

10. The exposure of different workers to potential trade barriers between the UK and the EU

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Key findings

- **The EU accounts for 44% of UK exports (equal to 13% of GDP) and more than half of UK imports (17% of GDP).** Leaving the Single Market and Customs Union will increase trade barriers and make both importing and exporting more costly.
- **Some industries, such as clothing and transport equipment (including car manufacturing), are likely to be especially badly affected by these changes because they sell a large fraction of their output to EU countries.** The transport equipment sector will also be hard hit because it imports 25% of its inputs from the EU. The same is true for the chemicals and pharmaceuticals sector. Finance is the most exposed services industry, as it currently exports a relatively large share of its output (12%) to the EU.
- **Industries such as agriculture may benefit from trade barriers (though at the expense of consumers)** because consumers will substitute away from more expensive imports towards products made by UK industries. However, the industries that could benefit make up a small share of the overall economy.
- **Men, in particular those with fewer formal qualifications, are more likely to be employed in the most exposed industries than women and more highly educated men.** Workers in process, plant and machinery operative occupations are particularly exposed. These tend to be older men with skills specific to their occupation who, history suggests, may struggle to find equally well-paid work if their current employment were to disappear.
- **On average, exposure to new trade barriers is set to weigh somewhat more heavily on the top half of the earnings distribution.** While earnings inequality may fall, it will come at the cost of making most UK workers poorer. The likely impacts on inequality between regions are both smaller and much more uncertain than the effects on earnings inequality.
- **Low-educated workers are more exposed in some regional labour markets than others.** While 19% of low-educated men work in industries we class as highly exposed in the UK as a whole, the fractions in Northern Ireland and the West Midlands are 25% and 24% respectively. Low-educated workers in these regions might find it particularly hard to adjust to the negative consequences of trade barriers.

10.1 Introduction

While there is no doubt that the UK's vote to leave the European Union ('Brexit') in June 2016 will have far-reaching consequences, there is much we do not know about what these consequences are likely to be. We do not know what form of trade agreement the UK will strike with the EU, what new trade barriers may be imposed on UK-EU trade or what effects these will have on UK industries.

In the face of all this uncertainty, various studies – conducted both inside and outside government – have attempted to predict Brexit's possible impacts on growth in the economy as a whole. These studies tend to find negative economic impacts of Brexit in both the short and long run, regardless of what kind of agreement the UK strikes with the EU.¹

However, these economy-wide effects are likely to mask considerable differences in Brexit's potential effects on different industries, workers and regions across the UK. Some people or places may be more negatively affected than others. Some may gain. This means Brexit could have important implications for both interpersonal and interregional inequalities within the UK.

In this chapter, we focus on one particular aspect of Brexit – changes in trade barriers with the EU – and examine the consequences these might have for different industries, workers and regions. Throughout, our aim is to shed light on *relative* impacts across different groups in the population rather than their overall scale. To conduct our analysis, we calculate measures of the impact of new barriers to trade on demand for goods and services produced in the UK, and how these are likely to affect different industries and, by extension, the workers that they employ.

We find that, while there is a great deal of uncertainty about the size of trade barriers with the EU after Brexit, there is perhaps more certainty about which industries and worker types are particularly likely to be affected by such barriers. Under every trade scenario we consider, our results suggest that workers in the most exposed industries are disproportionately male and have lower levels of formal education. Because exposure is greatest amongst higher-earning workers within different education groups, and because men tend to earn more than women, workers in the top half of the earnings distribution are also more likely to work in highly exposed industries than those in the bottom half. However, this is not a case of closing the gap by helping the worse-off. Our estimates suggest that all earnings groups are expected, on average, to be negatively affected. So while the new trade barriers might help to reduce earnings inequalities within the UK, this is only because their impact on lower-earning workers is expected to be less bad than their impact for higher-earning workers.

We also consider the possible impacts of Brexit on inequalities between regions. Here there is more uncertainty. The differences in exposure across the regions and nations of the UK are smaller than the differences between groups of workers. Moreover, levels of exposure in different areas have no clear relation with average earnings. In addition, our

¹ See, for example, S. Dhingra, G. Ottaviano, T. Sampson and J. van Reenen, 'The consequences of Brexit for UK trade and living standards', Centre for Economic Performance (CEP), Brexit Analysis 2, 2016, http://eprints.lse.ac.uk/66144/1/_lse.ac.uk_storage_LIBRARY_Secondary_libfile_shared_repository_Content_LS_E%20BrexitVote%20blog_brexit02.pdf.

estimated regional impacts are more sensitive to assumptions about the size of non-tariff barriers and how responsive patterns of demand in the UK and the EU are to new trade barriers. In particular, the estimated impact on London depends on assumptions about the size of potential non-tariff barriers faced by the finance industry.

All this means that the impact of new trade barriers on regional inequality is far less clear than the impact on pay inequality. This may help to explain why previous studies of Brexit's regional impacts have come to different conclusions.² However, we also find much clearer evidence of important regional differences in the proportion of low-educated workers who are employed in potentially highly exposed industries. Such industries employ 25% of low-educated men in Northern Ireland (which, if anything, is an underestimate) and 24% in the West Midlands, compared with 19% in the UK as a whole. This means that workers in exposed industries in these regions face the additional problem that there are fewer local job opportunities for workers like them in less affected industries. Policymakers may wish to pay closer attention to the effects of new trade barriers on workers in these regions, and if necessary design appropriate responses.

Brexit is all-encompassing, and will affect the economy in a number of ways besides the effects of changing trade barriers. It not only represents a fundamental shake-up of the UK's relationship with its largest trading partner but also implies a break with the rules governing the EU's Single Market. This may lead to changes to labour laws, product regulations and even some tax rates. Moreover, the government has indicated that it seeks to end freedom of movement for EU workers and to introduce new immigration controls. All of these factors will affect UK industries, regions and workers in different dimensions and to differing degrees.

The sheer complexity of Brexit means that we cannot hope to cover all of its possible ramifications in this chapter. But any future trade barriers will be an important driver of Brexit's overall effects. Focusing on the effects of trade barriers will allow us to examine an important set of economic impacts in more detail and makes it easier to see what is driving our results. It also allows us to assess how much our findings change when we make different assumptions about potential new trade barriers and their effects on patterns of demand for the output of different industries.

The remainder of this chapter is structured as follows. Section 10.2 describes current patterns of trade between the UK and the EU and their importance for different industries. Section 10.3 shows what these patterns mean for the dependence of different regions and workers on exports to the EU. Section 10.4 describes what the potential new trade barriers under different possible Brexit scenarios might be and how these could affect the exports and imports of different industries. Section 10.5 presents estimates of the effects of new trade barriers on the value added of different industries. Sections 10.6 and 10.7 discuss the implications of these changes in industry value added for different workers and regions respectively. Section 10.8 concludes. In order to keep the discussion concise, we

² Consider, for example, the differences between Dhingra, Machin and Overman (2017) and the government's own 'Whitehall analysis' of trade's regional impacts. We discuss these studies in relation to our own results further below. (S. Dhingra, S. Machin and H. Overman, 'Local economic effects of Brexit', *National Institute Economic Review*, 2017, 242, R24–36; House of Commons Exiting the European Union Committee, 'EU exit analysis cross Whitehall briefing', 2018, <https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Cross-Whitehall-briefing/EU-Exit-Analysis-Cross-Whitehall-Briefing.pdf>).

have placed more technical aspects of our approach in an online appendix, as well as some additional results and sensitivity checks in supplementary material online, for the interested reader.

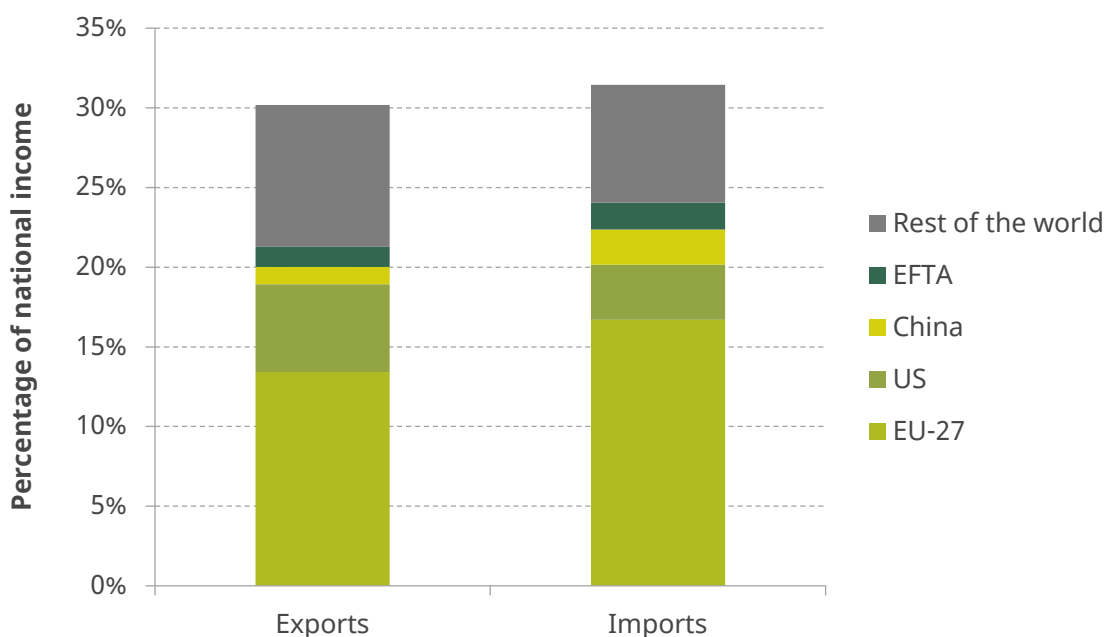
10.2 Trade with the EU: the status quo

The EU is the UK's largest trading partner. It is both the most important destination for UK exports and its most important source of imports. The importance of trade with the EU is shown in Figure 10.1, which plots the value of UK imports and exports that were bought from and sold to the EU, the European Free Trade Association (EFTA) countries (Iceland, Liechtenstein, Norway and Switzerland), the US, China and the rest of the world as a percentage of the UK's GDP in 2017. Nearly half – 44% – of all UK exports were sold to other EU member states. These had a value of £274 billion, equivalent to 13% of UK national income in that year. This is more than double the value of UK exports that were sold to the US, whose value accounted for just 5% of national income. The relative importance of the EU as a source of imports to the UK is even greater. The UK's imports from the EU amounted to £341 billion (equivalent to 17% of UK national income) in 2017, compared with just 3% from the US, which was again the second-most important area.

The sheer size of the trade flows passing between the UK and the EU means that any new trade barriers will have a big impact on UK industries and, in turn, on the workers they employ. In particular, we would expect the output of UK industries to be affected in three main ways:

- Through **impacts on UK firms' exports to the EU**: trade barriers would raise the cost of UK goods and services in EU markets. This would be likely to reduce demand for UK output in the EU.

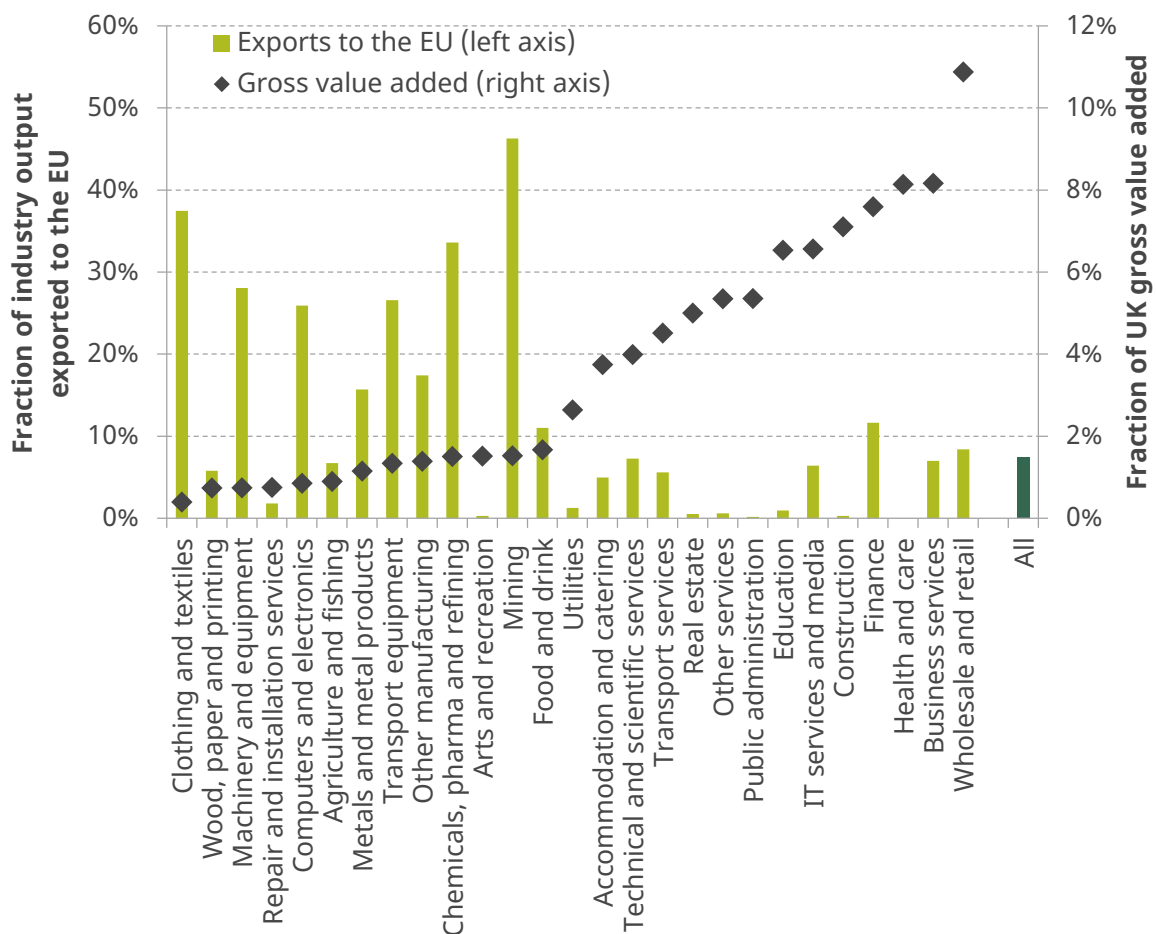
Figure 10.1. Value of exports from and imports to the UK, 2017



Source: Authors' calculations using ONS Pink Book 2018 and ONS Blue Book 2018.

- By **raising UK firms' costs**: UK firms purchase production inputs from the EU (for example, components for manufacturing or business services). If any new barriers reduce UK firms' ability to source inputs from the EU, they would most likely raise production costs in the UK.
- By **reducing competition in the UK**: EU firms compete with UK firms. Increased trade barriers could dampen competition and allow UK firms to increase their share of the domestic market. Although this may be good for individual firms and some workers, reduced competition also has costs for consumers in terms of higher prices and reduced variety. By creating incentives for firms to innovate, competition can also be an important driver of productivity growth. New trade barriers might therefore also reduce UK productivity.³

Figure 10.2. Exports to the EU and gross value added by industry, 2014



Note: Industries are ranked according to their contributions to the UK's gross value added.

Source: Authors' calculations using ONS analytical input-output tables 2014.

³ There are a few other ways that new trade barriers could affect demand for the output of UK industries. For instance, changing incomes in the UK could shift patterns of demand. Trade barriers could also have longer-run implications for UK industries' incentives to innovate. In what follows, we do not consider the effects of these channels. Instead, we focus purely on shifting patterns of demand for UK exports and EU imports as a result of changes in relative prices.

As we show in the following set of figures, these channels vary in their importance across different industries. Starting with the importance of exports to the EU, Figure 10.2 shows the proportion of different industries' output that is currently exported to the EU. Industries have been sorted according to their contribution to the UK's total economic output (as measured by the fraction of UK gross value added that they account for).⁴

Figure 10.2 shows that the industries that export the most to the EU relative to their total output are mining (46%), clothing and textiles (37%), chemicals, pharmaceuticals and refining (34%) and machinery and equipment (28%). Service industries tend to export relatively less of their output to the EU. However, because these industries also tend to make up a larger share of the UK economy's total value added, they account for a disproportionate share of the UK's total exports. In 2017, £277 billion of the UK's total exports, or 45%, came from the service sector.⁵

In Figure 10.3, we turn to examining the importance of imports from the EU for different UK industries by showing the share of each industry's inputs that are purchased from the EU. These inputs can be goods or services. For example, they could include German engine parts used by the UK car industry, or back-office functions that have been outsourced by UK banks to firms in Poland.

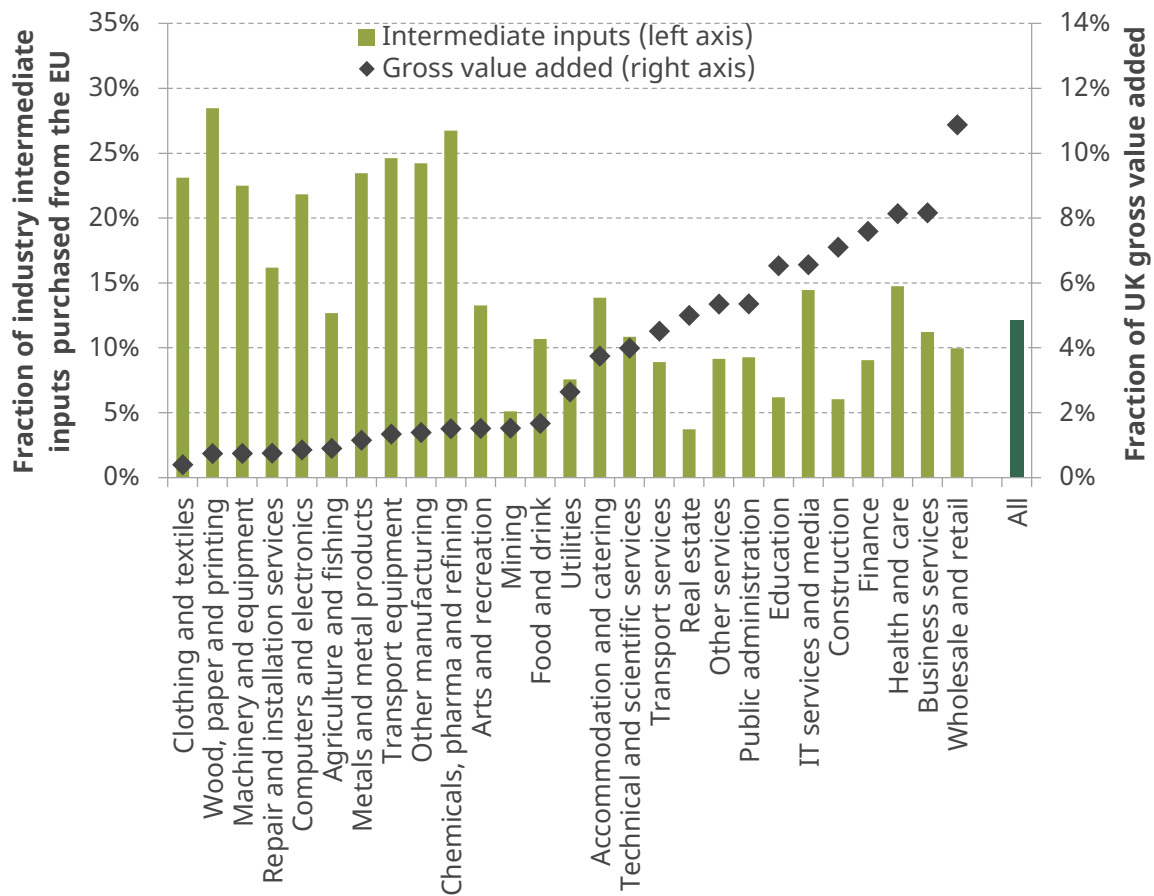
Figure 10.3 shows that intermediate inputs from the EU are in general more important for manufacturing firms. They are most important for the wood, paper and printing industry, which obtains 28% of its inputs from the EU. This is followed by chemicals, pharmaceuticals and refining (27%), transport equipment (25%) and other manufacturing (24%).⁶ It is noteworthy that some of these industries are also significant exporters to the EU. For instance, the chemicals, pharmaceuticals and refining industry and the transport equipment industry are in the top five industries in terms of their current reliance on the EU both as a destination for their output and as a source of production inputs. If new trade barriers resulting from Brexit impose costs on both imports and exports, firms in these industries would be among the worst affected on both margins: they import a lot of intermediate goods from the EU and they sell a lot of goods back to the EU.

A third factor that will determine how UK industries will be affected by new trade barriers is the degree to which they are able to benefit from reduced import competition. No single statistic summarises how important this is; many factors will play a role. In particular, it will depend on the importance of EU imports in the UK market (i.e. the potential size of the domestic market that domestic firms might be able to capture), the importance of the UK market for each industry (and thus the potential gain from increased domestic demand) and the degree to which domestic consumers switch to UK products in place of EU ones as the cost of imported goods increases.

⁴ In our full analysis, we look separately at the impact of trade barriers on 102 separate industries, the workers these industries employ and the regions they are located in. For presentational purposes, we group these industries into 27 larger groups when presenting results at an industry level.

⁵ Authors' calculations using ONS Pink Book 2018.

⁶ Transport equipment includes the car industry.

Figure 10.3. Intermediate inputs from the EU and gross value added by industry, 2014

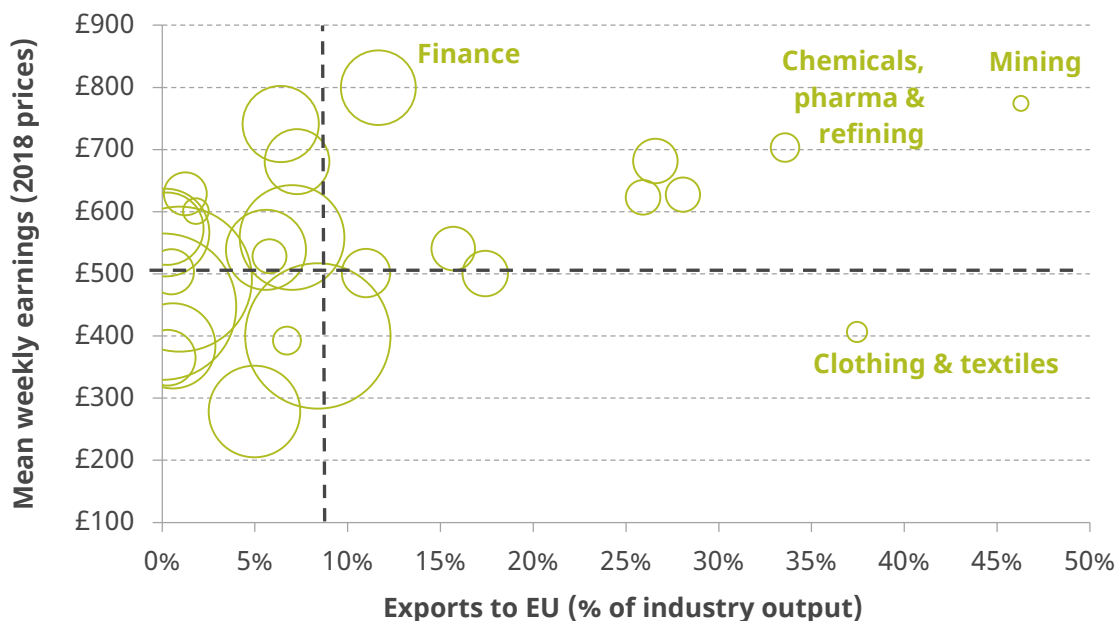
Note: We estimate the importance of EU inputs for each industry by combining information on imported inputs from the ONS input-output tables with information from the World Input-Output Database (WIOD) that breaks down imports into those used for final and intermediate consumption. See the online appendix for details. Industries are ranked according to their contributions to the UK's gross value added.

Source: Authors' calculations using ONS analytical input-output tables 2014 and the World Input-Output Database.

10.3 Workers' and regions' involvement in trade with the EU

The previous section showed there is large variation in the importance of trade with the EU across industries. Because different industries are located in different parts of the UK and employ different types of workers, such variation at the industry level is likely to mean that trade with the EU also varies in its importance across regional labour markets and different worker types. In this section, we examine this directly to highlight which parts of the UK and which groups of workers may be more exposed to the consequences of new trade barriers.

To help understand how trade barriers are likely to impact earnings inequality, Figure 10.4 shows how the fraction of industry output exported to the EU relates to average earnings and the numbers employed by each industry (represented by the size of the bubbles). This shows that industries where exports to the EU account for a greater fraction of output than average also tend to have higher average pay levels. Finance stands out in particular

Figure 10.4. Average earnings in each industry versus share of output sold to the EU

Note: The size of each circle represents industry employment. Dashed lines represent national averages. When calculating mean weekly earnings, we trim the distribution at the 2nd and 98th percentiles and express monetary values in 2018 prices using the Consumer Prices Index (CPI) taken from the Office for Budget Responsibility's March 2018 Economic and Fiscal Outlook.

Source: Authors' calculations using ONS analytical input-output tables 2014 and the Annual Survey of Hours and Earnings 2017.

as the industry with the highest average earnings and one that exports an above-average share of its output to the EU. One exception to this general pattern is clothing and textiles. This industry exports a lot to the EU, but on average workers in this industry earn less than in many other industries.

The various industries are not equally important around the country. To understand how the mix of industries in each part of the UK influences the exposure of different areas to potential new trade barriers, we weight the share of output that each industry exports to the EU by the number of workers it employs in each region. This analysis does not take into account that, within an industry, firms in some regions (such as Northern Ireland) may be more likely to export to the EU than firms in the same industry that are located elsewhere. As a measure of which regions export more to the EU, it is thus imperfect. However, we discuss these figures as they are useful in explaining differences in regional impacts that we report in Section 10.7.

Industries that are relatively more important employers in the East and West Midlands, London and the North West currently export more to the EU than the industries that are relatively more important in other parts of the UK. The average proportion of output exported to the EU among workers in the East Midlands was 5.3%, in the West Midlands

5.2% and in London 5.0%.⁷ These figures compare with an employment-weighted average export share of 4.9% for the UK as a whole.

This variation across regions reflects the fact that manufacturing industries – which Figure 10.2 shows are more dependent on exports to the EU than other industries – account for 12% of employment in the East Midlands, 11% in the West Midlands and 9% in the North West, compared with 7% in the UK as a whole. In London, only 2% of employees are employed in manufacturing. There, the relatively high export share is due to the greater importance of finance in local employment (accounting for 7% of local employment, as opposed to 4% across the UK as a whole) and the lower proportion of workers in low-exporting service sectors such as education, health and care, and public administration. These account for 21% of workers in London compared with 26% of workers in the population as a whole.

Industries that employ relatively more workers in Scotland and Northern Ireland tend to be slightly less dependent on exports to the EU than the industries that are relatively more important in other parts of the UK. However, as we noted above, firms in a given industry in Northern Ireland might well be likely to export a greater share of their output to the EU than firms in that same industry in other parts of the UK.

10.4 Potential changes in trade barriers between the UK and the EU

Having considered a few channels through which trade barriers affect companies' value added in Section 10.2, we now turn to the question of what these trade barriers might be.

The simplest and most transparent form of trade barrier is an import tariff. This is a tax levied on goods imported from other countries. It can either be 'specific' (levied according to the quantity that is imported) or '*ad valorem*' (levied according to the imported good's value).

However, explicit import tariffs are far from the only form of barrier to trade. Regulatory differences between countries can also hamper trade – for example, by requiring companies to register and comply with different authorities in each country. There can also be new barriers to the process of trade itself; for instance, shipments of goods may need to be checked by customs to ensure the correct tariff has been paid and that domestic environmental and safety standards are met. These checks can introduce delays and other costs for importing firms. Collectively, these other costs of importing and exporting goods and services are known as non-tariff barriers. Unlike tariffs, non-tariff barriers have the effect of reducing trade flows without the benefit of raising revenue for the government. We describe these sorts of costs in more detail below.

At present, the UK is a member of both the EU Customs Union and the Single Market. These entities were established with the aim of removing tariffs and reducing non-tariff barriers between EU member states and other participating countries.

⁷ Authors' calculations using ONS analytical input-output tables 2014 and the Business Structure Database (local unit file) 2016. These averages differ from the average share in Figure 10.2 as they are employment-weighted averages of different industries' export shares rather than an average weighted by industry output.

The EU Customs Union is a collection of states that have agreed to remove tariffs and customs checks on goods travelling between member states, and to apply a common external tariff and a common 'Union Customs Code' (governing customs rules and procedures) to goods entering the Customs Union from countries outside it. The EU Customs Union currently comprises all the present 28 EU member states plus Monaco.⁸

The Single Market is a collection of rules designed to reduce or eliminate various non-tariff barriers to trade in goods and services. This includes a body of legislation that harmonises product standards for some goods and services. For other products, Single Market rules can sometimes ensure that goods made to standards applied in some member states are also accepted for sale in other member states (a principle known as mutual recognition). The Single Market includes all the current 28 members of the EU, but a few non-members also participate to various degrees. For instance, both Norway and Switzerland are subject to some Single Market rules and enjoy corresponding access to some markets of other members.

At the time of writing, the UK has indicated its intent to leave both the EU Customs Union and the Single Market. This will undoubtedly create new barriers to trade with the EU's existing members, but it is far from clear what form these will take. The UK government has stated that it would like trade with the EU to remain 'as frictionless as possible', with no new tariffs on UK-EU trade and a 'common rule book' for highly regulated sectors to minimise the need for new customs checks for goods passing between the UK and the EU. However, the UK government also wants the power to set its own tariffs and strike its own trade deals with third countries, as well as the freedom to deviate from Single Market rules in some cases. To ensure that this does not lead to customs checks being carried out at a new 'hard border' between Northern Ireland and the Republic of Ireland, the government has proposed conducting customs checks and collecting EU tariffs on the EU's behalf on goods imported to the UK from third countries for onward shipment to the EU. The idea is that, by conducting these checks on the UK's other borders, there would be no need for additional checks of any goods being transported from Northern Ireland to the Republic.⁹

So far, however, the EU has indicated it is not willing to accept an agreement of this kind. In response to the UK's proposals, the EU's chief negotiator, Michel Barnier, has raised concerns over the possibility that firms might fraudulently declare goods to be destined for the UK rather than the EU in order to avoid paying EU tariffs, and over whether the UK ought to be granted the level of access to the Single Market it seeks without being subject to the same oversight and obligations that apply to other members.¹⁰ At the time of writing, it is not clear how these differences are likely to be resolved.

In the absence of clarity on the exact form the UK's post-Brexit trading arrangements with the EU will take, we consider three alternative scenarios based on the EU's current trading arrangements with other countries.

⁸ Turkey is outside the EU Customs Union though it has formed its own customs union with the EU. This is not comprehensive as it does not cover agricultural goods.

⁹ HM Government, *The Future Relationship between the United Kingdom and the European Union*, Cm 9593, 2018, <https://www.gov.uk/government/publications/the-future-relationship-between-the-united-kingdom-and-the-european-union>.

¹⁰ http://europa.eu/rapid/press-release_STATEMENT-18-4626_en.htm.

One such arrangement would be a free trade agreement (FTA) of the kind the EU has recently signed with Canada, for example (known as the Comprehensive Economic and Trade Agreement, CETA). An agreement of this kind would largely or entirely eliminate tariff barriers. However, it would not eliminate the need for customs checks, and while such agreements may contain provisions that reduce other non-tariff barriers, they are far less comprehensive than arrangements such as the EU Single Market. In what follows, we refer to this as the FTA scenario. In this case, we assume that the agreement entails no tariffs on UK-EU trade, but does lead to increases in trade costs through higher non-tariff barriers than currently apply.

A second scenario is an arrangement of the kind the EU currently has with other members of the European Economic Area (EEA), which comprises Iceland, Liechtenstein and Norway as well as EU countries. This would keep the UK more closely integrated with the EU than an FTA, with the UK accepting some EU rules and regulations, for example. We assume that this entails zero tariffs and reduced non-tariff barriers to EU-UK trade relative to a free trade agreement, but an increase in non-tariff barriers relative to the status quo.¹¹

A third arrangement we consider is a case where the UK and the EU do not strike a comprehensive trade deal. In the event that London and Brussels fail to find a mutually acceptable trade deal, the UK and the EU would default to trading under World Trade Organisation (WTO) rules. These rules (described in more detail in Box 10.1) specify that neither the UK nor the EU can offer each other lower import tariffs than they charge on imports from other countries with which they do not have a trade agreement. A 'WTO-rules' Brexit would therefore mean the imposition of new tariffs on EU-UK trade in addition to any new non-tariff barriers that are created by customs checks and regulatory divergence. In addition to these new tariffs, this scenario also involves larger non-tariff barriers being imposed on UK-EU trade than in either the FTA or EEA scenarios.

Box 10.1. What are WTO rules?

Members of the World Trade Organisation must, broadly speaking, adhere to two key principles. The first is that they are bound by commitments made through various rounds of negotiations to open their markets to other WTO members in certain ways: for example, they may not set tariffs above an agreed level and are not permitted to introduce trade-distorting subsidies. The second commitment is to a principle of non-discrimination. Countries should grant all other WTO members the same access to their markets as they have granted the 'most-favoured nation' (MFN) and should not, for example, levy tariffs on imports from one country and not on those from another.

Both of these principles have important exceptions. For example, countries may introduce protective measures ('safeguards') in response to unexpected 'surges' of imports from a particular source. Both the US and the EU have employed such measures to restrict imports of Chinese textiles and steel. Countries can also levy duties on products deemed to have been sold below cost onto their markets, through so-called 'anti-dumping' duties, and, in the event that they are subject to trade barriers that are not permitted under WTO rules, they may be authorised by a WTO panel to apply

¹¹ In practice, the EU and Norway, for example, do charge tariffs and impose quotas on imports of agri-food products from each other. We assume tariff- and quota-free trade, as is the UK government's aspiration.

‘countervailing duties’ against the offending party until the dispute is resolved. These measures must be commensurate with the adverse impacts of the subsidy.^a

Countries can also selectively open their borders to particular trading partners provided they do so through formal trading agreements (which we will refer to as free trade agreements, FTAs). FTAs include, for example, the North American Free Trade Agreement and a number of bilateral free trade agreements signed between WTO members such as CETA. So-called ‘preferential’ trading agreements are FTAs whereby advanced economies make unilateral trade concessions to developing countries. For instance, the EU grants tariff- and quota-free access to developing countries through the ‘Everything but Arms’ scheme and the Generalised Scheme of Preferences. WTO members must notify the WTO of all trade agreements and their provisions while they are being negotiated, at which point they are monitored and assessed to ensure compliance with WTO rules.^b Free trade agreements are common. Since Mongolia and Japan signed a regional trade agreement in June 2016, it has been the case that every WTO member has an FTA of some kind in force.^c

Currently, as a member of the EU Customs Union without the ability to negotiate its own trade deals, the UK is represented at the WTO by the EU. Following Brexit, the UK would become a WTO member in its own right.^d This would mean it would have the same rights and obligations as other WTO members, including compliance with WTO limits on tariffs and with the MFN rules.

While the process of becoming a WTO member is one of the less complex aspects of Brexit, there are a few important implications of an independent WTO membership that are worth noting. WTO rules would require customs checks on goods passing between the UK and the EU in the absence of a formal UK-EU trade deal. To do otherwise would fall foul of WTO rules regarding non-discrimination, since customs checks are currently imposed on goods entering the UK from non-EU WTO members. In addition, the UK could, for example, at some point be subject to EU anti-dumping duties and, even if not, the *risk* of such duties being imposed can act as a deterrent to investment.^e

^a See Article 7 of the WTO Agreement on Subsidies and Countervailing Duties, https://www.wto.org/english/docs_e/legal_e/24-scm.pdf.

^b Such rules are described under Article XXIV of the GATT treaty. They include, for example, that barriers to trade among contracting parties of regional trade agreements (RTAs) with respect to the outside world be no higher after the formation of the RTA than they were before.

^c https://www.wto.org/english/tratop_e/region_e/region_e.htm#rules_ita.

^d L. Bartels, ‘The UK’s status in the WTO after Brexit’, September 2016.

^e M. Crowley, H. Song and N. Meng, ‘Tariff scares: trade policy uncertainty and foreign market entry by Chinese firms’, Cambridge Working Paper in Economics 1676, 2016, <http://www.econ.cam.ac.uk/research-files/repec/cam/pdf/cwpe1676.pdf>.

In this chapter, we present results for the third of these scenarios, a WTO-rules Brexit. We have also done similar analysis for the FTA and EEA arrangements; these estimates can be found in the online supplementary material. It turns out that the relative impacts across groups (i.e. which groups do relatively well and which relatively badly) are very similar across these alternative trading arrangements.

None of these scenarios takes into account possible changes in the UK's trading arrangements with non-EU countries. These could be affected in two ways. First, the UK may face increased trade barriers in foreign markets that the EU has negotiated trade agreements with. These could include, for example, the EU's trade agreements with Canada and South Korea as well as its agreements with the non-EU EEA countries and Switzerland. The nature of the UK's participation in these agreements going forward is somewhat uncertain, and so we do not attempt to account for the possibility of new trade barriers that might apply to UK industries when exporting to or importing from these countries.

Second, the UK may strike new trade agreements with non-EU countries. Indeed, this is one of the reasons the UK government currently seeks to leave the EU Customs Union (so as to be able to operate an independent trade policy). These new agreements may in future reduce trade barriers between the UK and other non-EU countries. However, at present, it is not clear with whom these agreements are likely to be made and what areas of trade they will cover. As a result, we do not take the possible effects of such agreements into account in the following analysis either.

In addition, it is also worth noting that we focus on the long-run trade barriers associated with each outcome rather than short-term costs associated with moving to a new set of trading arrangements. This can be thought of as an assumption of any transition being fairly orderly. This means we are not, for example, considering the possible costs of a chaotic 'no-deal' scenario in which the UK abruptly leaves the EU without any kind of transition arrangements; customs barriers are hastily erected on both the EU and UK sides; and UK exporters become subject to the same regulatory compliance checks that the EU currently applies to third countries, with very limited time to prepare. The consequences of this scenario have been spelt out in the UK in a Changing Europe's 'Cost of No Deal' publication.¹² It is a situation best avoided.

Quantifying trade barriers

In this subsection, we set out how we quantify the trade barriers that we assume apply in each of the post-Brexit scenarios we consider.

Tariffs on UK-EU trade are only imposed under our 'WTO rules' scenario. In this case, we assume that both the UK and the EU apply the EU's current most-favoured nation (MFN) tariffs to each other's imports. In principle, both the UK and the EU could adjust these tariffs from their current rates after Brexit. For instance, the UK could lower MFN tariffs below the rates the EU currently levies once it left the Customs Union.¹³ However,

¹² See UK in a Changing Europe, 'Cost of no deal', 2017, <http://ukandeu.ac.uk/research-papers/cost-of-no-deal> and 'Cost of no deal revisited', 2018, <http://ukandeu.ac.uk/research-papers/cost-of-no-deal-revisited>.

¹³ The EU's current MFN tariffs are already close to the maximum allowable rates under its commitments to the WTO. This means that both the UK and the EU would only have limited scope to raise tariffs above their current levels.

reductions in the UK's MFN tariffs would have to apply to all the UK's imports in order to be compliant with WTO rules. While there are good reasons why economists often call for tariff reductions, unilateral liberalisation of this kind would prevent the UK from using the offer of tariff reductions as bargaining chips in future trade negotiations. It could also be politically difficult, as it would expose hitherto protected industries to greater import competition. In any case, while tariff reductions might well be sensible in the longer term, there would be a case for lowering them gradually. We therefore take as our baseline case a situation where the UK replicates the EU's existing MFN tariffs post-Brexit. For similar reasons, we assume that the EU does not adjust its tariffs, meaning that the EU applies the MFN tariffs it applies to countries with which it has no trade agreements to imports from the UK.¹⁴

The non-tariff barriers that would apply in different scenarios are, by their nature, much harder to quantify than tariff barriers. However, the potential importance of non-tariff barriers both overall and in particular sectors means that they should not be neglected. We therefore draw on available estimates of the size of non-tariff barriers for different sectors.

In particular, we take our estimates of non-tariff barriers from the government's 'EU exit analysis cross Whitehall briefing'.¹⁵ This document sets out estimates of possible long-run non-tariff barriers under the three scenarios we described above (expressed in terms of the *ad valorem* tariff rates they would be equivalent to – for example, 20% of the value of a good or service). These estimates are subject to various uncertainties, not least the fact that there is essentially no historical precedent of countries leaving major trading blocs from which reliable estimates of the effects of non-tariff barriers could be obtained. An additional source of uncertainty is the fact that the exact nature of non-tariff barriers will depend on both future political choices by the UK and the outcome of negotiations between the UK and the EU. It is therefore far from clear at present how large they are likely to be. These estimates nonetheless give an idea of the extent of possible non-tariff barriers across different sectors, and associated with different Brexit scenarios, that we can use to get an idea of their distributional impact. These figures were also estimated using standard techniques and are broadly comparable to those estimated in other studies.¹⁶

Figure 10.5 sets out the tariff and non-tariff barriers we assume would apply to both the exports and imports of goods and services for different industries under the WTO-rules Brexit described above.¹⁷ Under this scenario, new trade barriers are expected to be greatest for food and drink products (where increased trade costs amount to a substantial 38% of the value of each product on average). These are followed by the barriers in agriculture and fisheries, for which new trade costs reach 25% of the value of exported

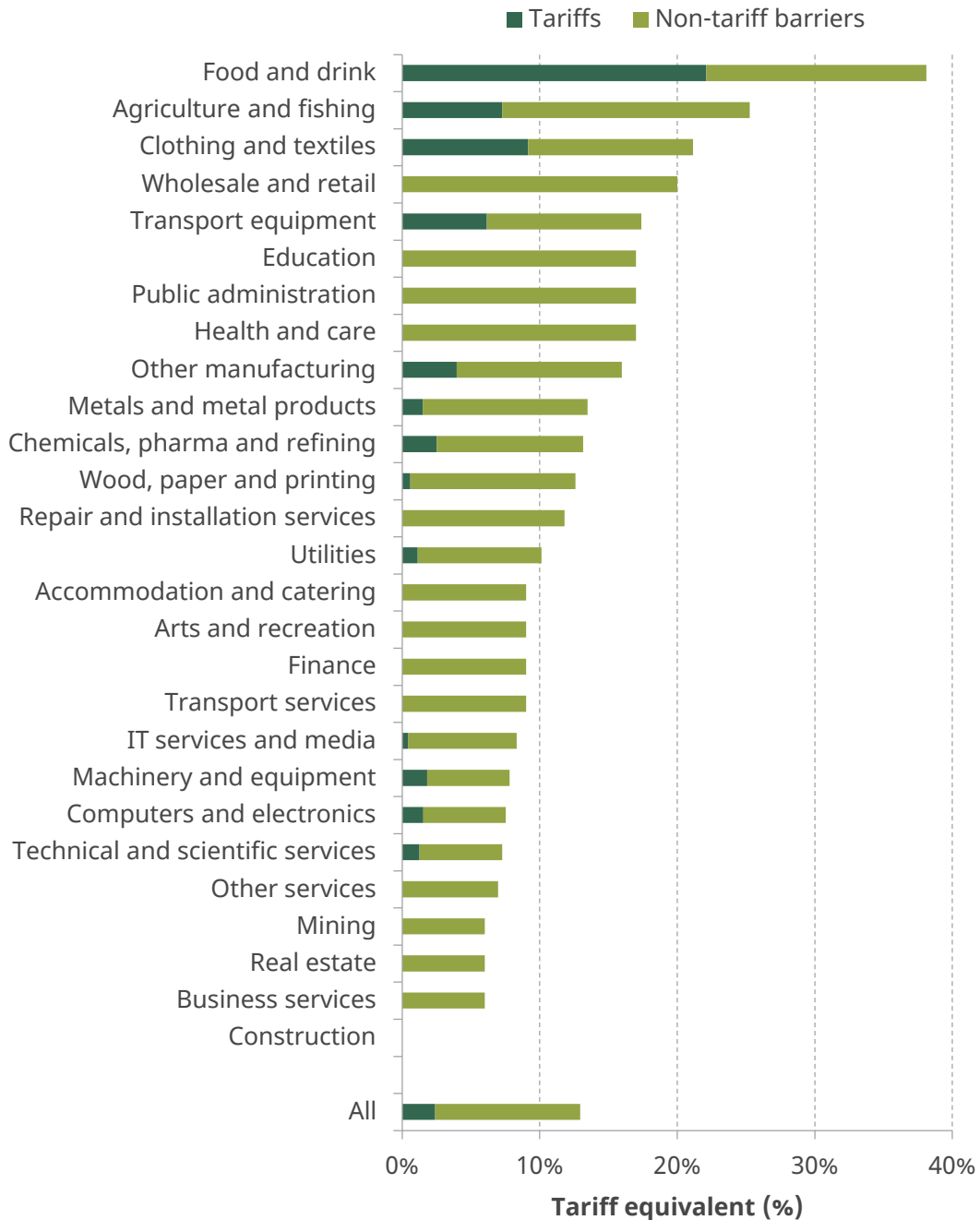
¹⁴ The EU's current MFN tariffs are available online from the World Integrated Trade Solution tariffs database, <https://wits.worldbank.org/>.

¹⁵ House of Commons Exiting the European Union Committee, 'EU exit analysis cross Whitehall briefing', 2018, <https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Cross-Whitehall-briefing/EU-Exit-Analysis-Cross-Whitehall-Briefing.pdf>.

¹⁶ For a comparison of non-tariff barriers from different studies, see figure 7 in International Monetary Fund, *Euro Area Policies: Selected Issues*, IMF Country Report 18/224, 2018, <https://www.imf.org/en/Publications/CR/Issues/2018/07/18/Euro-Area-Policies-Selected-Issues-46097>.

¹⁷ Table A.1 in the online supplementary material shows the non-tariff barriers used in the FTA and EEA scenarios.

Figure 10.5. Tariffs and non-tariff barriers between the EU and the UK under the WTO rules scenario, by industry



Note: MFN tariffs represent the average tariff among goods produced by each industry weighted by exports to the EU. No non-tariff barriers are associated with exports of the construction industry (a service industry associated with negligible exports; see Figure 10.2).

Source: World Integrated Trade Solution tariffs database, <https://wits.worldbank.org/>; House of Commons Exiting the European Union Committee, 'EU exit analysis cross Whitehall briefing', 2018, <https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Cross-Whitehall-briefing/EU-Exit-Analysis-Cross-Whitehall-Briefing.pdf>.

goods, and clothing and textiles, for which new trade costs amount to 21% of the value of each good.

For most industries, higher trade costs are largely driven by the impacts of new non-tariff barriers. Indeed, non-tariff barriers are the most important source of new trade costs for all industries except food and drink. They range from 20% of the value of services for retail and wholesale trade to around 12% for most manufacturing industries and just below 10% for service industries such as finance and business services. Overall, the average export-weighted non-tariff barrier is estimated at 10.5% while the export-weighted average tariff barrier is just 2.4%.

Since non-tariff barriers are going to be important in driving many of our results, it is worth discussing a few of the reasons why these numbers tend to be so large.

One aspect of these costs is the delays and uncertainty associated with customs checks. These can cause obvious problems for trade in agricultural and food products, whose shelf life can sometimes be a matter of days. To take one example, at present, animal products such as eggs and meat that are imported from outside the EU confirm their compliance with EU safety standards with a health certificate. These documents must be verified by customs authorities. In addition, shipments may be physically inspected by a veterinarian at a designated border inspection post.¹⁸ All these checks have costs in terms of both time and money.

Customs delays and procedures are also likely to cause problems for firms that make use of so-called just-in-time production methods. Industries such as car and aircraft manufacturing now often rely on quick deliveries from suppliers that are made with limited notice so as to minimise inventory and storage costs. The flexible supply chains that underpin these production methods may be frustrated by customs delays, introducing trade costs that are similar in their effects to new tariffs. These sorts of costs would potentially have important consequences both for UK industries that make heavy use of EU suppliers and for UK suppliers to manufacturers in the EU.

Not all non-tariff barriers are incurred at the point at which a good crosses a border. 'Behind-the-border' barriers stemming from differences in regulations across countries may also prevent firms from importing or exporting certain products. For instance, if environmental or safety requirements of trading partners differ, or the approval of foreign regulators is not recognised in other countries, then it may be costly for firms to produce goods that are accepted for sale in both domestic and foreign markets. This may discourage firms from exporting or importing certain goods and services at all. These sorts of costs can be important for many service providers. One salient example of a non-tariff barrier that may affect UK service exporters is the potential loss of 'passporting' rights for financial firms in the event of the UK leaving the EU Single Market. Without these rights, UK financial firms that want to sell services in the EU will be required to seek separate authorisation from local banking authorities. They may also be subject to additional regulations applied to third-country financial service providers.

¹⁸ See, for example, <https://www.food.gov.uk/business-guidance/importing-products-of-animal-origin>.

Although the precise level of non-tariff barriers is unknown, existing research confirms that they are generally much more costly than tariffs.¹⁹ However, we might be less certain about their relative impacts across sectors, which could be important for determining their distributional impact. For example, estimates of the non-tariff barriers on the finance industry and transport equipment sector in the ‘Whitehall analysis’ are much lower than those predicted by the International Monetary Fund.²⁰ For this reason, we also look at how our results change when we apply the same export-weighted average non-tariff barrier to all industries (so that it is possible to see the extent to which assumptions over differences in non-tariff barriers between industries drive our results).

10.5 Impacts of new trade barriers on different sectors

In Section 10.2, we showed that the importance of trade with the EU varied across different industries. In Section 10.4, we also showed that Brexit might result in larger trade barriers for some industries than others. In this section, we draw these facts together to consider which industries are relatively more and less likely to gain or lose from increased trade barriers under the WTO rules scenario described above (results for the other scenarios can be found in the online supplementary material).

Assessing the economic impact of trade barriers is a complex task as trade barriers can affect industries in a number of ways. Despite this complexity, the logic that underpins our analysis is straightforward: increases in trade barriers after Brexit will make EU products more expensive in the UK and make UK products more expensive in the EU. This will affect the demand and the price paid for different industries’ output in the UK, EU and non-EU export destinations.

To calculate measures of the relative exposure of different industries to new trade barriers, we work out the answer to the following hypothetical question: ‘By how much would the industry have to adjust its output prices in response to changes in demand patterns in order to keep its current output levels constant?’. For industries that have experienced a reduction in demand, this would require them to reduce their prices until demand increased to justify current output levels. For industries that have experienced an increase in demand (for example, because UK consumers buy their output instead of more expensive EU imports), this would lead to them increasing their prices.

We then work out what change this implies for each industry’s *value added* given both changes in their output prices and changes in their input costs. Value added is a measure of the value of an industry’s output minus the costs of inputs purchased from other industries. It thus takes into account the impacts of changes in firms’ output prices and in their input costs.

Of course, we do not expect firms to keep their output levels constant in response to the changes in trade barriers. Output may fall in negatively affected industries and rise in

¹⁹ For example, non-tariff barriers between the EU and the US are estimated to be equivalent to a 10% tariff (figure 3.1 in ECORYS, *Non-Tariff Measures in EU-US Trade and Investment: An Economic Analysis*, Final Report, commissioned by European Commission, Directorate-General for Trade, reference OJ 2007/S180-219493, 2009, http://trade.ec.europa.eu/doclib/docs/2009/december/tradoc_145613.pdf).

²⁰ See figure 7 in International Monetary Fund, *Euro Area Policies: Selected Issues*, IMF Country Report 18/224, 2018, <https://www.imf.org/en/Publications/CR/Issues/2018/07/18/Euro-Area-Policies-Selected-Issues-46097>.

positively affected ones. However, this approach allows us to get an idea of the *relative* impacts across different industries and the mechanisms that are likely to drive them.

The figures we obtain for different industries' value added changes should therefore *not* be treated as estimates or exact predictions of the value added change they would experience after Brexit. Rather, we use them to assess which industries are likely to be most and least affected by new trade barriers. In addition, for a variety of additional reasons, these measures do not tell us exactly how much the wages of workers currently employed in each industry will change. As we describe in more detail in Section 10.6, this will depend on a number of other factors, including whether workers in adversely affected industries are able to find alternative employment in other industries as well as Brexit's overall effect on productivity growth. However, our measures can be used to indicate what sorts of workers are currently employed in the industries that will face the greatest pressure to cut their costs or output and thus, other things equal, would be expected to experience the greatest wage pressures.²¹ This is what we will do in the following sections.

To quantify the size of demand responses by firms in the EU, the UK and non-EU countries in response to a given set of trade barriers, we need to make assumptions about the responsiveness of demand to changes in prices. For example, if EU demand for UK exports is highly responsive to changes in prices, then even a small increase in tariffs or non-tariff barriers would cause a large reduction in demand for UK exports. The results we present below are calculated using estimates of the price sensitivity of demand drawn from research on the impact of tariff reductions on trade flows for different industries.²² Details are set out in the online appendix.

Figure 10.6 shows the predicted change in value added due to trade barriers under the WTO rules scenario for our 27 industry groups.²³ Overall, our estimates suggest that UK gross value added would fall by around 2.6%. The most adversely affected industries are transport equipment, clothing and textiles, and chemicals, pharmaceuticals and refining, which are estimated to experience reductions in value added of 20%, 18% and 16% respectively. But not all industries are expected to be negatively affected: the figure also shows that value added is estimated to *increase* in the agriculture and fishing industry by 11% and in the wood, paper and printing industry by 3%. However, these increases are far smaller than the reductions across other industries. These industries are also relatively small, accounting for 0.9% and 0.7% of UK gross value added respectively.

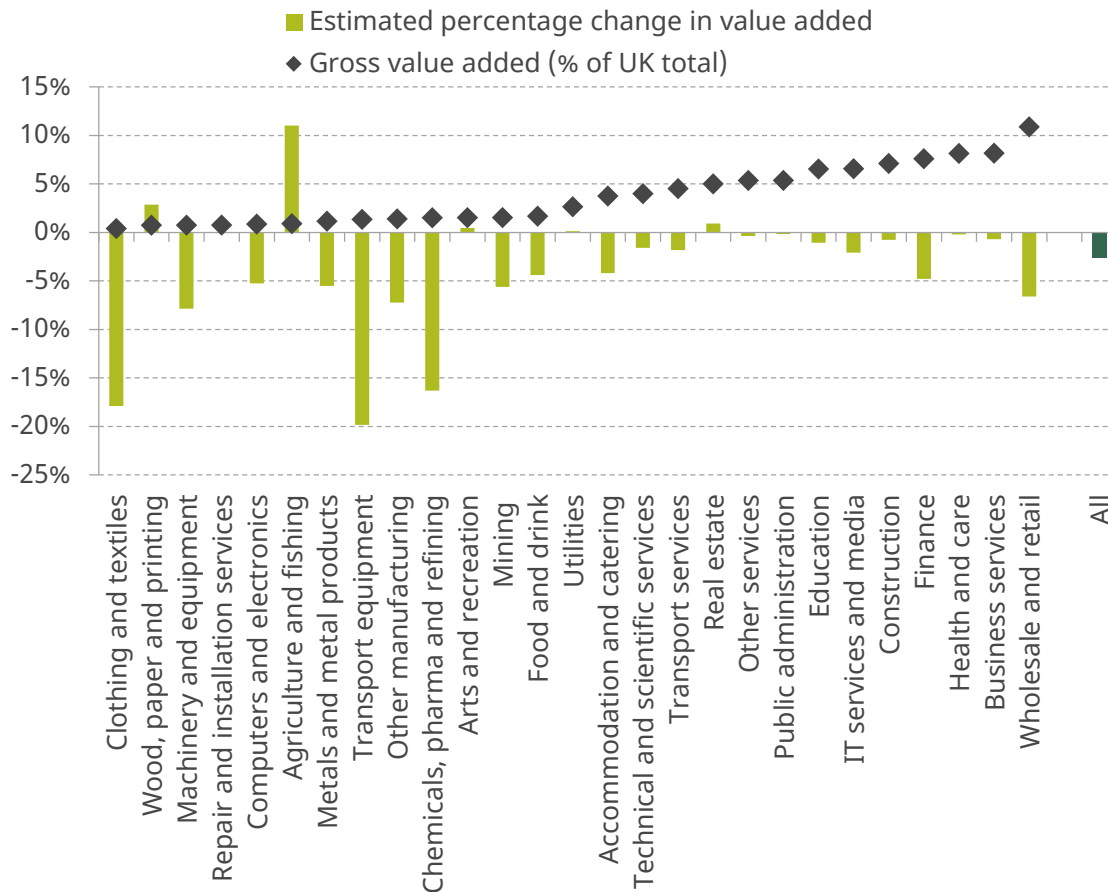
It is also worth re-emphasising that the estimates account solely for the impact of changes in trade policy following Brexit. They do not consider, for example, any changes in state funding, regulations or the availability of immigrant workers that may also affect different industries in various ways.

²¹ An alternative measure of industry exposure would be to calculate how much each industry's output would change to keep the price of their output constant. This alternative approach, however, does not capture how UK firms might reduce their output price in order to increase demand for their products within the UK or in non-EU export destinations.

²² L. Caliendo and F. Parro, 'Estimates of the trade and welfare effects of NAFTA', *Review of Economic Studies*, 2015, 82, 1–44.

²³ We present results on value added changes for all 102 industries we consider in Table A.2 in the online supplementary material.

Figure 10.6. Estimated percentage change in value added due to WTO rules trade barriers and gross value added, by industry



Note: Industries are ranked according to their contributions to the UK's gross value added.

Source: Authors' calculations using ONS analytical input-output tables 2014.

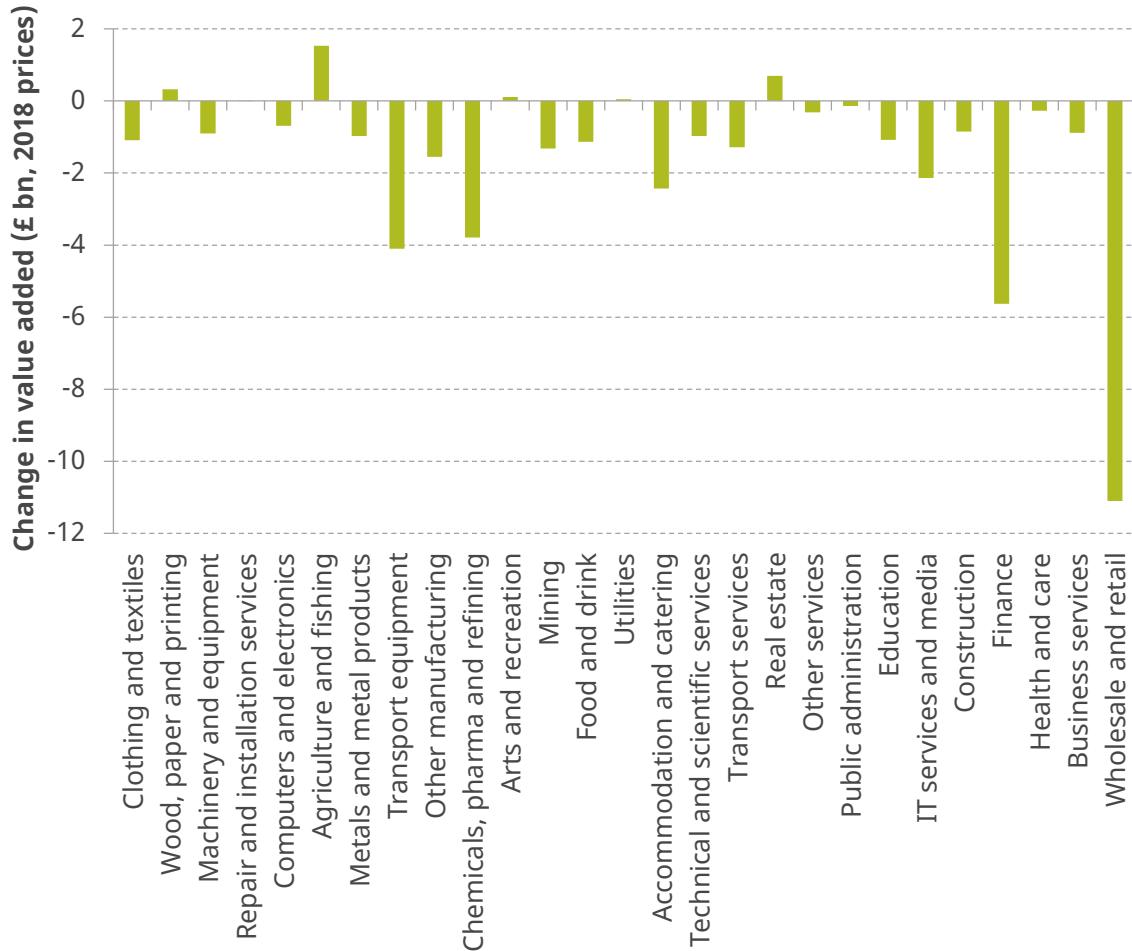
While it is often the case that the industries that tend to see the largest negative impacts are big exporters to the EU, this is not always true. For example, the mining industry exports the largest share of its output to the EU but only experiences a modest decline in its value added. Nor is it always true that the industries facing the largest increases in trade barriers face the worst declines in value added. The agriculture and fishing sector is predicted to see an increase in value added despite its exports facing particularly high new trade barriers. To explain what drives the impacts on individual industries, it is worth focusing on a few selected industries.

- The large negative impact on the **clothing and textiles** industry is primarily driven by its high dependence on the EU as an export market (as shown in Figure 10.2) and the high trade barriers that apply to its exports under our WTO rules scenario (as shown in Figure 10.5).
- The particularly negative impact on manufacturers of **transport equipment** is primarily due to declines in the UK motor vehicle sector. This sector sources 32% of its intermediate inputs from, and exports 32% of its output to, the EU. This dependence on the EU means the UK motor vehicle sector is estimated to experience a 12% fall in EU

demand and a 3% increase in input costs (much larger than the average increase across all industries of 1%). On top of this, the value added by the transport equipment industry is already relatively low. This means that a given decline in price will lead to a large proportional change in value added.

- Manufacturers in the **chemicals, pharmaceuticals and refining** industry are also highly dependent on the EU as a source of inputs and a market for exported output. Like motor vehicles, this industry also has a relatively low value added share. It is estimated to experience a 16% reduction in value added as a result of new trade barriers.
- The positive impact on **agriculture and fishing** occurs because UK consumers and firms switch to consuming domestic goods rather than EU ones as the cost of EU imports rises. The positive effect of this substitution away from EU goods and towards UK firms is particularly large for this industry for three reasons. First, domestic sales are important for this industry. Small proportional changes in demand from UK consumers therefore have a bigger impact on total demand for this industry's output than they would for other industries. Second, EU firms currently have a significant market share in the UK that domestic firms could capture once trade barriers increase. Third, according to the estimates we use, consumers regard agricultural products from different countries as reasonably close substitutes for one another. These effects are magnified by the fact that the increase in the costs of EU imported goods is large (as shown in Figure 10.5). These effects are offset by a reduction in exports to the EU, though the share of this industry's output that is exported to the EU is relatively small. Similar mechanisms explain why the **wood, paper and printing** industry is estimated to experience an increase in value added, although in this case the positive impact of increased domestic demand is offset to a greater extent by an increase in input costs as EU inputs are more important in this industry than in agriculture and fishing.
- The fall of value added in the **wholesale and retail** sector is particularly important as it is a large employer, with around 3.7 million workers. Declines in value added in this industry are largely driven by falls in exports by the wholesale trade services industry. This industry is affected by high non-tariff barriers and there is little scope for it to capture new domestic market share from EU competitors.
- Finally, the **mining** industry is expected to experience a relatively small reduction in its value added. This is despite the fact that it is the sector that currently exports the largest fraction of its output to the EU. But the industry is relatively insulated from big losses in value added because demand for goods in this sector is very responsive to price. As a result, even a small reduction in prices driven by a loss in EU demand leads to a large increase in demand from UK and non-EU sources. The industry is therefore in a position to maintain current production levels for only small changes in its value added.

As explained above, the estimated impacts shown in Figure 10.6 depend on assumptions about the responsiveness of demand to changes in price and the magnitude of non-tariff barriers for different sectors. To examine how these assumptions affect our results, Figure A.1 in the online supplementary material shows the same information as Figure 10.6 under three additional scenarios: where the responsiveness of demand is assumed to be constant across industries, where non-tariff barriers (NTBs) are assumed to be constant

Figure 10.7. Estimated absolute change in value added due to WTO rules trade barriers, by industry

Note: Monetary amounts are calculated using value added figures from the 2014 ONS input-output tables and are expressed in 2018 prices using the GDP deflator taken from the Office for Budget Responsibility's March 2018 Economic and Fiscal Outlook. Industries are ranked according to their contributions to the UK's gross value added.

Source: Authors' calculations using ONS analytical input-output tables 2014.

across industries (equal to their export-weighted average under the WTO rules scenario) and where both the responsiveness of demand and non-tariff barriers are assumed to be constant across industries. Figure A.1 shows that estimated impacts under each of these scenarios are similar to the baseline results shown in Figure 10.6. This means that, while there is uncertainty around the magnitude of non-tariff barriers and how demand would respond to changes in prices, we can be relatively confident that transport equipment, clothing and textiles, and chemicals, pharmaceuticals and refining are the industries that are most exposed to negative impacts of trade barriers, and that the agriculture and fisheries industry is likely to be least exposed.²⁴

²⁴ Our findings for impacts across industries are broadly consistent with those in other studies. Dhingra, Machin and Overman (2017) also find that the chemicals and clothing industries are particularly badly affected but that the agriculture and wood products industries gain under a WTO-rules Brexit. They also find similar declines for the finance industry, though larger losses for business activities and services and somewhat

Overall, trade barriers in the WTO scenario are estimated to reduce value added by 2.6%. To understand which industries drive this overall impact, it is helpful to examine the estimated changes in value added in terms of monetary amounts. These are presented in Figure 10.7, which shows that the wholesale and retail sector is the most important cause of the overall £40 billion decline in value added, followed by the finance, transport equipment, and chemicals, pharmaceuticals and refining sectors. The estimated gross gains – across industries such as agriculture and fishing, real estate, and wood, paper and printing – offset just 6% of the total gross losses across other industries.

10.6 Exposure of workers to negative impacts

In this section, we use data on the industries individuals are employed in to examine the possible impacts of post-Brexit barriers on different types of workers.

We assess these impacts by looking at which workers are employed in industries that are expected to see a boost or a hit to their value added. As Section 10.5 showed, most industries would be expected to see their value added reduced as a result of new trade barriers with the EU. How these changes would translate into effects on those employed in these industries is less obvious and would depend on two main factors.

The first factor is how firms respond to these changes. Business managers may decide to respond to falls in value added by cutting wages or reducing the size of their workforce. Alternatively, they may opt to leave pay and employment largely unchanged and reduce their profit margins instead. In addition, they may try to find ways to make more efficient use of intermediate inputs and raw materials, or otherwise improve their productivity.²⁵

For workers whose companies do pass along some of the impact – either in lower wages or employment losses – the second factor that matters for how these changes will affect workers' well-being is how easily negatively affected workers are able to find new employment in other industries. Workers who are more able to move from shrinking to growing industries will tend to fare better. This will depend on whether there are alternative employment opportunities in their home region, how easily workers can move to new locations if there are not, and whether they possess skills that are easily transferable between industries.

We do not model impacts on individual workers, which would require making assumptions about all of these things.²⁶ However, it is reasonable to assume that the

smaller declines in value added for the transport equipment sector. (S. Dhingra, S. Machin and H. Overman, 'Local economic effects of Brexit', *National Institute Economic Review*, 2017, 242, R24–36.)

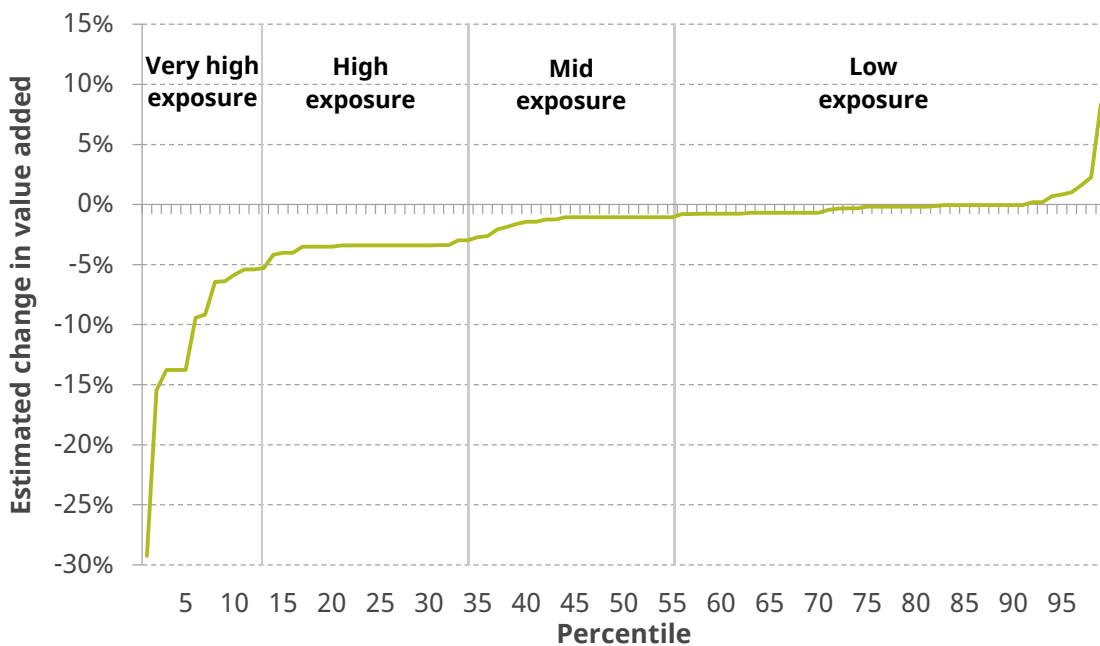
²⁵ Guiso, Pistaferri and Schivardi (2005) find that firms are more likely to change employee earnings if they experience permanent shocks to productivity rather than temporary shocks, but the authors do not examine whether firms change the number of workers they employ. Lagakos and Ordoñez (2011) find that wages respond more to productivity shocks in industries that employ relatively high fractions of low-educated workers, but again they do not examine how industry employment levels respond to shocks. (L. Guiso, L. Pistaferri and F. Schivardi, 'Insurance within the firm', *Journal of Political Economy*, 2005, 113, 1054–87; D. Lagakos and G. L. Ordoñez, 'Which workers get insurance within the firm?', 2011, *Journal of Monetary Economics*, 58, 632–45.)

²⁶ In this chapter, we have also not considered how increased trade barriers might differentially affect the costs of consumer goods and services. Other analysis suggests that price increases from a WTO-rules Brexit would have the largest negative impacts on lower-income consumers. See S. Clarke, I. Serwicka and L. A. Winters,

impact of new trade barriers on an industry's value added and the impacts on its employees would be closely related. We can therefore get a good idea of how different types of worker might be affected by looking at the characteristics of workers employed in industries that would be more exposed to new trade barriers after Brexit.

To do this, Figure 10.8 lines up workers in order according to the predicted value added change of their current industry of employment under a WTO rules scenario.²⁷ We also group workers according to their exposure. We classify workers as 'very highly exposed' if we predict their industry is predicted to experience a value added decline of more than 5%, as 'highly exposed' if their industry is predicted to experience a value added decline of 3–5%, as having 'mid exposure' if their industry is predicted to experience a value added decline of 1–3%, and as having 'low exposure' if their industry is predicted to experience a decline in value added of 1% or less (or an increase in value added). The graph shows that most workers are in industries that have quite low exposure. However, a small proportion of workers are in industries that are predicted to experience quite sharp reductions in value added. For instance, 5% of workers (or about 1.3 million people) are employed in industries that are predicted to experience a value added decline of 14% or more, while

Figure 10.8. Distribution of estimated change in employer value added under the WTO rules scenario among UK employees



Note: Employees are assigned an estimated change in value added based on their main industry of employment. 'Very high', 'high', 'mid' and 'low' exposure industries are those that are estimated to experience a reduction in value added of more than 5%, more than 3% but less than or equal to 5%, more than 1% but less than or equal to 3%, and less than or equal to 1% or an increase in value added, respectively.

Source: Authors' calculations using ONS analytical input-output tables 2014 and the Quarterly Labour Force Survey 2017 quarters 1–4.

Changing Lanes: The Impact of Different Post-Brexit Trading Policies on the Cost of Living, 2017, Resolution Foundation, <https://www.resolutionfoundation.org/publications/changing-lanes/>.

²⁷ Figure A.2 in the online supplementary material shows similar information for the FTA and EEA scenarios, alongside that for the WTO rules scenario.

45% (11.9 million) work in industries where the predicted decline in value added is 1% or less.

Table 10.1 shows the proportions of male and female employees in different education groups in industries with low, medium, high and very high exposure, alongside the average exposure among each group. For instance, it shows that 14% of workers (or 3.7 million) are employed in industries which we classify as very highly exposed.

The table also shows that the average exposure among industries that men work in is much greater than for women. The average predicted value added fall among the industries men work in is 3%, compared with 2% for women. This is not because all men work in more exposed industries than women do. In fact, the proportions of men and women working in low-exposure industries are quite similar (at 43% and 47% respectively). Rather, it is primarily due to the fact that men are more likely to work in very highly exposed industries than women: 17% of men work for such industries compared with just 10% of women.

Table 10.1. Exposure of workers to new trade barriers under the WTO rules scenario^a

	Number employed ('000s)	Mean change in employer value added	Fraction of group employed in ...			
			Low-exposure industries	Mid-exposure industries	High-exposure industries	Very-high-exposure industries
All	26,500	-2.5%	45%	22%	19%	14%
Women: All	13,100	-2.0%	47%	25%	19%	10%
Low-educated	4,400	-2.5%	42%	17%	28%	12%
Mid-educated	3,800	-1.9%	52%	19%	20%	9%
High-educated	4,900	-1.7%	47%	35%	10%	8%
Men: All	13,400	-3.0%	43%	20%	19%	17%
Low-educated	5,100	-3.5%	45%	11%	24%	19%
Mid-educated	3,700	-3.1%	45%	16%	21%	18%
High-educated	4,600	-2.4%	40%	32%	13%	15%

^a Tables A.3a and A.3b in the online supplementary material contain the same analysis for the FTA and EEA scenarios, respectively.

Note: Employees are assigned an estimated change in value added based on their main industry of employment. Workers are classed as 'low-educated' if their highest educational qualification is at GCSE level or lower, as 'mid-educated' if their highest educational qualification is at A level or is another form of further education below degree level, and as 'high-educated' if they hold a degree or degree-equivalent qualification. 'Very-high-', 'high-', 'mid-' and 'low-' exposure industries are those that are estimated to experience a reduction in value added of more than 5%, more than 3% but less than or equal to 5%, more than 1% but less than or equal to 3%, and less than or equal to 1% or an increase in value added, respectively.

Source: Authors' calculations using ONS analytical input-output tables 2014 and the Quarterly Labour Force Survey 2017 quarters 1-4.

Looking across education groups, average exposure is greatest among the less educated – and particularly high in the industries that tend to employ low-educated men. This is because, while the proportion of low-educated men in industries with low exposure is greater than the proportion of high-educated men in those industries, more low-educated workers are employed in industries with high or very high exposure. Industries with high or very high exposure employ 19% and 17% of low-educated men respectively, compared with 13% and 15% of men with a degree. In Tables A.3a and A.3b in the online supplementary material, we look at how these impacts vary under our FTA and EEA scenarios. While the size of predicted impacts is lower under both of these alternative scenarios, the relative impacts remain greatest for low-educated workers, and for low-educated male workers in particular.

We next focus on differences in exposure across occupations. Whereas a worker's industry of employment is determined by the goods or services their employer produces, their occupation is determined by their job title and the tasks they perform at work. As a result, workers are likely to find it harder to move between different occupations than they are to move between different industries. For example, someone working as a secretary for a drinks manufacturer would likely find it easier to move to a new job as a secretary for a toy manufacturer (i.e. change industry but not occupation) than to move to a new job as an accountant for a drinks manufacturer (i.e. change occupation but not industry). This is important as it means that, if certain occupations are concentrated in industries that experience large negative impacts due to trade barriers, it may be more challenging for workers in these occupations to find alternative employment in less-affected industries.

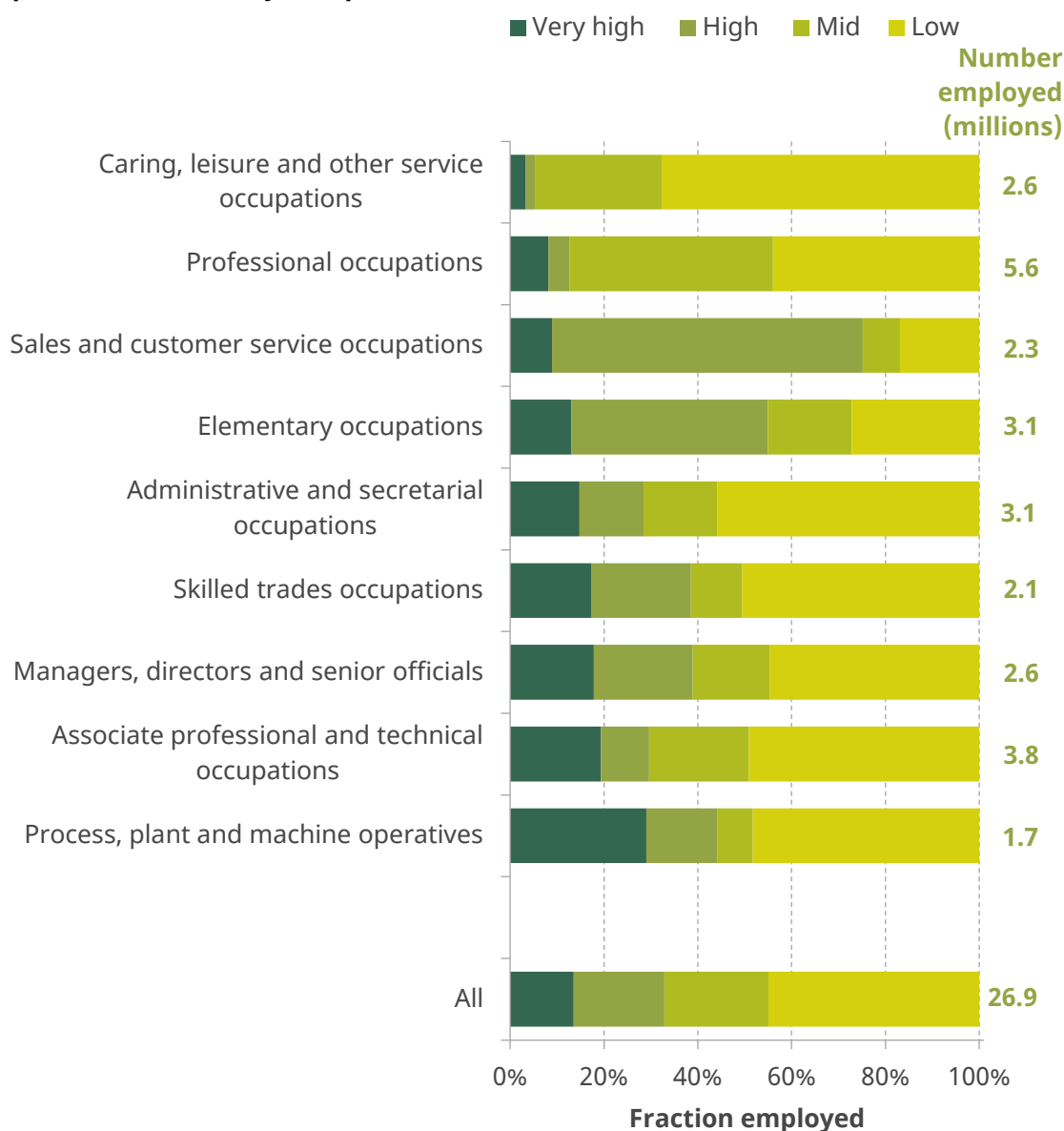
Figure 10.9 shows the proportions of workers in each occupation group who are employed in industries with different degrees of exposure. The occupation with the greatest proportion of workers employed in very highly exposed industries is 'process, plant and machine operatives'. Roughly 480,000 of the 1.7 million workers in this occupation group – 29% – are employed in very highly exposed industries. This is because industries with relatively high estimated reductions in value added – such as clothing and textiles and other manufacturing industries – tend to employ more process, plant and machine operatives than other, less-exposed industries. By contrast, industries such as health and education are estimated to experience relatively small reductions in value added and tend to employ more workers in caring, leisure and service occupations. As a result, the proportion of workers in this occupation who are employed in very highly exposed industries is the lowest of all occupation groups (at just 3%, or about 90,000 workers).

The fact that process, plant and machine operatives are more likely to be employed in the industries that would probably be worst affected by UK-EU trade barriers should be a matter of particular concern for policymakers. Since workers in this occupation group tend to be older and less likely to have a degree, they are more likely to have skills that are specific to their current roles and industries of employment.²⁸ As a result, they may find it particularly difficult to find employment in other less adversely affected industries. Previous research has found that workers in this occupation are unlikely to switch into other less exposed but still well-paid occupations than other groups over the course of

²⁸ We set out the characteristics of workers in each occupation group in Table A.5 of the online supplementary material.

their careers, suggesting that workers in this group may indeed be less likely to find new roles if they are exposed to negative impacts following Brexit.²⁹

Figure 10.9. Percentages of employees working in low-, mid-, high- and very-high-exposure industries, by occupation: WTO rules scenario^a



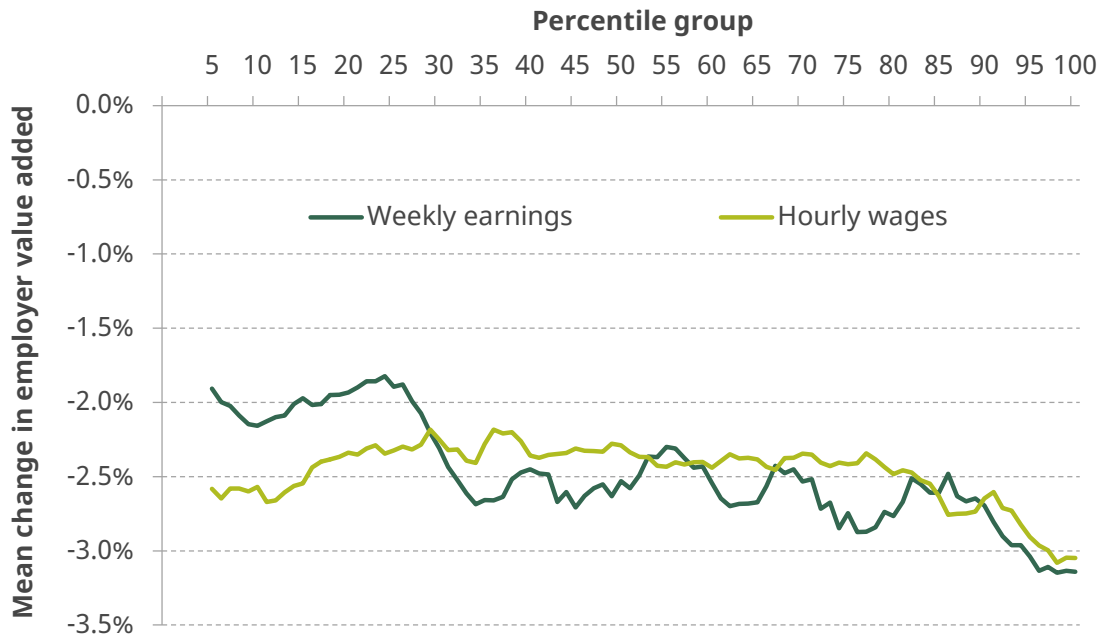
^a Table A.4 in the online supplementary material contains similar analysis for the FTA and EEA scenarios, alongside that for the WTO rules scenario.

Note: Employees are assigned an estimated change in value added based on their main industry of employment.

Source: Authors' calculations using ONS analytical input-output tables 2014 and the Quarterly Labour Force Survey 2017 quarters 1–4.

²⁹ See table 5 of C. Carrillo-Tudela, B. Hobijn, P. She and L. Visschers, 'The extent and cyclical of career changes: evidence for the U.K.', *European Economic Review*, 2016, 84, 18–41.

Figure 10.10. Mean predicted change in employer value added under the WTO rules scenario, by pay percentile group (Great Britain)



Note: Employees are assigned an estimated change in value added based on their main industry of employment. Mean changes in employer value added are plotted as a five-percentile moving average.

Source: Authors' calculations using ONS analytical input-output tables 2014 and the Annual Survey of Hours and Earnings 2017.

We next turn to how exposure varies according to the level of workers' pay. Figure 10.10 shows average changes in employer value added for workers at different points in the distributions of earnings and wages.³⁰ The dark green line shows that employees who have higher levels of weekly earnings are estimated to see greater reductions in employer value added on average than those on low weekly earnings. For example, the average change in employer value added among workers in the 10th percentile group of the earnings distribution is 2.2%, compared with 2.5% among workers in the very middle of the earnings distribution and 2.7% among workers in the 90th percentile group. This suggests that post-Brexit trade barriers would act to reduce inequality in weekly earnings. However, it is important to note that value added is estimated to fall across the entirety of the earnings distribution.

The reason that reductions in employer value added are smaller towards the bottom of the earnings distribution is that many low-earning workers are employed in service industries that tend to export less to the EU – a pattern shown in Figure 10.4. By contrast, estimated changes in employer value added are greatest at the top of the earnings distribution as very highly paid workers are more likely than other workers to be employed in industries with relatively large estimated reductions in value added, such as finance.

³⁰ Figure 10.10 shows the earnings and wage distributions in Great Britain only, as Northern Ireland is not included in the version of the Annual Survey of Hours and Earnings that was used in this analysis.

These findings initially appear puzzling given the results in Table 10.1, which showed that low-educated workers were more exposed to the negative consequences of trade barriers than more highly educated workers. The result in Figure 10.10 – that post-Brexit trade barriers will act to reduce earnings inequality – arises for two reasons. First, rather than comparing between workers of the same sex as Table 10.1 does, the figure looks at all workers together. Since male workers tend to work in worse-affected industries and men tend to earn more than women, trade barriers will weigh more heavily on the (more male-dominated) upper end of the earnings distribution. Second, within each broad education group – GCSEs and below, A level or equivalent, and degree level or higher – the workers who work in the most affected industries also tend to earn more than other workers.³¹ This again means that impacts are likely to be larger in the upper part of the earnings distribution.

The light green line in Figure 10.10 shows how impacts differ according to workers' *hourly wages* (their weekly earnings divided by hours worked per week). It shows that workers who are paid relatively low hourly wages tend to do worse than workers with relatively low weekly earnings. This indicates that some of the patterns in the figure are driven by the fact that low-earning workers, who are less likely to work in exposed industries, tend to be working fewer hours. However, workers paid the highest hourly wages are more exposed than lower-paid workers, implying that increases in trade barriers with the EU are likely to reduce hourly wage inequality.

Figures A.3a and A.3b in the online supplementary material show that the patterns in exposure across the pay distribution are robust to different assumptions about the responsiveness of demand and non-tariff barriers, which suggests they are driven by the importance of trade with the EU. Figure A.4 shows how impacts across the pay distribution vary according to the trade scenario we consider. Average exposure is lower under the FTA and EEA scenarios across the earnings distribution, but in all three scenarios higher-earning workers tend to be the ones employed in the most negatively affected industries.

10.7 Impacts across the UK

We can also investigate where more exposed industries tend to be located to get an idea of Brexit's possible impact on different regions. This is an area where estimating the likely effect of Brexit is particularly uncertain. Previous studies on Brexit's regional impacts have come to different conclusions. For example, the government's 'Whitehall analysis' found that the gross value added would fall furthest in the North East of England and least in London.³² However, a similar analysis by researchers at the Centre for Economic Performance at LSE found that parts of London were some of the most affected areas.³³

³¹ For example, very highly exposed workers in the 'low education' group have average earnings that are 24% higher than other low-educated workers (the equivalent figures for mid- and high-educated workers are 35% and 24% respectively). (Source: Authors' calculations using ONS analytical input-output tables 2014 and the Quarterly Labour Force Survey 2017 quarters 1–4.)

³² House of Commons Exiting the European Union Committee, 'EU exit analysis cross Whitehall briefing', 2018, <https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Cross-Whitehall-briefing/EU-Exit-Analysis-Cross-Whitehall-Briefing.pdf>.

³³ S. Dhingra, S. Machin and H. Overman, 'Local economic effects of Brexit', *National Institute Economic Review*, 2017, 242, R24–36.

We obtain a simple measure of the impacts of post-Brexit trade barriers by calculating the average change in value added in each region and nation of the UK, taking into account the local employment mix. As is the case when considering impacts on individual workers, it is important to remember that the way in which reductions in employers' value added will impact workers in different regions will depend on firms' responses to new trade barriers. In addition, there is also uncertainty over the extent to which firms in a given industry are more or less likely to export to the EU – for instance, depending on where they are located. Since we do not have good data on this question, we assume that the share of exports to the EU from a given industry does not vary across regions (as we did in Section 10.3). This means we are likely to overestimate the exposure in some regions and underestimate it in others (for example, trade with the EU is likely to be more important for industries in Northern Ireland than for the same industries located elsewhere). Despite these uncertainties, however, it is likely that negative impacts will be larger in areas of the UK where the industries that experience the greatest declines in value added account for a relatively high fraction of local employment. This is what we analyse below.

The results are presented in Table 10.2. In our baseline WTO rules scenario, we find that the West Midlands, East Midlands and North West are the worst-affected areas, with average employer value added falling by 2.7%, 2.5% and 2.5% respectively in comparison with the national average of 2.3%. This is largely due to the fact that the industries that are more important in these regions tend to export more to the EU. In particular, the larger negative impact in the West Midlands reflects the fact that the transport equipment industry accounts for 2.2% of employment in the West Midlands (around 60,000 workers), in comparison with just 0.9% of employment in the UK as a whole.

There is no clear correlation between average impacts and average earnings in each region, making the effects on interregional inequality ambiguous.

However, it is worth noting that the differences in average impacts across regions are not as great as the differences across different worker types shown in Table 10.1. This suggests that differences in exposure between workers *within* a region are likely to be more important than differences in average worker outcomes *between* regions.

Moreover, we find that the relative ranking of some regions is quite sensitive to the estimates of non-tariff barriers we use. Table 10.2 also shows results for situations where we assume that all industries face a common non-tariff barrier (in the second column), where we hold the responsiveness of demand to price changes constant across industries (in the third column) and where we hold both of these things constant across industries (in the fourth column). It is noteworthy that while in our baseline results London is the sixth-worst-affected region, it becomes the third-worst-affected when we assume constant non-tariff barriers across industries. This is because while the North East, East Midlands, and Yorkshire and the Humber are worse affected than London when we use the non-tariff barrier estimates from the government's 'Whitehall analysis', they are less badly hit than London in a case where we hold non-tariff barriers constant across industries. An important reason for this is the fact that the non-tariff barriers that we assign to exports of the finance industry in our baseline results are lower than those for other industries. The finance industry accounts for 7% of employment in London, nearly double the fraction in the UK as a whole.

Table 10.2. Average estimated change in employer value added, and median employee earnings, by region and nation of the UK^a

	Mean change in employer value added				Median gross employee earnings
	WTO rules	Constant NTBs	Constant responsiveness	Constant NTBs & responsiveness	
UK	-2.3%	-2.1%	-2.2%	-2.0%	£24,100
West Midlands	-2.7%	-2.4%	-2.6%	-2.3%	£22,800
North West	-2.5%	-2.3%	-2.4%	-2.2%	£22,700
East Midlands	-2.5%	-2.2%	-2.4%	-2.1%	£21,800
North East	-2.4%	-2.2%	-2.3%	-2.1%	£22,300
Yorkshire & Humber	-2.4%	-2.1%	-2.3%	-2.0%	£21,800
London	-2.3%	-2.2%	-2.2%	-2.2%	£33,000
South East	-2.3%	-2.0%	-2.2%	-2.0%	£25,300
Wales	-2.3%	-2.1%	-2.2%	-2.0%	£21,800
East of England	-2.1%	-1.9%	-2.1%	-1.8%	£23,300
South West	-2.0%	-1.9%	-2.0%	-1.9%	£22,300
Scotland	-2.0%	-1.9%	-1.9%	-1.8%	£23,800
Northern Ireland ^b	-1.7%	-1.7%	-1.7%	-1.6%	£21,800

^a Table A.6 in the online supplementary material shows the mean change in employer value added for the FTA and EEA scenarios, alongside that for the baseline WTO rules scenario, by region and nation of the UK.

^b We assume that the share of exports to the EU from a given industry does not vary across regions. This may underestimate the degree to which Northern Ireland in particular is exposed.

Note: Mean estimated change in employer value added is calculated as the mean estimated change in value added across all active local units in a given region weighted by local unit employment. Median earnings are rounded to the nearest £100 and expressed in 2018 prices using the CPI taken from the Office for Budget Responsibility's March 2018 Economic and Fiscal Outlook. UK-wide impacts differ from those in Table 10.1 as the employment-weighted average impact is calculated using the Business Structure Database here rather than the Quarterly Labour Force Survey.

Source: Mean changes in employer value added are the authors' calculations using ONS analytical input-output tables 2014 and the Business Structure Database (local unit file) 2016. Median gross employee earnings are taken from table 7.1 of the Annual Survey of Hours and Earnings 2017.

This suggests that the impact of trade barriers on London relative to other regions is particularly sensitive to assumptions about the (uncertain) size of non-tariff barriers in finance relative to other industries. Since London is the region with the highest average earnings, this makes the impact of trade barriers on interregional inequality similarly uncertain.³⁴

³⁴ It is worth comparing the results we obtain here with previous estimates of relative regional impacts due to Brexit. Los et al. (2017) look at regions' direct and indirect exports to the EU and find, as we do, that areas in the north and the Midlands are most exposed (B. Los, P. McCann, J. Springford and M. Thissen, 'The mismatch between local voting and the local economic consequences of Brexit', *Regional Studies*, 2017, 51, 786–99).

Table 10.3. Fraction employed in very highly exposed industries under the WTO rules scenario by region, education and gender^a

	Men			Women		
	Low education	Mid education	High education	Low education	Mid education	High education
UK	19%	18%	15%	12%	9%	8%
West Midlands	24%	19%	18%	12%	10%	6%
North West	19%	21%	14%	11%	9%	8%
East Midlands	21%	21%	17%	17%	10%	7%
North East	17%	16%	12%	9%	7%	7%
Yorkshire & Humber	23%	21%	15%	14%	9%	7%
London	14%	12%	14%	9%	8%	10%
South East	17%	19%	16%	11%	9%	9%
Wales	21%	17%	11%	9%	7%	7%
East of England	17%	16%	19%	17%	6%	12%
South West	20%	19%	14%	12%	9%	7%
Scotland	16%	16%	15%	11%	8%	8%
Northern Ireland	25%	19%	12%	13%	6%	7%

^a Tables A.7a and A.7b in the online supplementary material contain the same analysis for the FTA and EEA scenarios, respectively.

Note: Employees are assigned an estimated change in value added based on their main industry of employment. Workers are classed as 'low-educated' if their highest educational qualification is at GCSE level or lower, as 'mid-educated' if their highest educational qualification is at A level or is another form of further education below degree level, and as 'high-educated' if they hold a degree or degree-equivalent qualification. 'Very highly' exposed industries are those that are estimated to experience a reduction in value added of more than 5%.

Source: Authors' calculations using ONS analytical input-output tables 2014 and the Quarterly Labour Force Survey 2017 quarters 1–4.

Dhingra, Machin and Overman (2017) find a weak positive relationship between value added losses at the level of local authorities and local incomes. They find that the worst-affected areas are local authorities located in London and the South East. This is likely due to the fact that these authors find large losses for business activities sectors, owing to the fact they assume relatively larger non-tariff barriers apply to these sectors than we do. They also find smaller effects for areas in the West Midlands than we do, possibly because they predict smaller losses in the transport equipment sector. (S. Dhingra, S. Machin and H. Overman, 'Local economic effects of Brexit', *National Institute Economic Review*, 2017, 242, R24–36.) The government's 'Whitehall analysis' also includes estimates of effects by region, finding that the North East is the region most affected, with London the least affected. It also finds, as we do, relatively large effects for the West Midlands. One key difference between this study and ours is that the Whitehall analysis incorporates growth in industries' value added that is due to workers reallocating from shrinking to growing industries. This may lead to growth in the *total* value added of industries located in particular regions; however, this growth would not benefit workers currently employed in those industries (the benefit to them will depend on value added *per worker*). This could explain some of the differences in regional outcomes that we obtain. (House of Commons Exiting the European Union Committee, 'EU exit analysis cross Whitehall briefing', 2018, <https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Cross-Whitehall-briefing/EU-Exit-Analysis-Cross-Whitehall-Briefing.pdf>.)

Alongside average exposure across workers in each region, it is also worth considering whether exposed industries are particularly important employers of workers of a given type. Specifically, it is interesting to examine whether very highly exposed industries are important employers of workers with low educational qualifications. This is because, as we discussed in Section 10.6, these workers may have fewer transferable skills and may have skills more specific to their current industry of employment. We look at this in Table 10.3, which shows the proportion of male and female employees with different education levels in ‘very highly’ exposed industries in different parts of the UK.

The table shows that very highly exposed industries tend to be particularly important employers of low-educated men in Northern Ireland and the West Midlands, employing 25% and 24% of low-educated men respectively (compared with 19% in the UK as a whole).³⁵ This suggests that low-educated workers in these regions may be particularly vulnerable if highly exposed industries shrink as a result of new trade barriers.

Policymakers should pay attention to such areas, especially as there may be concentrations of particular industries in certain towns and cities within these broad regions. For example, employment in car plants can account for as much as 10% of local private sector employment in some local authorities.³⁶

Low-educated women are less likely to be employed in highly exposed industries in general. However, they are more likely to work in such industries in the East Midlands and East of England. In these regions, 17% of low-educated women work in such industries, relative to 12% of women in the UK as a whole.

10.8 Conclusion

In this chapter, we have considered how new barriers to UK–EU trade would affect different UK industries. Certain industries are likely to be worse affected than others. The transport equipment, clothing and textiles, and chemicals, pharmaceuticals and refining industries appear to be particularly badly affected due to the fact that these industries export a lot to the EU or use a relatively large amount of inputs imported from the EU (or both).

Industries that are more exposed to negative impacts of trade barriers also tend to employ different types of workers from the average employer. Men, for example, are much more likely to work in highly exposed industries than women. Less-educated men are also disproportionately likely to work in the most exposed industries, as are workers in ‘process, plant and machine operatives’ occupations. This may be a matter of particular concern to policymakers, as workers in this group may find it harder to shift out of their current job and into new roles in the event of a negative shock than other groups. These issues may prove particularly acute in regions such as Northern Ireland and the West Midlands, where highly exposed industries employ a disproportionately large number of such workers. Policymakers should consider whether specific interventions (such as retraining and employment support) could help workers in these particularly highly exposed groups to adjust to the introduction of new trade barriers.

³⁵ The Northern Ireland figure is likely, if anything, to be an underestimate given that industries in that country are likely to conduct more trade with the EU than otherwise-similar industries located elsewhere in the UK.

³⁶ S. Bernick, R. Davies and A. Valero, *Industry in Britain: An Atlas*, Centre for Economic Performance, Special Paper 34, 2017, <http://cep.lse.ac.uk/pubs/download/special/cepsp34.pdf>.

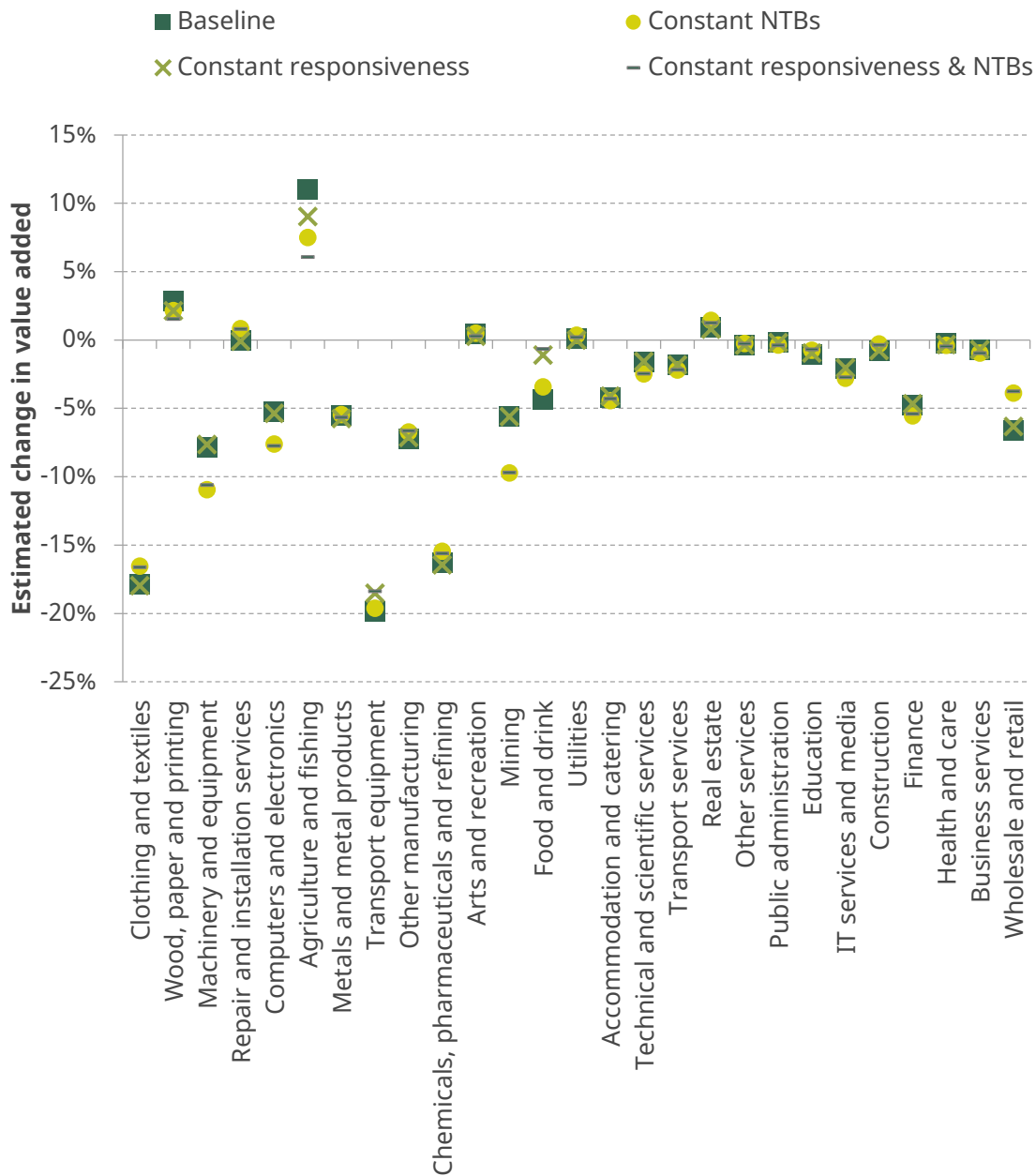
Overall, the average exposure of industries employing higher-earning workers tends to be greater than the exposure of industries employing those in the bottom half of the earnings distribution. While this suggests trade barriers may lead to a reduction in earnings inequality, their impact on interregional inequality is more uncertain, and will depend importantly on whether non-tariff barriers on industries such as finance turn out to be small or large.

However, in all scenarios we consider, new trade barriers have a negative impact on average for all earnings groups. This suggests that even if changing patterns of demand resulting from higher trade costs with the EU act to mitigate some aspects of inequality in the UK, it would come at the cost of making the vast majority of UK workers poorer.

A. Online supplementary material

This appendix contains various figures and tables with additional results that are referred to in the main text.

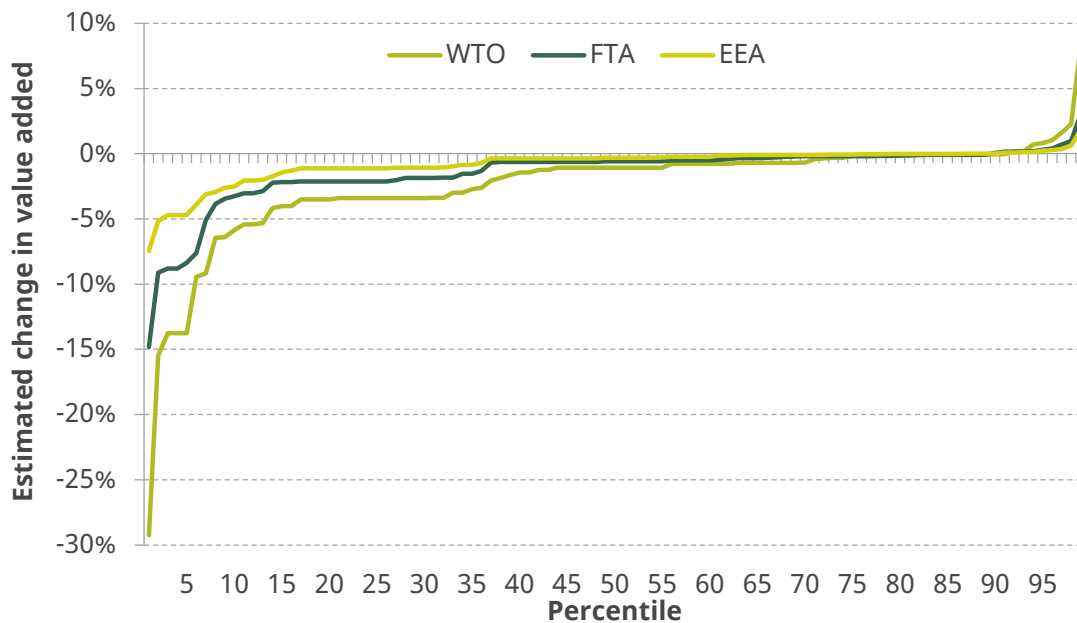
Figure A.1. Sensitivity of estimated change in value added due to WTO trade barriers, by industry



Note: Industries are ranked according to their contributions to the UK's gross value added.

Source: Authors' calculations using ONS analytical input-output tables 2014.

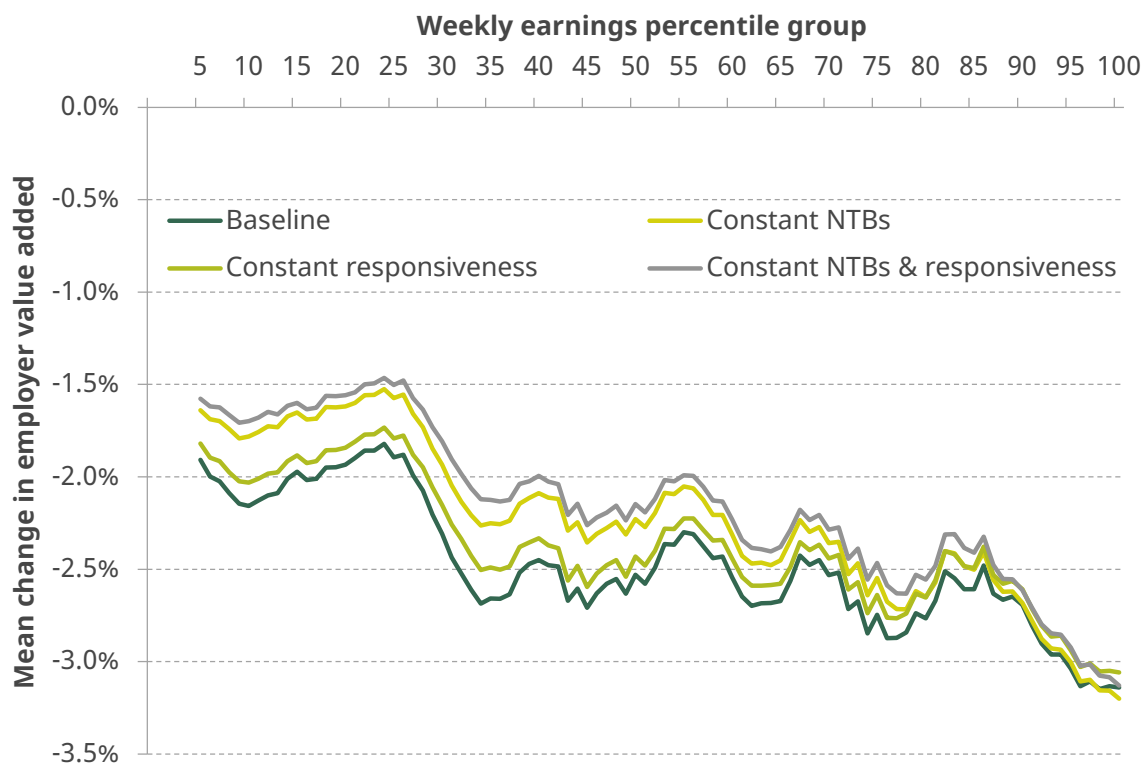
Figure A.2. Distribution of estimated change in employer value added under different trade policy scenarios among UK employees



Note: Employees are assigned an estimated change in value added based on their main industry of employment.

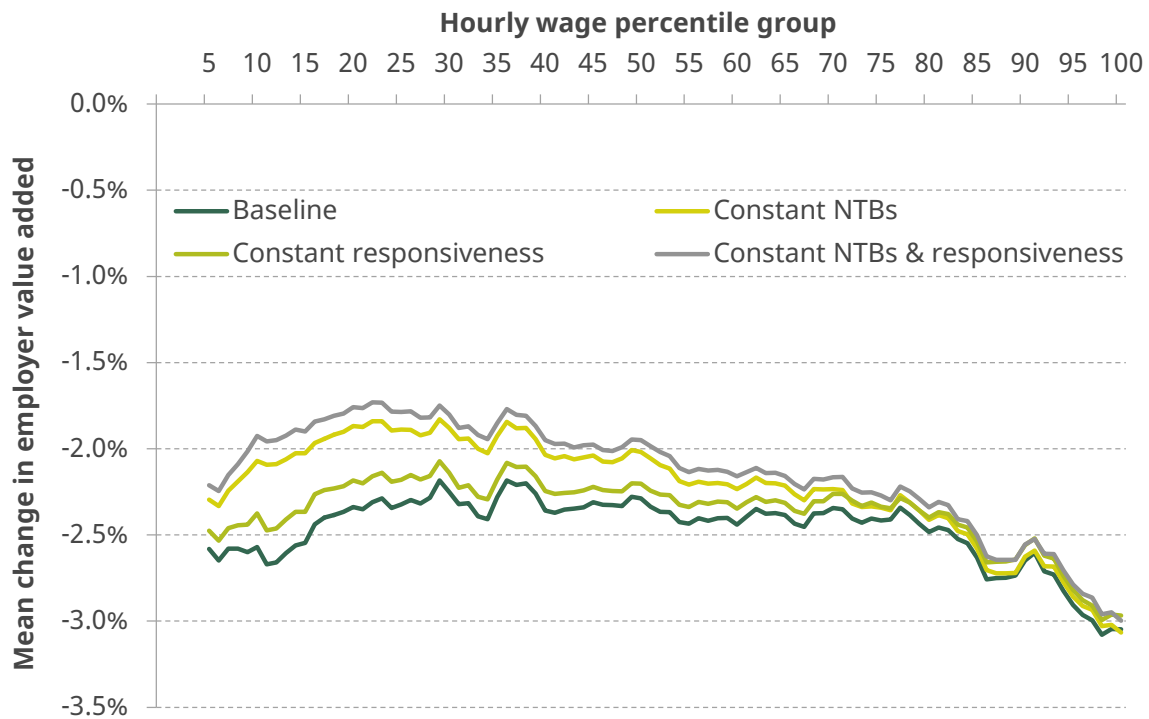
Source: Authors' calculations using ONS analytical input-output tables 2014 and the Quarterly Labour Force Survey 2017 quarters 1–4.

Figure A.3a. Mean predicted change in employer value added under WTO rules trade policy scenario, by weekly earnings percentile group (Great Britain)



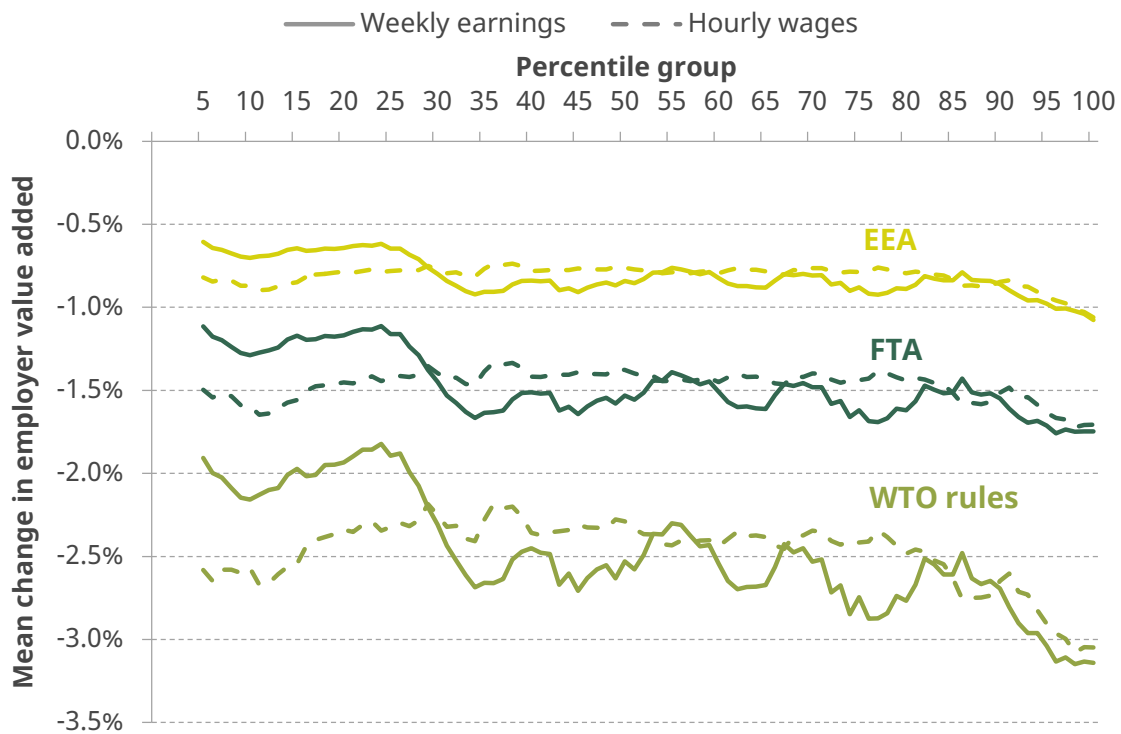
Note and source: See Figure 10.10.

Figure A.3b. Mean predicted change in employer value added under WTO rules trade policy scenario, by hourly wage percentile group (Great Britain)



Note and source: See Figure 10.10.

Figure A.4. Mean estimated change in employer value added under different trade policy scenarios, by percentile group (Great Britain)



Note and source: See Figure 10.10.

Table A.1. Non-tariff barriers and estimated change in value added under the WTO rules, FTA and EEA scenarios by industry

	Non-tariff barrier (tariff equivalent)			Estimated change in value added		
	WTO	FTA	EEA	WTO	FTA	EEA
All	11%	7%	4%	-2.6%	-1.5%	-0.9%
Accommodation & catering	9%	5%	3%	-4.2%	-2.2%	-1.3%
Agriculture & fishing	18%	15%	8%	11.0%	6.1%	3.3%
Arts & recreation	9%	5%	3%	0.5%	0.3%	0.2%
Business services	6%	1%	0%	-0.7%	-0.2%	-0.1%
Chemicals, pharma & refining	11%	10%	6%	-16.3%	-12.5%	-7.2%
Clothing & textiles	12%	10%	5%	-17.9%	-8.7%	-4.4%
Computers & electronics	6%	4%	2%	-5.3%	-2.9%	-1.5%
Construction	0%	0%	0%	-0.8%	-0.5%	-0.2%
Education	17%	10%	6%	-1.1%	-0.6%	-0.4%
Finance	9%	5%	3%	-4.8%	-2.6%	-2.5%
Food & drink	16%	14%	8%	-4.4%	-3.0%	-1.6%
Health & care	17%	10%	6%	-0.2%	-0.3%	-0.1%
IT services & media	8%	4%	2%	-2.1%	-0.9%	-0.4%
Machinery & equipment	6%	4%	2%	-7.9%	-4.3%	-2.1%
Metals & metal products	12%	10%	5%	-5.5%	-3.9%	-2.0%
Mining	6%	4%	2%	-5.6%	-3.7%	-1.8%
Other manufacturing	12%	11%	6%	-7.2%	-4.9%	-2.7%
Other services	7%	2%	1%	-0.4%	-0.3%	-0.2%
Public administration	17%	10%	6%	-0.2%	-0.1%	0.0%
Real estate	6%	1%	0%	0.9%	0.2%	0.1%
Repair & installation services	12%	10%	5%	-0.1%	0.1%	0.1%
Technical & scientific services	6%	1%	0%	-1.6%	-0.3%	-0.1%
Transport equipment	11%	8%	4%	-19.9%	-10.3%	-5.1%
Transport services	9%	5%	3%	-1.8%	-1.0%	-0.5%
Utilities	9%	5%	3%	0.1%	0.2%	0.1%
Wholesale & retail	20%	13%	7%	-6.6%	-4.2%	-2.2%
Wood, paper & printing	12%	10%	5%	2.8%	2.7%	1.3%

Note: Non-tariff barriers represent the average NTB among goods and services produced by each industry weighted by exports to the EU.

Source: Authors' calculations using ONS analytical input-output tables 2014; House of Commons Exiting the European Union Committee, 'EU exit analysis cross Whitehall briefing', 2018, <https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Cross-Whitehall-briefing/EU-Exit-Analysis-Cross-Whitehall-Briefing.pdf>.

Table A.2. Value added, fraction of output exported to the EU and estimated change in value added under the WTO rules, FTA and EEA scenarios by industry

Aggregate industry	Industry	Value added (2018 £bn)	Fraction of output exported to the EU	Estimated change in value added		
				WTO	FTA	EEA
	All	1,545	7%	-2.6%	-1.5%	-0.9%
Agriculture & fishing	Products of agriculture, hunting and related services	13	5%	13.3%	7.5%	4.0%
	Products of forestry, logging and related services	-	11%	-14.0%	-10.0%	-5.2%
	Fishing and aquaculture products and services	1	27%	-29.9%	-18.6%	-9.8%
Mining	Coal and lignite	-	7%	-2.7%	-1.5%	-0.6%
	Petroleum, gas and metal ore extraction	18	60%	-6.4%	-4.3%	-2.1%
	Other mining and quarrying products	3	11%	-3.2%	-2.0%	-1.0%
	Mining support services	3	5%	-2.4%	-1.6%	-0.8%
Food & drink	Preserved meat and meat products	4	11%	-2.7%	-2.8%	-1.4%
	Other processed and preserved food products	3	9%	-6.8%	-3.2%	-1.7%
	Vegetable and animal oils and fats	-	25%	-37.9%	-20.8%	-11.6%
	Dairy products	1	12%	8.7%	-6.5%	-3.2%
	Grain mill products, starches and starch products	1	10%	-24.5%	-10.2%	-5.5%
	Bakery and farinaceous products	4	6%	8.8%	3.1%	1.8%
	Other food products	5	14%	-16.8%	-8.2%	-4.5%
	Prepared animal feeds	1	11%	-34.7%	-16.7%	-9.2%
	Alcoholic beverages and tobacco products	5	11%	4.4%	2.0%	1.2%
	Soft drinks	1	9%	6.7%	4.0%	2.4%
Clothing & textiles	Textiles	3	27%	-14.0%	-7.6%	-3.9%
	Wearing apparel	3	49%	-22.4%	-9.8%	-4.9%
	Leather and related products	1	39%	-15.9%	-8.9%	-4.5%
Wood, paper & printing	Non-furniture products made of wood etc.	2	4%	8.3%	6.3%	3.1%

Aggregate industry	Industry	Value added (2018 £bn)	Fraction of output exported to the EU	Estimated change in value added		
				WTO	FTA	EEA
	Paper and paper products	5	11%	-0.3%	0.4%	0.1%
	Printing and recording services	4	0%	3.1%	3.0%	1.5%
Chemicals, pharmaceuticals & refining	Coke and refined petroleum products	2	23%	-13.5%	-7.8%	-4.0%
	Chemicals	4	41%	-35.0%	-24.3%	-14.0%
	Paints and varnishes	1	8%	-0.7%	-0.5%	-0.2%
	Soap and cleaning substances	3	36%	-15.5%	-13.6%	-7.9%
	Other chemical products	2	58%	-46.3%	-30.6%	-17.7%
	Basic pharmaceutical products	11	38%	-8.9%	-8.4%	-4.8%
Other manufacturing	Rubber and plastic products	9	22%	-13.4%	-9.1%	-5.2%
	Glass and stone abrasives	3	17%	-6.0%	-3.8%	-2.0%
	Cement, lime and plaster	2	2%	4.3%	3.2%	1.6%
	Furniture	4	8%	0.8%	0.7%	0.4%
	Other manufactured goods	5	30%	-8.2%	-5.8%	-2.9%
Metals & metal products	Basic iron and steel	2	30%	-31.2%	-23.9%	-12.2%
	Other basic metals and casting	2	24%	-28.7%	-19.3%	-9.7%
	Metal products excl. machinery	14	8%	0.8%	0.7%	0.4%
Machinery & equipment	Weapons and ammunition	2	2%	-0.3%	-0.4%	-0.2%
	Machinery and equipment n.e.c.	9	32%	-9.4%	-5.1%	-2.5%
Computers & electronics	Computer, electronic and optical products	8	29%	-5.3%	-3.0%	-1.5%
	Electrical equipment	5	21%	-5.2%	-2.9%	-1.4%
Transport equipment	Motor vehicles, trailers and semi-trailers	12	32%	-29.3%	-14.8%	-7.5%
	Ships and boats	2	11%	-2.6%	-1.5%	-0.7%
	Air and spacecraft and related machinery	6	21%	-9.2%	-5.3%	-2.6%
	Other transport equipment	1	10%	-1.0%	-0.5%	-0.2%
Repair & installation services	Ships repair and maintenance	1	0%	9.1%	6.2%	3.1%
	Aircraft and spacecraft repair and maintenance	2	0%	8.1%	5.5%	2.8%

Aggregate industry	Industry	Value added (2018 £bn)	Fraction of output exported to the EU	Estimated change in value added		
				WTO	FTA	EEA
	Other repair and installation	6	3%	-3.3%	-2.0%	-1.0%
	Computer and personal goods repair	4	0%	0.3%	0.3%	0.2%
Utilities	Electricity transmission and distribution	14	0%	1.6%	1.0%	0.6%
	Gas distribution	11	0%	-0.3%	0.0%	0.0%
	Water treatment and supply	5	0%	0.8%	0.4%	0.3%
	Sewerage services	5	0%	-0.1%	0.0%	0.0%
	Waste collection and treatment	7	8%	-2.7%	-1.3%	-0.7%
	Other waste management services	-	0%	1.6%	1.0%	0.6%
Construction	Construction	110	0%	-0.8%	-0.5%	-0.2%
Wholesale & retail	Motor vehicle wholesale and retail trade and repair	30	1%	-0.8%	-0.3%	-0.1%
	Wholesale trade services	59	19%	-13.8%	-8.8%	-4.7%
	Retail trade services	78	2%	-3.4%	-2.1%	-1.1%
Transport services	Rail transport services	5	2%	0.1%	0.2%	0.1%
	Land transport services	26	2%	0.2%	0.1%	0.1%
	Water transport services	7	15%	-5.3%	-3.0%	-1.7%
	Air transport services	9	11%	-5.5%	-3.1%	-1.8%
	Warehousing and transport support services	13	6%	-3.4%	-1.8%	-1.1%
	Postal and courier services	10	3%	-0.4%	-0.2%	-0.1%
Accommodation & catering	Accommodation services	14	12%	-6.4%	-3.4%	-2.0%
	Food and beverage serving services	44	3%	-3.5%	-1.9%	-1.1%
IT services & media	Publishing services	9	11%	-2.9%	-1.7%	-1.0%
	Audiovisual media production and distribution	15	9%	-5.3%	-2.4%	-1.4%
	Telecommunications services	28	6%	-1.2%	-0.7%	-0.3%
	Computer programming, consultancy and related services	44	4%	-1.4%	-0.3%	0.0%
	Information services	6	10%	-2.2%	-0.5%	0.0%

Aggregate industry	Industry	Value added (2018 £bn)	Fraction of output exported to the EU	Estimated change in value added		
				WTO	FTA	EEA
Finance	Financial services, except insurance and pension funding	62	9%	-4.0%	-2.2%	-2.0%
	Insurance and pension funding	34	11%	-5.9%	-3.3%	-3.1%
	Auxiliary finance and pension services	21	25%	-5.4%	-3.0%	-2.9%
Real estate	Real estate services and imputed rent	71	0%	1.0%	0.2%	0.1%
	Real estate services on a fee or contract basis	6	3%	-0.7%	-0.1%	0.1%
Business services	Legal services	24	5%	-0.8%	-0.1%	0.0%
	Accounting and auditing services	14	3%	-0.6%	-0.1%	0.0%
	Head office and management consulting services	26	5%	-1.9%	-0.4%	-0.1%
	Advertising and market research services	18	5%	-0.7%	-0.3%	-0.1%
	Employment services	21	2%	2.3%	0.3%	0.0%
	Office admin and support services	24	19%	-2.1%	-0.7%	-0.3%
Technical & scientific services	Architecture and engineering services	25	5%	-1.2%	-0.2%	0.0%
	Scientific research and development services	22	6%	-1.6%	-0.5%	-0.1%
	Other professional, scientific and technical services	12	17%	-2.6%	-0.4%	0.0%
	Veterinary services	3	0%	-0.3%	0.0%	0.0%
Other services	Rental and leasing services	20	2%	1.2%	0.1%	0.0%
	Travel agency and related services	10	0%	0.0%	0.0%	0.1%
	Security and investigation services	4	1%	-4.2%	-2.2%	-1.3%
	Services to buildings and landscape	9	1%	-3.0%	-1.5%	-0.9%
	Services furnished by membership organisations	16	0%	-0.3%	-0.2%	-0.1%
	Other personal services	17	0%	-0.4%	-0.2%	-0.1%

Aggregate industry	Industry	Value added (2018 £bn)	Fraction of output exported to the EU	Estimated change in value added		
				WTO	FTA	EEA
	Services of households as employers of domestic personnel	7	0%	0.0%	0.0%	0.0%
Public administration	Public administration and defence services	83	0%	-0.2%	-0.1%	0.0%
Education	Education services	101	1%	-1.1%	-0.6%	-0.4%
Health & care	Human health services	94	0%	-0.1%	-0.2%	-0.1%
	Residential care and social work services	32	0%	-0.7%	-0.6%	-0.3%
Arts & recreation	Creative, arts and entertainment services	5	1%	-0.2%	-0.1%	0.0%
	Libraries, archives, museums and other cultural services	5	0%	0.7%	0.4%	0.3%
	Gambling and betting services	9	0%	1.0%	0.6%	0.4%
	Sports services and amusement and recreation services	4	0%	0.0%	0.2%	0.2%

Note: Value added figures are taken from the 2014 ONS input-output tables and are expressed in 2018 prices using the GDP deflator taken from the Office for Budget Responsibility's March 2018 Economic and Fiscal Outlook. '-' indicates value added of less than £0.5 billion.

Source: Authors' calculations using ONS analytical input-output tables 2014.

Table A.3a. Exposure of workers to new trade barriers under the FTA scenario

	Number employed ('000s)	Mean change in employer value added	Fraction of group employed in ...			
			Low-exposure industries	Mid-exposure industries	High-exposure industries	Very-high-exposure industries
All	26,500	-1.5%	64%	24%	4%	8%
Women: All	13,100	-1.2%	69%	23%	4%	5%
Low-educated	4,400	-1.5%	55%	33%	5%	6%
Mid-educated	3,800	-1.1%	69%	23%	4%	4%
High-educated	4,900	-1.0%	80%	13%	3%	4%
Men: All	13,400	-1.7%	59%	25%	5%	11%
Low-educated	5,100	-2.0%	52%	30%	4%	14%
Mid-educated	3,700	-1.8%	57%	27%	5%	12%
High-educated	4,600	-1.4%	70%	18%	5%	7%

Note and source: See Table 10.1. Totals do not equal those in Table A.4 as not all individuals in the Quarterly Labour Force Survey report their education or occupation.

Table A.3b. Exposure of workers to new trade barriers under the EEA scenario

	Number employed ('000s)	Mean change in employer value added	Fraction of group employed in ...			
			Low-exposure industries	Mid-exposure industries	High-exposure industries	Very-high-exposure industries
All	26,500	-0.8%	68%	25%	5%	2%
Women: All	13,100	-0.7%	71%	24%	4%	1%
Low-educated	4,400	-0.8%	60%	34%	5%	1%
Mid-educated	3,800	-0.6%	71%	25%	3%	1%
High-educated	4,900	-0.6%	82%	14%	3%	1%
Men: All	13,400	-1.0%	64%	27%	6%	3%
Low-educated	5,100	-1.1%	58%	30%	7%	4%
Mid-educated	3,700	-1.0%	62%	29%	6%	3%
High-educated	4,600	-0.8%	73%	21%	5%	2%

Note and source: See Table 10.1. Totals do not equal those in Table A.4 as not all individuals in the Quarterly Labour Force Survey report their education or occupation.

Table A.4. Employment by occupation and industry exposure across different trade policy scenarios ('000s)

Occupation	WTO				FTA				EEA			
	Industry exposure:				Industry exposure:				Industry exposure:			
	Low	Mid	High	Very high	Low	Mid	High	Very high	Low	Mid	High	Very high
Caring, leisure & other service occupations	1,778	709	51	87	2,446	94	77	8	2,487	130	4	4
Professional occupations	2,481	2,445	252	458	4,822	441	123	248	4,943	497	139	55
Administrative & secretarial occupations	1,739	490	426	459	2,175	513	206	221	2,234	641	196	44
Associate professional & technical occupations	1,863	806	392	731	2,571	578	293	351	2,687	761	280	65
Managers, directors & senior officials	1,144	423	539	457	1,482	671	140	271	1,573	744	183	64
Skilled trades occupations	1,063	229	448	362	1,194	576	62	270	1,356	561	80	104
Elementary occupations	836	549	1,284	400	1,088	1,598	149	234	1,376	1,488	145	60
Sales & customer service occupations	397	185	1,550	209	562	1,587	69	123	582	1,620	121	18
Process, plant & machine operatives	798	126	249	479	838	359	53	402	923	406	189	134
All	12,099	5,961	5,191	3,642	17,178	6,416	1,171	2,129	18,160	6,848	1,338	548

Note: Employees are assigned an estimated change in value added based on their main industry of employment. 'Very high', 'high', 'mid' and 'low' exposure industries are those that are estimated to experience a reduction in value added of more than 5%, more than 3% but less than or equal to 5%, more than 1% but less than or equal to 3%, and less than or equal to 1% respectively. Totals do not equal those in Tables A.3a and A.3b as not all individuals in the Quarterly Labour Force Survey report their education or occupation.

Source: Authors' calculations using ONS analytical input-output tables 2014 and the Quarterly Labour Force Survey 2017 quarters 1–4.

Table A.5. Characteristics of workers by occupation group

	Proportion with degree	Proportion male	Average age
Caring, leisure and other service occupations	18%	19%	40
Professional occupations	75%	48%	41
Administrative and secretarial occupations	26%	25%	42
Associate professional and technical occupations	47%	57%	39
Managers, directors and senior officials	47%	65%	44
Skilled trades occupations	9%	89%	39
Elementary occupations	9%	53%	38
Sales and customer service occupations	17%	38%	36
Process, plant and machine operatives	7%	88%	44
All	35%	51%	40

Source: Authors' calculations using the Quarterly Labour Force Survey 2017 quarters 1–4.

Table A.6. Average estimated change in employer value added under different trade policy scenarios, and median employee earnings, by region and nation of the UK

	Mean change in employer value added			Median gross employee earnings
	WTO rules	FTA	EEA	
UK	–2.3%	–1.4%	–0.8%	£24,100
West Midlands	–2.7%	–1.6%	–0.9%	£22,800
North West	–2.5%	–1.5%	–0.8%	£22,700
East Midlands	–2.5%	–1.5%	–0.8%	£21,800
North East	–2.4%	–1.4%	–0.8%	£22,300
Yorkshire and Humber	–2.4%	–1.4%	–0.8%	£21,800
London	–2.3%	–1.3%	–0.8%	£33,000
South East	–2.3%	–1.3%	–0.7%	£25,300
Wales	–2.3%	–1.4%	–0.8%	£21,800
East of England	–2.1%	–1.3%	–0.7%	£23,300
South West	–2.0%	–1.2%	–0.7%	£22,300
Scotland	–2.0%	–1.2%	–0.7%	£23,800
Northern Ireland	–1.7%	–1.1%	–0.6%	£21,800

Note and source: See Table 10.2.

Table A.7a. Fraction employed in very highly exposed industries under the FTA scenario, by region, education and gender

	Men			Women		
	Low education	Mid education	High education	Low education	Mid education	High education
UK	14%	12%	7%	6%	4%	4%
West Midlands	20%	15%	12%	7%	5%	4%
North West	15%	15%	9%	6%	4%	4%
East Midlands	18%	15%	13%	11%	6%	5%
North East	14%	11%	9%	6%	3%	5%
Yorkshire and Humber	18%	16%	9%	8%	6%	4%
London	8%	5%	3%	3%	3%	3%
South East	11%	10%	8%	5%	3%	5%
Wales	16%	12%	8%	6%	5%	4%
East of England	12%	10%	9%	8%	4%	4%
South West	14%	12%	6%	5%	3%	3%
Scotland	12%	8%	6%	5%	3%	3%
Northern Ireland	20%	13%	8%	7%	3%	4%

Table A.7b. Fraction employed in very highly exposed industries under the EEA scenario, by region, education and gender

	Men			Women		
	Low education	Mid education	High education	Low education	Mid education	High education
UK	4%	3%	2%	1%	1%	1%
West Midlands	9%	7%	5%	1%	1%	1%
North West	5%	4%	2%	1%	1%	1%
East Midlands	5%	3%	1%	2%	1%	0%
North East	6%	5%	4%	2%	1%	1%
Yorkshire and Humber	6%	6%	2%	2%	1%	1%
London	1%	0%	0%	0%	0%	0%
South East	3%	3%	2%	1%	1%	1%
Wales	6%	4%	2%	2%	1%	0%
East of England	4%	2%	2%	1%	1%	0%
South West	3%	3%	1%	0%	1%	0%
Scotland	5%	2%	2%	1%	1%	1%
Northern Ireland	6%	4%	1%	2%	1%	1%

Note and source to Tables A.7a and A.7b: See Table 10.3.

B. Online technical appendix

In this appendix, we set out how we calculate our estimates of changes in value added due to trade barriers.

B.1 Estimating each industry's use of EU inputs from different industries

The UK input-output tables from the Office for National Statistics (ONS) record supply-use relationships between different UK industries. We group these into 102 industries.¹ The tables also tell us how much each industry imports from the rest of the world. However, they do not record the source of these inputs. Since we are considering a situation in which trade barriers are raised specifically on EU imports, we need to understand what proportion of each industry's imported inputs come from EU countries.

To do this, we combine the information in the input-output tables with data from the World Input-Output Database (WIOD).² This database records supply-use relationships between industries across countries, showing for example the importance of UK imports of French machinery for the UK transport equipment industry. The WIOD contains data on all EU member countries (including the UK) and for 56 different industries.

Our aim is to use the data on the 56 industry groupings in the WIOD tables in combination with data from the ONS input-output tables to estimate the importance of EU inputs for all the 102 industries in our analysis.

To do this, we make use of the following approach. Let i denote one of the 102 industries we take from the UK input-output tables and g one of the 56 industry groupings used in the WIOD. Let m_i denote the share of each industry's inputs that are imported. Let the share of intermediate imports that are imported by the EU in the WIOD tables by industry group g be denoted by m_g^{EU} . Then denote purchases of imported intermediate inputs by industry i from industry j (where industry j is in WIOD industry g) by x_{ijg} . We want to estimate the share of UK inputs purchased from EU industry i that are purchased from j , which we call $\hat{m}_{ij}^{EU}$.

We calculate this as

$$(B1) \quad \hat{m}_{ij}^{EU} = m_i \times m_g^{EU} \times \frac{x_{ijg}}{\sum_{k \in g} x_{ikg}},$$

which is the share of industry i 's inputs that are imported multiplied by the share of intermediate inputs that WIOD industry g purchases from the EU multiplied by the proportion of imported inputs within WIOD group g that UK industry i purchases from industry j .

¹ We aggregate some industries so as to be able to map these industries to external trade and tariff data.

² For details, see M. Timmer, P. Dietzenbacher, R. Stehrer and G. de Vries, 'An illustrated user guide to the World Input-Output Database: the case of global automotive production', *Review of International Economics*, 2014, 23, 575–605.

B.2 Calculating industry-level exposure measures

Our exposure measures can be thought of as capturing the change in each industry's *value added* (the value of output less the value of inputs) under the assumption that UK industries do not change their output levels. To obtain these, we calculate: the price change needed to ensure that demand for each industry's output remains constant after trade barriers are introduced; the change in input costs per unit of output each industry experiences; and, from those, the proportional change in each industry's value added.

Change in demand for output

Demand for output produced by industry i is given by

$$(B2) \quad X_i = X_i^{EU} + X_i^{NEU} + X_i^{Final} + \sum_j X_{ij}^{Inter},$$

which is the sum of exports to the EU X_i^{EU} , exports to non-EU destinations X_i^{NEU} , UK final demand X_i^{Final} and intermediate demand for inputs from other UK industries X_{ij}^{Inter} .

This means we can write the proportional change in output as

$$(B3) \quad \hat{X}_i = \sigma_i^{EU} \hat{X}_i^{EU} + \sigma_i^{NEU} \hat{X}_i^{NEU} + \sigma_i^{Final} \hat{X}_i^{Final} + \sum_j \frac{\gamma_{ij}^{UK} X_j}{X_i} \hat{X}_{ij}^{Inter},$$

where $\hat{x}$ denotes a proportional change in some variable x . σ_i^{EU} , σ_i^{NEU} and σ_i^{Final} refer to the shares of output for each industry sold to the EU, to non-EU countries and for final consumption in the UK and γ_{ij}^{UK} is the value of inputs from industry j needed to produce a unit of industry i 's output X_i .

It is convenient to write (B3) in terms of vectors and matrices, with each row denoting an industry. Letting bold terms denote vectors/matrices, we can write the following system of equations:

$$(B4) \quad \hat{\mathbf{X}} = \mathbf{\Sigma}^{EU} \hat{\mathbf{X}}^{EU} + \mathbf{\Sigma}^{NEU} \hat{\mathbf{X}}^{NEU} + \mathbf{\Sigma}^{Final} \hat{\mathbf{X}}^{Final} + \mathbf{S} \hat{\mathbf{X}}^{Inter},$$

where $\mathbf{\Sigma}^{EU}$, for example, is a diagonal matrix with $\sigma_1^{EU} \dots \sigma_N^{EU}$ on the diagonal. $\mathbf{S}$ is a matrix with $\frac{\gamma_{ij}^{UK} X_j}{X_i}$ in element ij .

Let us now assume that UK firms view inputs from the EU, non-EU and UK as imperfect substitutes. In particular, let us assume that they are combined with a constant elasticity of substitution (CES) production function. This implies that the change in intermediate demand for UK output given a marginal change in prices of EU imports is given by

$$(B5) \quad \hat{X}_{ij}^{Inter} = \hat{X}_j + \xi_j (\theta_{ij}^{UK} - 1) \hat{P}_i + \xi_j \theta_{ij}^{EU} \hat{\tau}_i^{EU,M},$$

where ξ_j is the elasticity of substitution between UK, non-EU and EU inputs, and θ_{ij}^{UK} and θ_{ij}^{EU} are the shares of inputs used by industry j from industry i that are drawn from the UK and the EU respectively. $\hat{\tau}_i^{EU,M}$ is the change in the *ad valorem* trade cost applying to imports of goods or services produced by industry i from the EU following Brexit, and $\hat{P}_i$ is the output price change for UK output produced by industry i . Substituting (B5) into (B4) and rearranging gives

$$(B6) \quad \hat{\mathbf{X}} = (\mathbf{I} - \mathbf{S})^{-1} (\mathbf{\Sigma}^{EU} \hat{\mathbf{X}}^{EU} + \mathbf{\Sigma}^{NEU} \hat{\mathbf{X}}^{NEU} + \mathbf{\Sigma}^{Final} \hat{\mathbf{X}}^{Final} + \mathbf{B}^{EU} \hat{\boldsymbol{\tau}}^{EU,M} + \mathbf{B}^{UK} \hat{\mathbf{P}}),$$

where $\mathbf{B}^{EU}$ has diagonal entries $\sum_j \frac{\gamma_{ij}^{UK} X_j}{X_i} \xi_j \theta_{ij}^{EU}$ and $\mathbf{B}^{UK}$ has diagonal entries $\sum_j \frac{\gamma_{ij}^{UK} X_j}{X_i} \xi_j (\theta_{ij}^{UK} - 1)$. Finally, we can also write

$$(B7) \quad \hat{\mathbf{X}} = (\mathbf{I} - \mathbf{S})^{-1} (\mathbf{\Sigma}^{EU} \mathbf{E}^{EU} (\hat{\mathbf{P}} + \hat{\boldsymbol{\tau}}^{EU,X}) + \mathbf{\Sigma}^{Final} (\mathbf{E}^{UK,EU} \hat{\boldsymbol{\tau}}^{EU,M} + \mathbf{E}^{UK} \hat{\mathbf{P}}) \\ + \mathbf{\Sigma}^{NEU} \mathbf{E}^{NEU} \hat{\mathbf{P}} + \mathbf{B}^{EU} \hat{\boldsymbol{\tau}}^{EU,M} + \mathbf{B}^{UK} \hat{\mathbf{P}}),$$

where $\mathbf{E}^{UK}$, $\mathbf{E}^{EU}$ and $\mathbf{E}^{NEU}$ are matrices of elasticities of demand for UK output in the UK, EU and non-EU countries respectively, $\hat{\boldsymbol{\tau}}^{EU,X}$ is a vector of changes in the *ad valorem* trade costs that apply to exports to the EU after Brexit and $\mathbf{E}^{UK,EU}$ is a matrix of cross-price elasticities giving the proportional change in demand for UK output by final consumers given a proportional change in the price of EU imports.

To pin down these elasticities for a given set of estimated trade elasticities, we need to impose some structure on consumers' preferences. We assume Cobb-Douglas preferences for demand across industries, but CES demands for different national varieties within each industry. That is, we assume that consumers in both the EU and the UK maximise utility U of the following form:

$$(B8) \quad U = \sum_i \alpha_i \ln c_i,$$

where

$$(B9) \quad c_i = \left[\pi_i^{UK} (c_i^{UK})^{\frac{\rho_i-1}{\rho_i}} + \pi_i^{EU} (c_i^{EU})^{\frac{\rho_i-1}{\rho_i}} + \pi_i^{NEU} (c_i^{NEU})^{\frac{\rho_i-1}{\rho_i}} \right]^{\frac{\rho_i}{\rho_i-1}}.$$

where ρ_i is the elasticity of substitution for industry i and c_i^{UK} , c_i^{EU} and c_i^{NEU} are goods or services produced by industry i in the UK, EU and non-EU respectively. π_i^{UK} , π_i^{EU} and π_i^{NEU} are parameters that determine consumers' preferences over these national varieties. Given these preferences, it follows that the demand elasticity for UK output given a change in the price of EU inputs is

$$(B10) \quad \epsilon_i^{UK,EU} = -s_i^{EU} (1 - \rho_i),$$

where s_i^{EU} is the market share of EU producers in final demand for the output of industry i .

Assuming that the market share of UK exporters in the EU-wide market is 'small', the elasticity of demand from EU consumers for UK output is $-\rho_i$.

We take the values of ρ_i and ξ_i for each industry using (1 plus) the trade elasticity estimates in Caliendo and Parro (2015).³ For service industries, for which Caliendo and Parro do not provide estimates, we follow Costinot and Rodríguez-Clare (2014) in choosing

³ L. Caliendo and F. Parro, 'Estimates of the trade and welfare effects of NAFTA', *Review of Economic Studies*, 2015, 82, 1–44.

an elasticity that is roughly the median of trade elasticities estimated in other studies (that is, a value of 5).⁴ Results shown below for which we employ a constant elasticity across sectors make use of an elasticity of substitution of 5 for all sectors.

These elasticities do not account for changes in UK demand as a result of changes in incomes following Brexit; they represent substitution responses to price changes only.

Changes in costs of inputs

As well as reducing the value of UK output, changes in trade barriers will also affect the costs of firms' inputs. We calculate these as

$$(B11) \quad \text{Change in input costs}_j = \gamma_{ij}^{UK} \hat{P}_i + \gamma_{ij}^{EU} \hat{\tau}_i^{EU,M},$$

where $\gamma_{ij}^{EU} = \gamma_{ij} \theta_{ij}^{EU}$, where γ_{ij} are the total inputs purchased from industry i by industry j .

Calculating value added changes

Output price changes are defined implicitly by setting $\hat{X} = \mathbf{0}$ in (B6) and solving.

Proportional value added changes for industry i are then given by

$$(B12) \quad \hat{p}_i = \frac{\hat{P}_i - \text{Change in input costs}}{(1 - \sum_j \gamma_{ji})}.$$

⁴ A. Costinot and A. Rodríguez-Clare, 'Trade theory with numbers: quantifying the consequences of globalization', in *Handbook of International Economics*, 2014, 4, 197–261.