Exports decreased by 80-90% for animal products and wheat, and by half for most plant-based products. Production increased in particular for pork and poultry (37%), and to smaller degrees for dairy (9%) and sugar (6%).

In the Soft Brexit scenario, the changes in trade and production were still significant, but less drastic than under the Hard Brexit scenario. Changes in imports ranged from increased imports of wheat (+3%) to reductions in imports of more than a tenth for sugar (-13%), much of which was due to affected sugar imports from countries outside of the EU. The imports of most other products were reduced by 2-4%. Increases in production were again highest for pork and poultry (8%), and reductions in exports ranged from 6-22%.

Table 2. Changes in trade and output in the Hard Brexit scenario (hard) and in the Soft Brexit scenario (soft).

Food commodities	ΔImports (%)		ΔExports (%)		ΔOutput (%)	
	hard	soft	hard	soft	hard	soft
Wheat	-29.3	3.4	-83.7	-20.7	1.4	2.3
Other grains	-0.3	0.9	-32.9	-5.8	0.5	0.7
Vegetables, fruits, roots, legumes	-8.2	-2.3	-47.1	-9.1	-0.2	1.4
Vegetable oil	-8.3	-4.3	-35.0	-14.3	1.1	1.2
Sugar	-39.4	-13.0	-56.0	-8.9	6.5	6.4
Beef and lamb	-36.3	-3.8	-92.9	-19.2	-2.2	0.3
Pork and poultry	-63.6	-2.4	-83.8	-21.6	37.4	7.7
Dairy	-65.9	-7.2	-83.4	-13.8	9.1	0.4

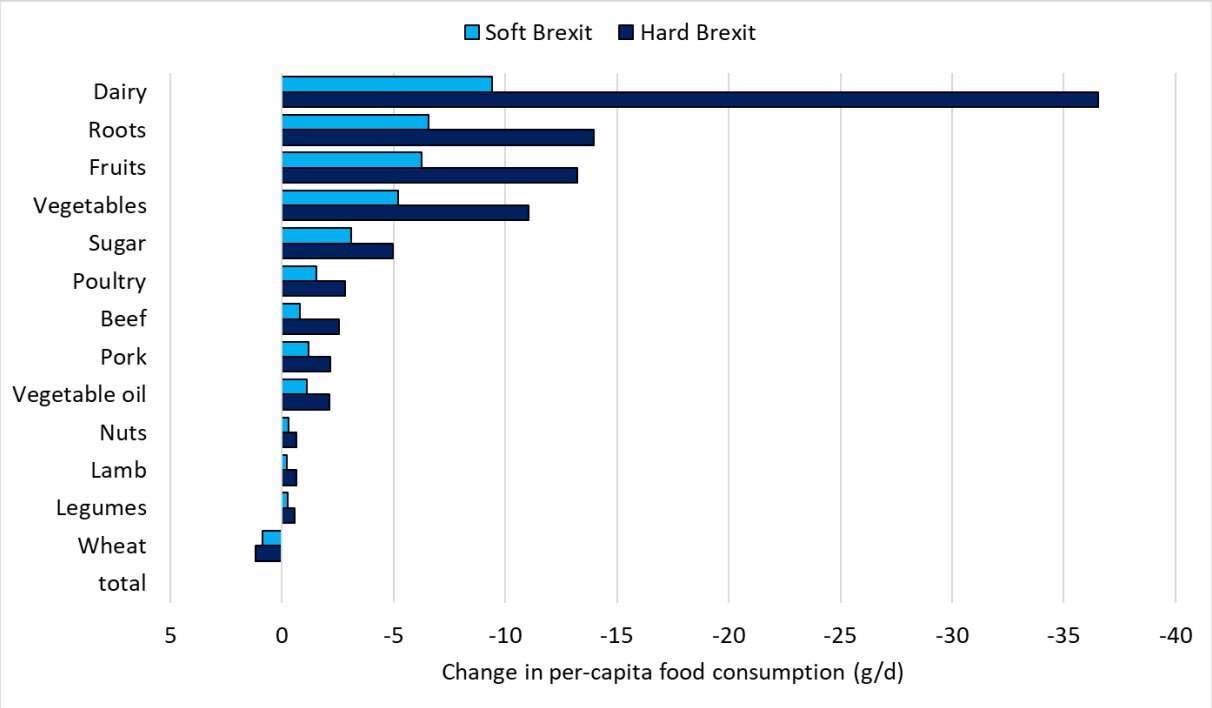
The changes in agricultural trade and production are the result of a chain of economic feedback effects. For example, the relative high tariff for pork and poultry makes production in this sector relatively attractive. The large increase in production in that sector drew in production factors from other sectors, such as the beef and lamb sector whose output decreased as a result in the Hard Brexit scenario and remained relatively unchanged in the Soft Brexit scenario. The increase in pork and poultry production also increased feed demand which led to an increase in wheat production. And the increase in wheat production left less arable land available for increasing the production of vegetables, fruits, legumes, nuts, and roots whose output decreased slightly as a result in the Hard Brexit scenario and remained relatively unchanged in the Soft Brexit scenario.

Changes in consumption, dietary risk factors, and health

The changes in trade and production are associated with changes in relative prices that also influence what is consumed by households (Figure 1). According to our estimates, the Brexit scenarios led to reductions in the consumption of most food commodities, with the exception of wheat. The reductions ranged from 4-7% in the Hard Brexit scenario, and from 2-4% in the Soft Brexit scenario. The absolute changes in per-capita consumption reflected the magnitude by which each food commodity is demanded. As a result, the greatest absolute changes in consumption were

for dairy (-37 g/d in the Hard Brexit scenario; -9 g/d in the Soft Brexit scenario), roots (-14 g/d; -7 g/d), vegetables (-11 g/d; -5g/d), and fruits (-13 g/d; -6g/d), moderate changes (-2 to -5 g/d in the Hard Brexit scenario; -1 to -3 in the Soft Brexit scenario) for sugar, poultry, beef, pork, and vegetable oils, and small changes (around 1 g/d or below in each scenario) for nuts, legumes, lamb, and wheat. Total energy intake was reduced by 91 kcal/d in the Hard Brexit scenario, and by 42 kcal/d in the Soft Brexit scenario.

Figure 1. Changes in average per-capita food consumption in the UK in the two Brexit scenarios.

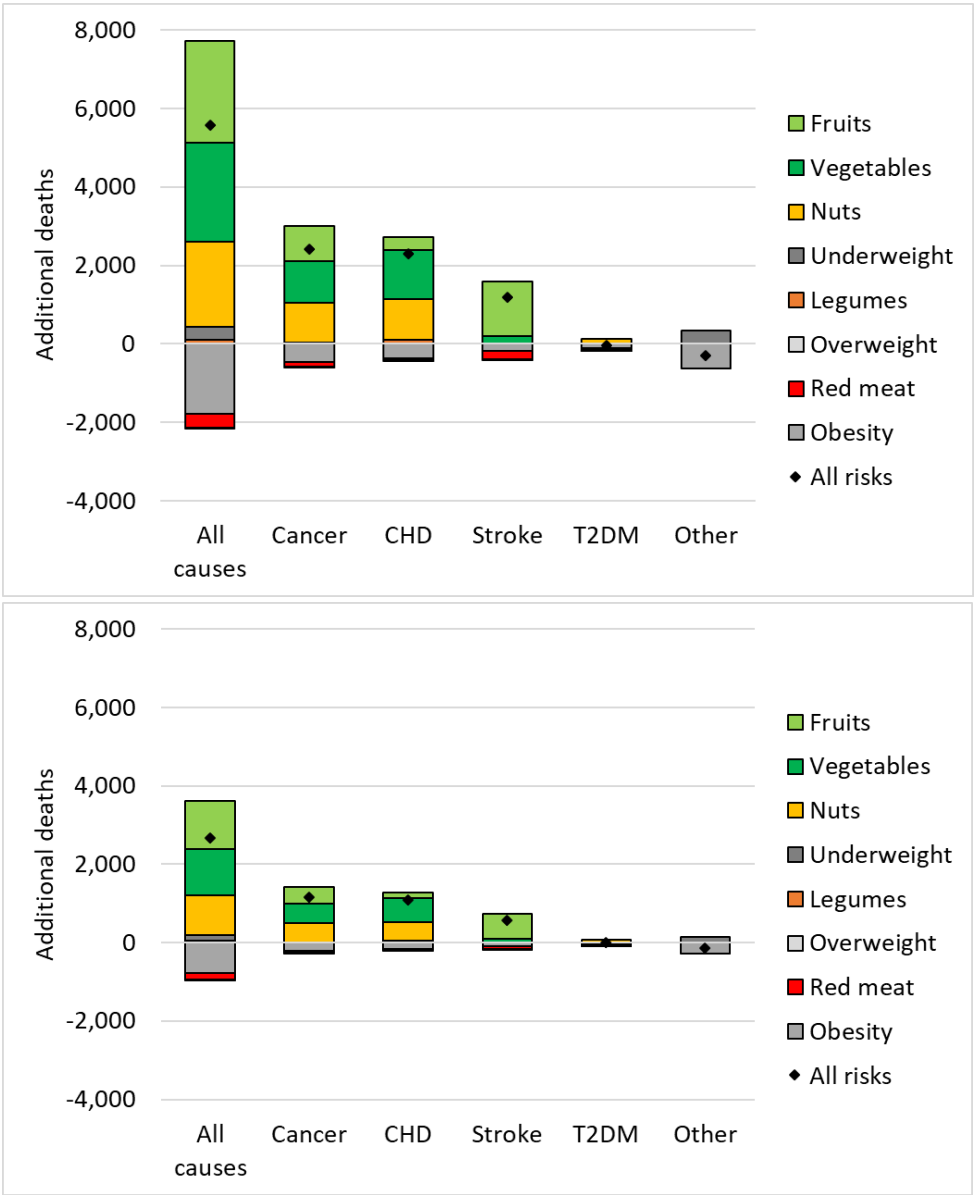


Several of those food commodities influence chronic-disease incidence and mortality. Reductions in fruits, vegetables, nuts, and legumes increase diet-related risks, whereas reduced red meat consumption (beef, lamb, pork) decreases them. The impacts of changes in total energy intake depend on the distribution of weight levels within a population, but reduced levels of overweight and obesity are generally associated with reduced risks, and increased levels of underweight with increased risks.

According to our estimates, the Brexit-related changes in food consumption could lead to 5,600 (95% CI, 5,250-5,900) additional deaths in the Hard Brexit scenario, and to 2,700 (95% CI, 2,520-2,820) additional deaths in the Soft Brexit scenario (Figure 2). About two fifths of those were each due to cancer (43%) and coronary heart disease (41%), and one fifth due to stroke (21%), whereas other, weight-related causes of death were reduced slightly (5%). By risk factor, most of the additional deaths were due to reduced consumption of fruits (2,600 in the Hard Brexit scenario; 1,200 in the Soft Brexit scenario), vegetables (2,500; 1,200), and nuts (2,200; 1,000), whereas reduced red meat consumption (400; 150) and reduced levels of obesity (1,800; 800), associated with a lower energy intake, had small positive impacts. The changes in mortality represented an increase in overall mortality of 0.9% in the Hard Brexit scenario, and 0.4% in the Soft Brexit scenario,

and an increase in premature mortality, i.e. deaths before the age of 70, of 1.3% and 0.6%, respectively.

Figure 2. Changes in mortality in the UK by risk factor and cause of deaths in the Hard Brexit scenario (top panel) and in the Soft Brexit scenario (lower panel).



Economic implications

The Brexit-related changes in chronic-disease mortality have several economic implications, including direct costs to healthcare. Accounting for the costs to healthcare and related services that are associated with death from a particular disease resulted in increases in healthcare-related expenditure of GBP 600 million (560-630) in the Hard Brexit scenario, and of GBP 290 million (270-300) in the Soft Brexit scenario (Table 3). About a third of the increases in expenditure was due to direct costs (GBP 200 million in the Hard Brexit scenario, GBP 100 billion in the Soft Brexit scenario), and the remainder due to indirect costs related to informal care and lost work days (390 million and 190 million, respectively). As a percentage of the total healthcare-related costs, the Brexit-related

changes amounted to an increase of 1.8% (1.7-1.9) in the Hard Brexit scenario, and of 0.9% (0.8-0.9) in the Soft Brexit scenario.

Table 3. Increases in healthcare-related expenditure in the Hard and Soft Brexit scenarios, and ascribed value of additional fatalities based on willingness to pay for changes in risk of mortality.

Economic indicator	ΔCosts in Hard Brexit (GBP million)			ΔCosts in Soft Brexit (GBP million)		
	mean	low	high	mean	low	high
Healthcare-related expenditure	598	563	632	286	270	302
> direct healthcare costs	205	187	223	99	91	107
> indirect healthcare costs	393	377	410	187	180	195
Value of additional fatality	11,886	11,197	12,575	5,697	5,377	6,016
> cancer value doubled	17,025	16,189	17,861	8,149	7,761	8,537

In addition to the specific healthcare-related costs, it is common practice in cost-benefit analysis to ascribe a more general value to additional or averted deaths which is based on revealed preferences to pay for (or accept) changes in risk of mortality. Using the UK-specific value of a prevented (statistical) fatality (VPF) led to values ascribed to the Brexit-related changes in mortality of GBP 11.9 billion (with an uncertainty range of GBP 11.2-12.6 billion) in the Hard Brexit scenario, and of GBP 5.7 billion (5.4-6.0) in the Soft Brexit scenario (Table 3). Valuing deaths from cancer at twice the standard VPF, a practice in use by the Office for Nuclear Regulation, increased those values by 40% to GBP 17.0 billion (16.2-17.9) and GBP 8.1 billion (7.8-8.5), respectively. As a percentage of real GDP in 2027, the estimated values of, in this case, additional fatalities amounted to 0.56-0.80% in the Hard Brexit scenario, and to 0.27-0.38% in the Soft Brexit scenario.

Apart from changes in health and healthcare-related expenditure, Brexit is expected to impact the general economic performance of the UK economy. For example, new trade barriers increase the price for imported inputs into production which increases production costs (e.g. of cars), and it increases the price of good and services produced for export which might be demanded less of as a result (e.g. financial services). According to our estimates, real GDP (a measure of changes in output that is corrected for price changes, such as inflation) would be reduced by 1.4% in the Hard Brexit scenario, and by 0.5% in the Soft Brexit scenario. Nominal changes in GDP that, in addition to output effects, also include changes in prices amounted to reductions of 3.6% and 1.6%, respectively. Adding the values of additional fatalities, which were assessed in real terms, to the Brexit-related changes in real GDP would increase the economic impacts of Brexit by 40% to 1.9% of GDP in the Hard Brexit scenario, and by 49% to 0.8% of GDP in the Soft Brexit scenario.

Sensitivity analysis

In our sensitivity analysis, we considered alternative Brexit scenarios. In our main analysis, we assumed that as the UK leaves the EU, it ceases being part of trade agreements the EU has negotiated with Third Countries and instead trades with Third Countries on WTO terms. The prospects of re-negotiating these trade deals is uncertain, but it would involve considerable time – the EU has negotiated 36 trade agreements with 58 different countries – and the outcome might be less favourable as the current situation, because the UK, due to its economic size, has a much smaller negotiating position than the EU. However, because re-negotiating some trade agreements

with Third Countries is a stated policy intention, we analysed the potential impacts of such re-negotiations should they result in comparable trade agreements with Third Countries. According to our analysis, the health impacts of Brexit would be reduced by a third (33%) to 3,800 (3.500-4000) additional deaths in a Hard Brexit scenario in which the UK can renegotiate trade agreements with Third Countries, and by two thirds (61%) to 1,000 (970-1,100) additional deaths in a Soft Brexit scenario in which trade agreements with Third Countries are maintained. The economic costs related to the health impacts changed in similar proportions.

Discussion

The British withdrawal from the EU is expected to lead to significant changes in the UK's trade relationships with the EU and other countries who currently have trade agreements with the EU. Because the UK is a large exporter of financial services, much previous work has analysed the potential implications of Brexit on the financial service industry [2]. However, the UK is also a large importer of food, and is especially reliant on imports of fruits and vegetables, and pork and poultry to meet its demand [4]. Here we analysed the potential implications of Brexit for changes in agricultural trade, food consumption, and chronic disease mortality related to changes in dietary risk factors.

We found that Brexit could have a large impact on food consumption and dietary health in the UK. Among others, average consumption of fruits and vegetables decreased each by up to one serving per week in a Hard Brexit scenario, and by half a serving per week each in a Soft Brexit scenario. Changes in these and other dietary and weight-related risk factors led to 5,600 (95% CI, 5,250-5,900) additional deaths for a Hard Brexit, and to 2,700 (95% CI, 2,520-2,820) additional deaths for a Soft Brexit. The economic implications of these increases in mortality included additional healthcare-related expenditure of GBP 600 (560-630) million in the Hard Brexit scenario, and of GBP 290 (270-300) million in the Soft Brexit scenario. Valuing the changes in mortality by the willingness of society to pay for reductions in the risk of mortality resulted in costs of GBP 11.9 (11.2-12.6) billion and GBP 5.7 (5.4-6.0) billion, respectively. Adding those values to Brexit-related changes in GDP would increase losses of real GDP by 40-49% to 1.9% for a Hard Brexit, and to 0.8% for a Soft Brexit.

For our analysis, we used a process-based modelling approach that represents the economic structure of the UK economy and its trading partners, as well as a risk-disease model based on epidemiological relationships. With this framework, we were able to trace, for the first time, the effects Brexit-related changes in agricultural trade could have for chronic-disease mortality in the UK. Where possible, we included estimates of uncertainty, e.g. for the disease-risk relationships, and we analysed Brexit scenarios with small and large increases in trade costs to provide a range of potential impacts. However, our analysis is subject to several additional uncertainties related to our model setup and scenario design.

We abstracted from several economic aspects which, when included, could further increase the economic feedback effects and losses identified in our analysis. Our economic estimates are within the range of literature values from similar modelling exercises that indicate losses in nominal GDP of 1.3-4.2% due to Brexit [35]. However, similar to other CGE-based studies, we did not account for potential changes in foreign direct investment, immigration, and international technology diffusion,

all of which have been shown to further increase the economic losses associated with increasing the costs of trade [2]. We also abstracted from several aspects that might be important for agriculture under Brexit, including potential reductions in the availability of migrant labour, renegotiation of existing EU tariff rate quotas, e.g. for beef imports, and new national legislation that would affect how agricultural production is supported in the UK [3,36].

Other caveats relate to the health model and its linkage with the economic model. In our health analysis, we calculated the potential changes in chronic-disease mortality in equilibrium, i.e. after an initial period in which changes in agriculture and consumption have taken place. This is in line with the time horizon of our scenarios (of ten years), but it abstracts from more concrete aspects of disease progression, which we defer for future research. Other areas of potential improvement include the aggregation of food groups in CGE models. For analysing the health implications of changes in food consumption, we had to rely on percentage changes for aggregates of food commodities, such as one aggregate for pork and poultry, and one aggregate for vegetables, fruits, nuts, and legumes. Disaggregating these food aggregates into individual food commodities would improve the detail and precision of our estimates, but are unlikely to change the general directions and conclusions of our analysis.

Conclusion

With only half a year left until the envisaged finalisation of the UK withdrawal agreement, the concrete details of Brexit and the future trade relationship between the UK on the one side, and the EU and its trading partners on the other side remain uncertain. We show that negative health impacts related to changes in agricultural trade and national food consumption can be expected under a broad range of possible future trade scenarios. The mechanisms behind these estimates reflect fundamental challenges to the British food system after Brexit. With its large import dependence, in particular of fruits and vegetables, any increase in trade costs – whether from new tariffs associated with a hard Brexit, or from non-tariff measures related to customs checks and regulatory differences that are associated with a soft Brexit – can be expected to negatively impact the availability and consumption of foods that are critical components of healthy diets and chronic-disease prevention. Aligning agricultural production and trade with public health objectives will be critical for preserving the health and welfare of British citizens irrespective of Brexit, but our results suggest that Brexit could make this challenge significantly harder.

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