Estimating the Impacts of US Tariffs on UK Exports of Single Malt Scotch Whisky

Discussion Paper

This discussion paper aims to estimate the impact of US tariffs on UK exports of single malt Scotch whisky between Q4 2019 – Q4 2020 using the novel synthetic control method.

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Summary

- In October 2019, the US government imposed a 25% tariff on single malt Scotch whisky imports from the UK. Impacts of this tariff will not only have been felt by US importers, but UK exporters as well.

- These tariffs are especially of interest since the United States is the largest overseas export destination for Scotch whisky. Single malt Scotch whisky exports to the US were valued at £344 million in 2018, accounting for 26% of total overseas single malt exports, and 21% of total drink exports to the US.

- This analysis aims to (a) provide a best-effort estimate of tariff impacts on exports while accounting for effects of Covid-19, (b) elicit discussion on the novel methods used, and (c) serve as a proof-of-concept for future analyses of trade deals and/or tariffs.

- The results suggest that the quantity of single malt exports declined by between 9.5% (1.0 million litres of pure alcohol, or LPA) and 19.6% (2.0 million LPA) between Q4 2019 and Q4 2020 as a result of the tariff. Impacts on export value were similarly negative but less precise, with an estimated impact between -100.0% (£506 million) and -4.7% (£24 million). Estimating the impact on average export price was also explored but this led to inconclusive results.

- The analysis itself uses the ‘synthetic control’ method to create a counterfactual – a hypothetical time series of single malt exports to the US in which a tariff was never introduced. It does this by creating a weighted average of single malt exports to other destinations. This collection of other destinations is referred to as the ‘donor pool’ and contains 28 OECD nations which had no change in tariff (and available data).

- It is important to highlight that the results presented above were sensitive to the frequency chosen (e.g. using monthly exports instead of quarterly exports), and also sensitive to the countries included in the donor pool. The method is fairly novel, with limited current use within trade economics. This analysis is therefore being published to generate discussion of the approach used.

- Not all potential effects of the tariff are taken into account in this analysis – only the impacts on exports. Other potential negative impacts on the sector include reductions in profitability and/or market share.

Any questions or comments can be sent to agric.stats@gov.scot. The team are especially interested in queries regarding the methods used.

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1 Introduction

1.1 US Tariffs

In October 2019, the US government imposed a 25% tariff on single malt Scotch whisky (hereafter 'single malt') imports from the UK. Before this, no tariff was in place. The background to these tariffs is explained in Box 1 below.

Box 1. Background

In May 2018, the World Trade Organisation (WTO) ruled that the EU had illegally subsidised the aerospace firm Airbus in providing financing to develop two aircraft at a lower rate of interest that would have been available on the open market, which resulted in lost sales for the American aerospace firm Boeing.

This ruling meant the USA could retaliate through sanctions on EU goods exported to the USA, at an amount set by a WTO arbitrator. On 2 October 2019, a WTO arbitrator authorised the USA to impose tariffs on $7.5 billion (£6.1 billion) of goods exported from the EU to the USA.

Subsequently, the US Trade Representative (USTR) released a list of proposed tariffs, with 10% tariffs on civil aircraft and 25% tariffs on a range of agricultural goods, including a 25% tariff on American imports of single malt Irish and Scotch whiskies and whisky liqueurs from the UK (blended Scotch is exempt, as is single malt Irish whiskey from the Republic of Ireland).

These tariffs came into effect on 18 October 2019; prior to this, the USA had no tariffs on imported whiskies.

Adapted from a debate pack circulated to Members of Parliament in the House of Commons. Available at the House of Commons Library (CDP 2020/0012, 24 January 2020).

The tariff on single malt is imposed on the HTS[1] commodity code 2208.30.30 (single malt Irish and Scotch Whiskies); this is the reason why both Scotch and Irish single malt whiskies exported from the UK are subject to the tariff.

The increase in import cost is not reflected in the export value reported by HMRC. However, some transport costs are included in the export value.[2] Changes in the

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[1] See the United States' Harmonized Tariff Schedule Search (usitc.gov)

[2] HMRC's Overseas Trade Methodology, Section 8: The valuation of exports/dispatches is on a Free on Board (FOB) delivery terms basis, i.e. the cost of goods to the purchaser abroad, including packaging, Inland and coastal transport in the UK, dock dues, loading charges and other profits, charges, and expenses (e.g. insurance) accruing up to the point where the goods are deposited on board the exporting vessel or aircraft or at the land boundary of Northern Ireland.

export value of single malt would primarily stem from changes in the average price or quantity.

1.2 Scotch Whisky Exports

The impacts of these agri-food tariffs on exports of single malt to the US are particularly of interest because (i) Scotch whisky has historically been a major UK agri-food export, and (ii) the United States is the single largest destination of UK Scotch whisky exports on a per-country-basis. This is demonstrated by the 2018 export values for Scotch whisky (the last full year before the introduction of US tariffs) in Table 1.

Table 1. UK Exports of Scotch Whisky & All Drinks, 2018

Destination Ranked by single malt export value	**All Drinks***	of which… **Scotch Whisky**			of which… **Single Malt**		
	Value £m	**Value** £m	**Volume** mLPA**	**Price** £/LPA	**Value** £m	**Volume** mLPA	**Price** £/LPA
1 United States	1,622	1,039	38.3	27.13	344	6.9	49.92
2 France	623	437	52.1	8.39	164	5.6	29.52
3 Taiwan	184	168	12.1	32.94	101	2.3	44.08
4 Germany	334	177	13.2	13.43	97	2.6	37.41
5 Singapore	365	320	5.5	25.65	83	2.7	30.82
Rest of world	4,661	2,570	238.0	10.80	516	14.5	35.51
Total	**7,789**	**4,712**	**359.2**	**13.12**	**1,306**	**34.6**	**37.75**

* ‘All Drinks’ is classed as HS2 Chapter 22 (beverages, spirits and vinegar) excluding 2209 (vinegar), where Scotch whiskies are relevant CN8 codes within 22. ** Millions of litres of pure alcohol. Source: HMRC Overseas Trade Statistics, February 2021.

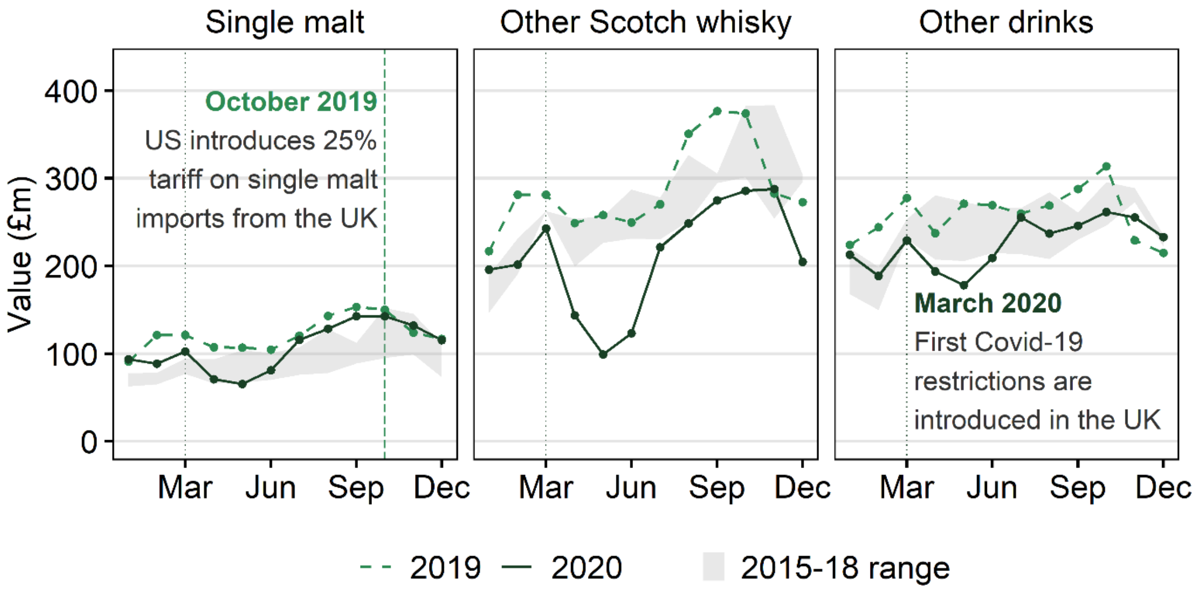
In 2018, UK exports of Scotch whisky to the US were valued at just over £1 billion, more than a fifth of total overseas Scotch whisky exports, and 64% of all UK drink exports to the US. In total, the UK exported £4.7 billion worth of Scotch whisky, three-fifths of total drink exports the same year. Single malt accounted for 28% of total Scotch whisky exports, and 33% of total Scotch whisky exports to the US.

1.3 Covid-19

Measuring the impact of the US tariffs on exports of single malt is complicated by the fact that UK drinks exports have generally seen major decreases in export value (and volume) throughout 2020 – likely as a result of Covid-19 (i.e. restrictions on hospitality sectors across the globe). This is true for most countries, including the United States. Other regions, particularly the EU, have also seen fluctuations in export value during 2019-2020, e.g. with relation to EU Exit.

Scotch whisky as a whole also seems to have been impacted more drastically than other drinks, as shown in Figure 1 below, with a large negative impact seen especially in non-single malt in early- and mid-2020.

Between April-October 2020, a period in which many countries experienced varying levels of Covid-19 restrictions, exports of Scotch whisky and other drinks were below or on par with the 2019 value. However, exports of single malt were not nearly as badly impacted: the initial 'shock' is smaller in magnitude, and the monthly export value since August 2020 has been close to 2019 values.

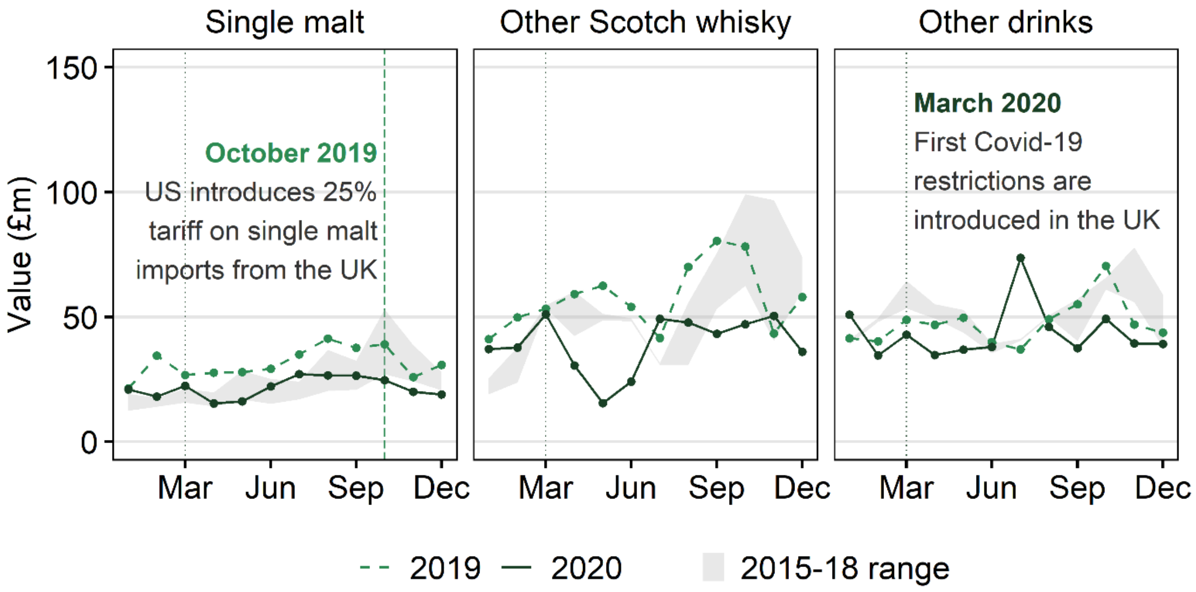


Source: HMRC OTS, RESAS calculations

Figure 1. UK overseas exports of single malt, other Scotch whisky, and other drinks between 2015-2020

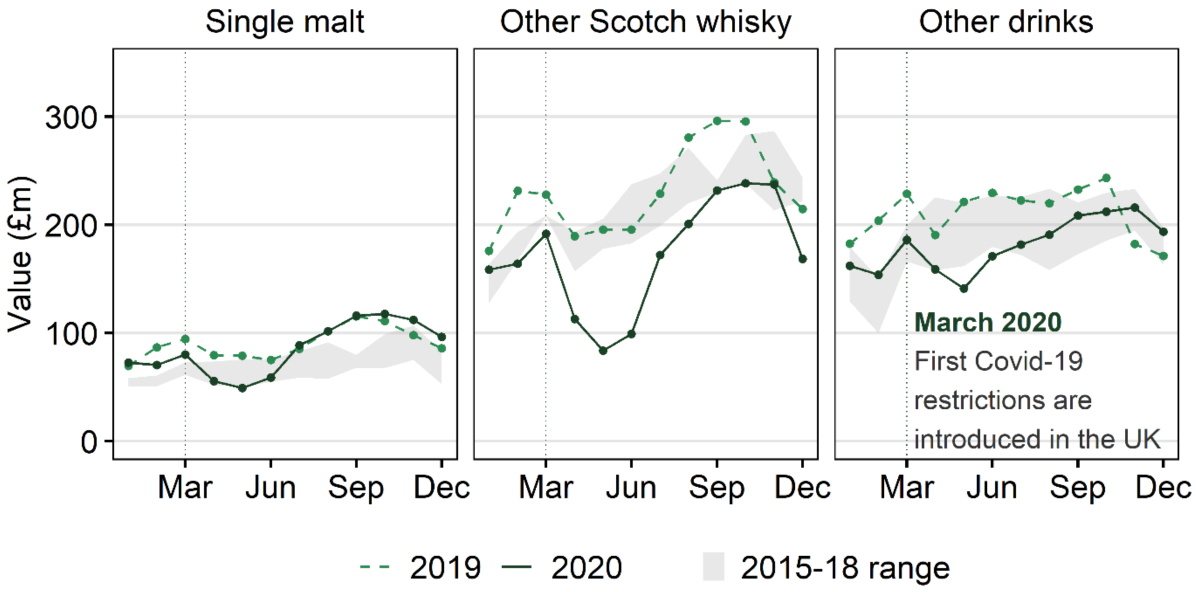
Looking at the time series in Figure 2, this worldwide Covid-19-related shock in early and mid-2020 seems to have impacted Scotch whisky exports to the US as well (similarly to world exports, exports of single malt to the US did not see as large of an initial shock). However, they have consistently been below 2019 values throughout 2020 – this is in contrast to single malt exports to the world, which returned to near-2019 values in the latter half of 2020.

Figure 3 shows the same three exports over 2019-20 to non-US countries (essentially Figure 1 minus Figure 2). Single malt exports to the rest of the world recovered to their 2019 levels in July 2020 and even exceeded them for the remainder of the year. This suggests that demand for (single malt) Scotch whisky was dampened in the US compared to other export destinations. This could be due to the tariff, but it could also be due to other factors – e.g. US-specific restrictions on hospitality sectors during the latter half of 2020.



Source: HMRC OTS, RESAS calculations

Figure 2. UK overseas exports of single malt, other Scotch whisky, and other drinks to the US between 2015-2020



Source: HMRC OTS, RESAS calculations

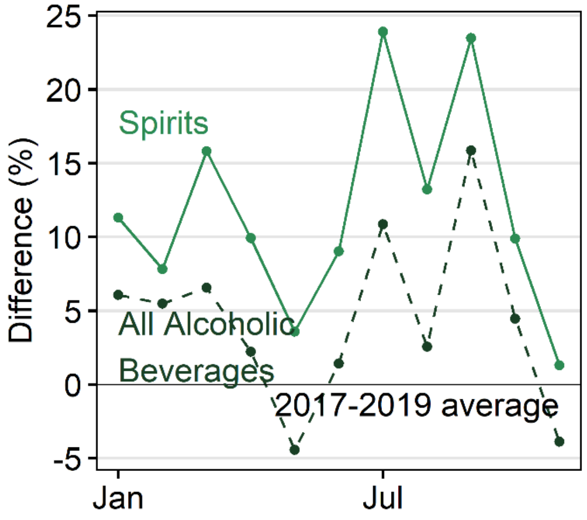
Figure 3. UK overseas exports of single malt, other Scotch whisky, and other drinks to non-US countries between 2015-2020

1.4 US Demand for Scotch Whisky

1.4.1 US Consumption Patterns

There is some evidence that the Covid-19 pandemic during 2020 may have increased the consumption of alcohol for Americans – this could be due to increased stress, increased alcohol availability, or boredom.[3,4] However, research is still ongoing, and some have found evidence of the contrary, while highlighting that a proportion of the population have indeed seen increases in alcohol consumption.[5]

Data from the National Institute of Alcohol Abuse and Alcoholism[6] suggests per-capita consumption of spirits was higher than the 2017-2019 average throughout 2020, with particularly large differences during Jul-Sep 2020. This is shown in Figure 4.



Source: National Insitute on Alcohol Abuse and Alcoholism, May 2021.

Figure 4. Average per-capita alcohol consumption for ten states in the US during Jan-Nov 2020 compared to the 2017-2019 average

1.4.2 Scotch Whisky Sales

Data from the IWSR suggests that retail sales of Scotch whisky in the US (including both on-trade and off-trade) decreased between 2019 and 2020 (a 1.5% decrease in volume, and a 3.1% decrease in value).

Decreases of this magnitude (or larger) were not unheard of in other countries – total global sales of Scotch whisky declined by 3.8% in terms of quantity (excluding travel retail sales). When taking into account these travel retail (duty free) sales, this global decrease was more pronounced at 9.5%. The global reduction in travel during 2020 will also have contributed to the decrease in exports of Scotch whisky to the US.

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[3] Elyse R. Grossman, Sara E. Benjamin-Neelon, Susan Sonnenschein, 2020. “Alcohol Consumption during the COVID-19 Pandemic: A Cross-Sectional Survey of US Adults.” International Journal of Environmental Research and Public Health, vol 17(24), p. 9189. doi:10.3390/ijerph17249189

[4] Michael S. Pollard, Joan S. Tucker, Harold D. Green, 2020. “Changes in Adult Alcohol Use and Consequences During the COVID-19 Pandemic in the US.” JAMA Network Open, vol 3(9): e2022942. doi:10.1001/jamanetworkopen.2020.22942

[5] Samantha N. Sallie, Valentin Ritou, Henrietta Bowden-Jones, et al, 2020. “Assessing international alcohol consumption patterns during isolation from the COVID-19 pandemic using an online survey: highlighting negative emotionality mechanisms.” British Medical Journal Open, vol 10: e044276. doi: 10.1136/bmjopen-2020-044276

[6] Available at: https://pubs.niaaa.nih.gov/publications/surveillance-covid-19/COVSALES.htm#fig19

Table 2. Whisky sales in the United States, 2019-20

Category	Year	Volume millions of 9-litre cases	Value $ billions
Scotch whisky	2019	8.51	3.47
	2020	8.38	3.36
	Change (%)	**-1.5**	**-3.1**
All whisk(e)y	2019	74.77	19.90
	2020	78.40	21.16
	Change (%)	**+4.9**	**+6.4**

Source: IWSR Drinks Market Analysis Ltd. (via the Scotch Whisky Association)

Many countries saw an increase in Scotch whisky sales between 2019 and 2020, largely driven by increases in off-trade sales. While the US saw a moderate 6.3% increase in off-trade sales, countries like the UK, Japan, Australia, and the Netherlands all saw double-digit growth.

It is also worth noting that US sales of all whisky/whiskey increased in quantity (+4.9%), as did sales of all spirits (+4.6%). This suggests at least some or all of the non-Scotch whisky varieties (e.g. US or Canadian whiskeys) increased in quantity, enough to offset the decreases in Scotch whisky retail sales. This total increase was again driven by increases in off-trade sales (+15.7% in terms of volume), enough to offset the 45.1% decrease in the volume of on-trade whisky sales.

1.5 Economic Theory

1.5.1 Elasticity

Economic theory dictates that, usually, an increase in import costs (for example due to the introduction or increase of an ad valorem tariff) for some good should decrease the quantity demanded for that import in a given country. The magnitude of that decrease depends on the way consumers, exporters, and importers react to a price change, and the timescale of these changes can differ as well. This magnitude, and its direction, is referred to as a price elasticity. A variety of different elasticities may come into play – for example:

1. **Price elasticity of demand –** this is a measure of how consumers’ demand for good A changes as the price for good A changes. For example, a 25% increase in retail price may only result in a 20% decrease in quantity demanded – some consumers may be willing and able to pay the higher price.

2. **Import price elasticity of demand (or elasticity of substitution) –** a measure of how importers or consumers react to a change in the prices of imported good A. For example, an increase in the price of imported single malt may prompt some domestic consumers to switch to other foreign imports or domestically produced substitutes (e.g. Irish whiskey or American Bourbon).

3. **Income elasticity of demand –** usually, import and export quantities are sensitive to changes in income domestically and abroad, respectively. A decrease in income domestically may reduce demand for imports.[7]

A key assumption with any elasticity is that everything except the change in price stays the same. For example, when there is a simultaneous change in price of two substitute goods A and B (e.g. whisky and gin), estimating the price elasticity of good A will be more difficult. This may also require controlling for any external factors affecting the demand of good A (not just the prices of goods A and B).

For that reason, estimating the import elasticity for single malt by only looking at changes in single malt export price and quantity will have its limitations. While some external factors can be accounted for (e.g. an overall decrease in consumption due to Covid-19), others cannot: taking into account changes in prices and quantities of other drinks, whether they are produced in the US or imported, would require modelling techniques outside the scope of this analysis.

1.5.2 Determinants of Trade

There is a vast and longstanding literature on finding determinants of trade. These could be used in estimating aggregate trade flows or controlling for external factors in elasticity estimations. One example of such an approach is Tinbergen’s so-called gravity model of trade (1962), which has since been widely used (and improved) since its introduction.[8] Chaney (2018) gives a comprehensive overview of the gravity model, and its empirical validity, in international trade.[9]

A simple gravity model essentially boils down to the following:

1. Larger economies tend to trade more with one another
2. Economies which are closer together tend to trade more with one another

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[7] OECD, 2010. “Sensitivity of trade flows to price and income changes,” Measuring Globalisation: OECD Economic Globalisation Indicators 2010, OECD Publishing, Paris. DOI: https://doi.org/10.1787/9789264084360-31-en

[8] See, for example: Marie M. Stack, Martin Bliss, 2020. “EU economic integration agreements, Brexit and trade.” Review of World Economics vol 156, pages 443–473. https://doi.org/10.1007/s10290-020-00379-x

[9] Thomas Chaney, 2018. "The Gravity Equation in International Trade: An Explanation," Journal of Political Economy, vol 126(1), pages 150-177.

Although the role of an economy’s size (GDP) is well-understood and has theoretical underpinnings, the role of distance is less understood. Despite this, the relationship has proven stable over time and across studies.

Chaney (2018) suggests that distance may actually be a well-behaved proxy for the cost of creating contacts (i.e. between suppliers and customers). He argues that although distance alone may not be enough to explain an individual firm’s exports at any given time (i.e. transport and communication technologies and the political environment matter), it may be sufficient to explain trade in the aggregate.

Since we are interested in the trade of a single good (single malt) as opposed to the sum of hundreds or thousands of goods, these aggregate determinants may hold less relevance. Instead, sector-specific determinants may be more relevant (e.g. alcohol consumption). There may also be more inherent volatility and less stability in the relationships between these determinants and observed trade flows of a single good.

2 Literature Review

Box 2. Literature Review Summary

In our setting (a single country applying a tariff on single malt imports), we do not have the opportunity to compare a random sample of regions with and without the introduction of a particular policy change as is often done in other comparative studies.

The ‘synthetic control’ method lends itself well to cases where we deal with analysing outcomes on aggregate units (e.g., a country). The method requires one or more affected countries (the United States), and one or more unaffected countries – the ‘donor pool’. Any uncertainty in the estimated impact of the tariff is associated with our choice of donor pool or predictors, and not with a random sample (as with other methods). This method is also summarised in Annex A2.6. of the UK Government’s Magenta Book (2020).

2.1 Comparative Studies

2.1.1 Difference-In-Differences

Many empirical studies in economics depend on estimating the effects of policy interventions or regime changes. In these studies, researchers estimate the change in aggregate outcomes (such as GDP per capita) for a unit affected by a particular policy intervention of interest and compare it to the change in the same aggregates estimated for some unaffected unit (or units).

For example, Card and Krueger (1994) compare the change in employment in fast-food restaurants in New Jersey and its neighbouring state Pennsylvania around the time of an increase in New Jersey’s minimum wage. In this study – and many others – information at the aggregate level was or will not be available. In these cases, a sample of disaggregated units (a handful of fast-food restaurants, rather than all minimum-wage employers) may be used to estimate the aggregate outcome of interest (change in the employment rate amongst minimum wage employers when the minimum wage is increased).[10]

Often, these comparative studies lend themselves well to difference-in-differences methods (DID), including in Card and Krueger’s case. Other examples include

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[10] David Card and Alan B. Krueger, 2000. “Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania: Reply”, The American Economic Review, Vol. 90(5), pp. 1397-1420

Meyer, Viscusi, and Durbin's (1995) article examining the effect of an increase in benefits for injured workers on time out of work[11], and Card (1990), who examined the impact of a sudden increase in Miami's labour force due to immigration ('the Mariel Boatlift') on the Miami Labour Market in 1980.

DID is particularly useful when one or more 'treatment' group of individual units (persons, firms, households) has been exposed to some policy intervention, and one or more 'control' group has not. This allows researchers the estimate the effect of the policy intervention in the form of the interaction between time and treatment.

The most critical assumption in the DID method is perhaps the parallel trend assumption: the difference between the treated group(s) and the control group(s) needs to be constant over time in the absence of the policy intervention. This is fundamentally unknowable and so depends highly on the chosen control group(s). However, the group structure of the errors and serial correlation are two other commonly overlooked pitfalls, as highlighted by Moulton (1990) and Bertrand, Duflo, and Mullainathan (2004), respectively[12,13]. This is explained further below.

- The treatment and control 'groups' are chosen by the researcher, making assumptions about their similarities both before the policy intervention and after crucial to estimating the effect of the intervention.

- Serial correlation is often not accounted for, which may lead to an overestimation of the true treatment effect. This is discussed by Bertrand, Duflo, and Mullainathan and can in some cases be remedied. Inference testing (or placebo testing) is the most favoured method to do so, meaning placebo treatments are generated for the control groups and effects estimated. The estimate for the actual treatment can then be compared to estimates for placebo treatments to gauge its precision and accuracy.

- Bertrand, Duflo, and Mullainathan (2004) highlight further drawbacks of the DID method, such as the assumption that the intervention is 'as good as' random (conditional on time and group fixed effects) which otherwise could signal potential treatment endogeneity.

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[11] Bruce D. Meyer, W. Kip Viscusi, David L. Durbin, 1995. "Workers' Compensation and Injury Duration: Evidence from a Natural Experiment." The American Economic Review, vol. 85(3), pp. 322–340.

[12] Moulton, B. (1990). An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables on Micro Units. The Review of Economics and Statistics, 72(2), 334-338. doi:10.2307/2109724

[13] Marianne Bertrand, Esther Duflo, Sendhil Mullainathan, 2004: "How Much Should We Trust Differences-In-Differences Estimates?". The Quarterly Journal of Economics, Oxford University Press, vol. 119(1), pages 249-275.

In our case, the assumption of random treatment assignment would be relevant if the United States Trade Representative chose to implement tariffs on single malt from the UK because they deemed the US to be importing too much single malt compared to countries without a (change in) tariff.

Although the decision was likely based on a multitude of factors (e.g., the relative importance of single malt in total drink exports to the US and the value of the spirits industry in the US), it is unlikely this was one of them. Add to this the fact that the tariffs were introduced as a result of a separate trade dispute over state aid given in the aeroplane industry, and this issue becomes even less worrisome.

The DID method has a further drawback which is especially relevant in our case:

- The majority of the uncertainty reflected in the DID estimator will be the uncertainty associated with not knowing the true population value (due to only having a sample of the ‘population’ control and treatment groups).

If we do know the aggregate data, this uncertainty can be disregarded. However, the uncertainty regarding the control group’s counterfactual trend remains (uncertainty which is not expressed within the regression framework’s standard errors).
Since, in our case, we do know the total monthly UK export figure in the case of single malt (we are not sampling whisky importers in the United States and Canada) the standard DID framework may not be the most appropriate. This is not to say that the estimate of the treatment effect will be biased or otherwise incorrect; however, the standard errors will not reflect the ‘true’ uncertainty.

The synthetic control methods described by Abadie and Gardeazabal (2003) may be more appropriate in these cases.[14] Abadie and Gardeazabal study the impact of political instability on economic prosperity in the context of terrorist activity in the Spanish Basque country. They do this using aggregate (county-level) observations. This political instability coincided with an economic downturn, which is in some ways similar to the Covid-19 outbreak coinciding with tariff effects in our case.

2.1.2 Synthetic Control

The synthetic control method is an extension of the DID method in which a so-called ‘synthetic control’ is constructed using a combination of unaffected (control) units, rather than a single unit (as with DID). This combination can take the form of a simple average or a weighted average. The synthetic control approach can limit the

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[14] Alberto Abadie and Javier Gardeazabal, 2003. "The Economic Costs of Conflict: A Case Study of the Basque Country." American Economic Review, 93 (1): 113-132. Obtained from: https://economics.mit.edu/files/11870.

risk of a bad choice of control unit or group resulting in overly large (or small) treatment effect estimates.

Abadie, Diamond, and Hainmueller (2010) (ADH hereafter) describe the synthetic control method in more detail and use it to estimate the effect of California's tobacco control program. They advocate for the use of data-driven procedures to *construct* suitable control groups.[15] It may be challenging to find the single unexposed unit that approximates the most relevant characteristics of the exposed unit(s). ADH argue that a combination of units often provides a better comparison for the unit exposed to the intervention than any single unit alone.

In our case, this may involve a combination of single malt exports to Canada, as well as single malt exports to other nations – or UK exports of goods to the US unaffected by the tariff(s). This is not a novel approach; for example, Card (1990) uses a combination of cities to construct a control unit.[16]

Because a synthetic control is a weighted average of the available control units, the synthetic control method makes explicit:

- the relative contribution of each control unit to the counterfactual; and
- the similarities (or lack thereof) between the unit affected by the policy intervention and the synthetic control in terms of pre-intervention outcomes and predictors.

However, exports of single malt are highly seasonal, potentially complicating the factor model ADH describe (this is less of an issue if the seasonality is of a similar magnitude between treatment and control units).

Additionally, the data requirements for this method are higher than conventional DID, since the same data is needed not only for the treated unit (the United States) and one control unit (e.g. Canada), but also a wide variety of control units.

The method described by ADH has been used by many others, both in econometrics and other fields. For example, Donohue, Aneja, and Weber (2018) use the method to study the impact of right-to-carry laws in the United States[17], while Cunningham and

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[15] Alberto Abadie, Alexis Diamond, Jens Hainmueller, 2010. Journal of the American Statistical Association. June 1, 2010, 105(490): 493-505. doi:10.1198/jasa.2009.ap08746. Version: Author's final manuscript.

[16] Note here the switch from ‘group’ to ‘unit’ showing that we are now dealing with aggregate observations.

[17] John J. Donohue & Abhay Aneja & Kyle D. Weber, 2019. "Right-to-Carry Laws and Violent Crime: A Comprehensive Assessment Using Panel Data and a State-Level Synthetic Control Analysis," Journal of Empirical Legal Studies, vol 16(2), pages 198-247.

Shah study the impacts of the decriminalisation of prostitution in Rhode Island[18], and Kleven et al (2013) study impacts of changes in tax legislation[19].

The use of synthetic control methods in trade economics is limited. Generally, analysis of trade agreements and legislation focus on the macroeconomic aspect – changes in trade flows, employment, economic output, income – and less on the trade in one specific good. Hannan (2016, 2017) uses it in two IMF working papers[20,21] to study the impacts of trade agreements in the 1980s and 1990s; more specifically, she studies the change in the value of exports/imports to/from countries entering a trade agreement.

Slaughter (2001) uses conventional DID with many control groups to gauge whether trade liberalisation has led to income convergence or divergence,[22] and Fotopoulus and Psallidas (2009) use an augmented DID approach where they match the most similar country pairs to estimate the effect of the introduction of the Euro on bilateral trade.[23] Fotopoulus and Psallidas use a country-level deflator in a gravity model for each country-pair, and use the resultant deflated real GDP as well as the real exchange rate, distance, common language, areas, and common border as confounders in this model. They show that the adoption of the Euro increased trade significantly and find no evidence of trade diversion.

2.1.3 Extensions and Other Methods

Conventional time series methods were also considered – structural break time series models, in particular. Investigating the presence of a structural break around October 2019 could provide some indication of a change in the data-generating process. However, a pure time series approach may not be able to properly account for the potential decreases seen because of Covid-19, which could lead to an overestimation of the effect of the tariffs.

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[18] Scott Cunningham & Manisha Shah, 2018. "Decriminalizing Indoor Prostitution: Implications for Sexual Violence and Public Health," The Review of Economic Studies, vol 85(3), pages 1683-1715.

[19] Kleven, Henrik Jacobsen, Camille Landais, and Emmanuel Saez, 2013. "Taxation and International Migration of Superstars: Evidence from the European Football Market," American Economic Review, vol 103(5), pages 1892-1924.

[20] Swarnali A. Hannan, 2016. “The Impact of Trade Agreements: New Approach, New Insights,” IMF Working Paper No. 16/117.

[21] Swarnali A. Hannan, 2017. “The Impact of Trade Agreements in Latin America using the Synthetic Control Method,” IMF Working Paper No. 17/45.

[22] Matthew J. Slaughter, 2001. “Trade liberalization and per capita income convergence: a difference-in-differences analysis,” Journal of International Economics, Vol 55(1), pages 203-228.

[23] Georgias Fotopoulus and Dionysios Psallidas, 2009. “Investigating the Effects of Euro on Bilateral Trade: a Kernel Matching Approach,” Journal of Economic Integration vol 24(4), pages 661-684.

Investigating a cointegrating relationship[24] between, for example, Canada and the US – and the change in this relationship – is another potential way of investigating a change seen in the US, but not Canada. However, this results in some of the same issues as conventional DID (namely, how to choose the ‘control’ unit).

The synthetic control method, as advocated by ADH, uses placebo studies to draw inferences (instead of large sample inferential techniques). As a result, no standard errors or confidence intervals are obtained. These outputs are particularly useful, for example, when the impact is close to zero – a small confidence interval could limit the impact to only negative values, for example. Additionally, a large number of controls is beneficial, as a p-value of 0.05 or smaller can only be generated when there are 20 or more control units.

Linden (2018) argues that standard errors, and confidence intervals are useful in gauging the causal impact and suggest using Newey-West standard errors to overcome some of the problems ADH highlight without using placebo studies.[25] This is done by way of using the synthetic control method in conjunction with interrupted time series analysis (ITSA, also known as quasi-experimental time series).

Lastly, as noted by Ferman et al (2020), there is little guidance available on the choice of predictor variables. They note that some authors use all pre-treatment outcomes (export values, in our case) as predictors, while some use a subset or an average in addition to other predictors.[26] Leaving the choice of which predictors to include until the end gives rise to potentially cherry-picking results which show statistically significant results (‘specification searching’). Abadie and Gardeazabal (2003), for example, use the mean of all pre-treatment outcome values (plus additional covariates), while others use various selected lagged values.

Ferman et al provide two recommendations to researchers in choosing a lagged dependent variable specification:

1. Use only specifications which use an infinitely large number of pre-intervention outcome values as the numbers of pre-intervention periods increases (i.e. approaches infinity).

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[24] In short: a relationship between two stochastic variables which individually may behave as a random walk, but a linear combination of them will not – i.e., there is a long-run relationship between them.

[25] Ariel Linden, 2018. “Combining synthetic controls and interrupted time series analysis to improve causal inference in program evaluation”, Journal of Evaluation in Clinical Practice, vol 24(2), pages 447-453. doi: 10.1111/jep.12882.

[26] Bruno Ferman, Cristine Campos de Xavier Punto, and Vítor Augusto Possebom, 2020. "Cherry picking with synthetic controls," Journal of Policy Analysis and Management, John Wiley & Sons, Ltd., vol. 39(2), pages 510-532. Draft version obtained from https://mpra.ub.uni-muenchen.de/85138/.

This rules out specifications which do not consider the dynamics of time series, such as the mean of all pre-treatment outcomes or a specification which uses a limited number of pre-treatment outcomes (e.g. first, middle, or last outcome).

2. Report results for different specifications.

The second recommendation complicates the reporting of an obvious point estimate. Ferman et al (2020) suggest basing an inference procedure on a new test statistic that is a function of all the test statistics for each individual specification and either:

a. using a weighted average of the point estimate if the function is a weighted average of test statistics (with the same weights), or

b. construct confidence intervals using a set identification procedure suggested by Firpo and Possebom (2018)[27].

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[27] Sergio Firpo and Vitor Possebom, 2018. "Synthetic Control Method: Inference, Sensitivity Analysis and Confidence Sets," Journal of Causal Inference, vol 6(2). https://doi.org/10.1515/jci-2016-0026

3 Methodology

Box 3. Methodology Summary

This section describes the synthetic control methodology in more detail. The aim of the methodology is to estimate a counterfactual – in our case this would entail estimating single malt exports to the US if there was no tariff introduced. The difference between this counterfactual and observed exports (with the tariff) would be the estimated tariff impact.

The counterfactual is constructed using a combination of countries which (a) do not have a change in tariff and (b) are comparable to the US in other respects. Many researchers suggest constructing this counterfactual (‘synthetic control’) using a weighted average, where the weights are chosen in such a way that our synthetic control resembles the US as closely as possible in its characteristics prior to the introduction of the tariff.

3.1 Synthetic Control

This section is adapted from the forthcoming Abadie (2020) paper discussing the synthetic control methodology and feasibility[28], as well as the Firpo and Possebom (2018) paper discussing alternative inference tests for the synthetic control methodology.

3.1.1 The Setting

Assume that we have data for all for $J + 1$ units: $j = 1,2, \dots, J + 1$, where J is the amount of control units and $j = 1$ is the treated unit (the United States, in our case). The donor pool $j = 2, \dots, J + 1$ is a collection of untreated units assumed to be not affected by the intervention.

$j = 1$	$j = 2, \dots, J + 1$
Treated (one unit)	Untreated (J units, referred to as the donor pool)

Assume that our data spans T periods, and that the first T_0 periods occur before the intervention. For each unit j and time t we observe the outcome of interest, Y_{jt}. For each unit j we also observe a set of k predictors of the outcome, $X_{1j}, \dots, X_{kj}$, which

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[28] Abadie, 2021. “Using Synthetic Controls: Feasibility, Data Requirements, and Methodological Aspects”. Journal of Economic Literature (forthcoming issue). Preview (2020) available at: https://economics.mit.edu/files/17847.

are themselves unaffected by the intervention. These predictors may include pre-intervention values of Y_{jt}.

$t = 1, \dots, T_0$	$t = T_0 + 1, \dots, T$
Pre-treatment period (T_0 periods)	Post-treatment period ($T - T_0$)

The $k \times 1$ vectors $\boldsymbol{X}_1, \dots, \boldsymbol{X}_{J+1}$ contain the values of the predictors for units $j = 1, \dots, J + 1$. The $k \times J$ matrix, $\boldsymbol{X}_0 = \left[\boldsymbol{X}_2 \cdots \boldsymbol{X}_{J+1}\right]$ collects the values of predictors for all untreated units (a $k \times 26$ matrix, in our case). For each unit j and time period t we can define $\mathrm{Y}_{\mathrm{jt}}^{\mathrm{N}}$ to be the potential response without intervention. For the single treated unit, $\mathrm{j} = 1$, and a post-intervention period $\mathrm{t} > \mathrm{T}_0$ we can define $\mathrm{Y}_{1\mathrm{t}}^{\mathrm{I}}$ to be the potential response with the intervention.

The effect of the intervention of interest for the treated unit in period $t > T_0$ can be written as:

$$\delta_{1t} = Y_{1t}^I - Y_{1t}^N$$

The challenge here is to estimate Y_{1t}^N for $t > T_0$: any outcome Y_{1t} we observe for the treated unit after the introduction of the tariff is by definition Y_{1t}^I. Note that the effect of the intervention can change over time (the t subscript is retained). For example, we may hypothesise that the tariff takes a number of months (or quarters) to reach its full impact as US importers work to find suitable substitutes with a lower price point, or set up new trading relations.

The synthetic control method approximates the treated unit by creating a weighted average of units in the donor pool. The synthetic control can be represented by a $J \times 1$ vector of weights, $\boldsymbol{W} = \left(w_2, \dots, w_{J+1}\right)'$. Using this set of weights, the synthetic control estimators of Y_{1t}^N and δ_{1t}, respectively, are:

$$\hat{Y}_{1t}^N = \sum_{j=2}^{J+1} w_j Y_{jt}$$

and

$$\hat{\delta}_{1t} = Y_{1t} - \hat{Y}_{1t}^N \tag{1}$$

To avoid extrapolation, the weights can be restricted to be non-negative and to sum to one:

$$\sum_{j=2}^{J+1} w_j = 1$$

If we were using nominal export values, this would be an issue – the Unites States is the top export market for Scotch whisky (single malt or otherwise), which means that any weighted average of countries in the donor pool would not be sufficient to approximate the actual values for $t \leq T_0$. Scaling the values, for example by using per-capita values or growth rates, could alleviate this issue.

3.1.2 Choosing weights

Weights in the $J \times 1$ vector $\boldsymbol{W} = \left(w_2, \dots, w_{J+1}\right)'$ can be chosen by the researcher (e.g. equal weights for a simple average or population-weights). Abadie (2020) proposes to choose $w_2, \dots, w_{J+1}$ so that the resulting weighted average (synthetic control) not only best resembles the pre-intervention outcome Y, but also the pre-intervention predictors for the treated unit.

Given the non-negative constants $v_1, \dots, v_k$ (for k predictors), a set of weights $\boldsymbol{W}^* = \left(w_2{}^*, \dots, w_{J+1}{}^*\right)'$ is chosen that minimises:

$$\|\boldsymbol{X}_1 - \boldsymbol{X}_0\boldsymbol{W}\| = \sqrt{\sum_{h=1}^{k} v_h\left(X_{h1} - w_2X_{h2} - \cdots - w_{j+1}X_{hJ+1}\right)^2} \qquad (2)$$

such that weights $w_2, \dots, w_{J+1}$ are non-negative and sum to one. This can be referred to as the ‘inner optimisation’. Some predictors will be more ‘important’ than others in this minimisation exercise. The positive constants $v_1, \dots, v_k$ therefore reflect the weight placed on each of the k predictors when reproducing the values of the treated unit’s predictors using the donor pool’s predictor values. The estimated treatment effect for time $t > T_0$ is then:

$$\hat{\delta}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j{}^* Y_{jt}$$

The set of weights $\boldsymbol{W}^*$ which minimises equation (2) needs a given set of constants $v_1, \dots, v_k$. For each choice of $\boldsymbol{V} = (v_1, \dots, v_k)$, a different synthetic control is generated:

$$\boldsymbol{W}(\boldsymbol{V}) = \begin{pmatrix} w_2(\boldsymbol{V}) \\ \vdots \\ w_{J+1}(\boldsymbol{V}) \end{pmatrix}$$

Much like choosing the set of weights $\boldsymbol{W}$, the choice of $\boldsymbol{V}$ can be left up to the researcher. For example, Abadie suggests choosing $\boldsymbol{V}$ such that the synthetic control $\boldsymbol{W}(\boldsymbol{V})$ minimises the mean squared prediction error (for example, by dividing up the pre-treatment sample in training and testing periods like in many other time series applications). Researchers may also simply minimise the mean squared error for the entire pre-treatment period (i.e. minimise the distance between the observed and synthetic outcome values). The process of this optimisation is referred to as the 'outer optimisation'.

3.1.3 Implementation

The process of choosing weights $\boldsymbol{W}^*$ and constants $\boldsymbol{V}$ (outer and inner optimisation, respectively) is handled by Becker and Klößner's R package `MSCMT` (multivariate synthetic control method using time series).[29] This implementation is able to handle time-series data, both in the outcome and predictors, as well as multiple outcome variables (if needed). A full description of the various optimisation algorithms and methods used in this package is available in Becker and Klößner (2018).[30]

3.2 Inference

3.2.1 Placebo tests

Abadie et al (2010) propose a benchmark similar to Fisher's Exact Hypothesis Test where they estimate, for each control unit $j = 2, \dots, J+1$ and post-treatment time period $t = T_0 + 1, \dots, T$ an estimate $\hat{\delta}_{jt}$. The distribution of these estimates, $\hat{\boldsymbol{\delta}}_j = \left(\hat{\delta}_{jT_0+1} \cdots \hat{\delta}_{jT}\right)'$, can then be compared to the vector of estimates for the treated unit, $\hat{\boldsymbol{\delta}}_1 = \left(\hat{\delta}_{1T_0+1} \cdots \hat{\delta}_{1T}\right)'$.

If the vector of estimated effects for the United States is substantially different in value than the distribution of effects for all control units, Abadie et al reject the null hypothesis of *no effect*.

In some cases, certain time periods $t \in \{T_0 + 1, \dots, T\}$ may show a large effect while others do not. In these cases, it may be unclear whether to reject the null or not. To that end, Abadie et al (2010) propose two potential test statistics: one based on the post-treatment (root) mean squared prediction errors (MSPEs), and one based on the ratio of the (root) MSPEs pre- and post-treatment.

3.2.1.1 Inference using the post-treatment fit

Using the post-treatment RMSPE for country $j = 1, \dots, J+1$:

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[29] See Becker and Klößner (2017): https://cran.r-project.org/package=MSCMT

[30] Martin Becker and Stefan Klößner, 2018. "Fast and reliable computation of generalized synthetic controls". Econometrics and Statistics, vol 5, pages 1-19. Preliminary version (2017) available at: http://www.oekonometrie.uni-saarland.de/papers/FastReliable.pdf

$$RMSPE_j^{post} = \sqrt{\frac{\sum_{T_0+1}^{T}\left(Y_{j,t} - \hat{Y}_{j,t}^{N}\right)^2}{T - T_0}}$$

the p-value proposed by Abadie et al (2010) is given by:

$$p = \frac{\sum_{j=1}^{J+1} \mathbb{I}\left[RMSPE_j^{post} \geq RMSPE_1^{post}\right]}{J+1} \qquad (3)$$

where the indicator function $\mathbb{I}\left[RMSPE_J \geq RMSPE_1\right]$ takes a value of 1 when $RMSPE_J \geq RMSPE_1$, and 0 otherwise. Alternatively, the $MSPE$ can be used.

Intuitively, this compares the post-treatment fit of the treated unit to the post-treatment fit of the placebo tests, and if it is unusually large compared to the fits obtained by the control units' synthetic controls, the p-value is small.

This, however, requires us to limit the control units used by comparing their pre-treatment fit: one of the control units will ultimately have the largest export value per capita, and its synthetic control will fit poorly. Therefore, its post-treatment fit will also be poor, and its RMSPE will be high. Abadie et al propose imposing a restriction on the ratio between the treated unit's pre-treatment fit and the control units' pre-treatment fits to remedy this.

3.2.1.2 Inference using the ratio of post- to pre-treatment fits

One way to avoid limiting the size of the donor pool is by using the ratio of post- to pre-treatment fits instead of only the post-treatment fit. This is also alluded to in Abadie et al (2010) and is the test statistic of choice in Abadie et al (2015).

Using a ratio of root mean squared prediction errors (RMSPE) given by:

$$RMSPE_j^{ratio} = \frac{RMSPE_j^{post}}{RMSPE_j^{pre}} = \sqrt{\frac{\sum_{T_0+1}^{T}\left(Y_{j,t} - \hat{Y}_{j,t}^{N}\right)^2 / (T - T_0)}{\sum_{t=1}^{T_0}\left(Y_{j,t} - \hat{Y}_{j,t}^{N}\right)^2 / T_0}} \qquad (4)$$

the p-value can be defined as:

$$p = \frac{\sum_{j=1}^{J+1} \mathbb{I}\left[RMSPE_j^{ratio} \geq RMSPE_1^{ratio}\right]}{J+1} \qquad (5)$$

where the indicator function $\mathbb{I}\left[RMSPE_j^{ratio} \geq RMSPE_1^{ratio}\right]$ takes a value of 1 when $RMSPE_j^{ratio} \geq RMSPE_1^{ratio}$, and 0 otherwise.[31]

In short, the $RMSPE_j^{ratio}$ test statistic is a ratio of root mean squared prediction errors for country j before and after the intervention. When a large enough proportion of control units have a ratio of pre- to post-treatment RMPSEs larger than the treated unit $j = 1$, the p-value is large (and we fail to reject the null hypothesis of *no effect* at some significance level α).

3.2.1.3 Null hypothesis

The (two-sided) null hypothesis for both of these tests is given by:

$$H_0 : \delta_{jt} = 0 \text{ for each region } j \in \{1, \ldots, J+1\} \text{ and time period } t \in \{1, \ldots, T\}$$

This is a fairly restrictive inference assumption, as recognised by Ferman, Pinto, and Possebom (2018). In the absence of random assignment (of the treatment), this p-value can be interpreted as the probability of obtaining an estimated value for the test statistic at least as large as the value obtained using the treated case, as if the treatment were randomly assigned among the data (i.e., our control units).

3.2.2 Confidence sets

Ferman, Pinto, and Possebom (2018) extend the inference procedure for the synthetic control method to allow for any sharp hypothesis, where the null hypothesis for a constant treatment effect is given by:

$$H_0^c : Y_{j,t}^I = Y_{j,t}^N + c \times \mathbb{I}[t \geq T_0 + 1]$$

in each region $j \in \{1, \ldots, J+1\}$ and time period $t \in \{1, \ldots, T\}$, and $c \in \mathbb{R}$. This can be rephrased as:

$$H_0^c : \delta_{jt} = c \times \mathbb{I}[t \geq T_0 + 1]$$

Ferman, Pinto, and Possebom also note that more general treatment effect functions can also be used – e.g., where the treatment effect is not constant over time, or varies by region as well as time.

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[31] A ratio of mean squared error predictions can also be used. This would alter the test statistic for each country and simply shift the scale. This is used, for example, in Firpo and Possebom, 2018.

The test statistic seen in equation (4) can be modified to allow for this intervention effect:

$$RMSPE_j^c = \sqrt{\frac{\sum_{T_0+1}^{T}\left(Y_{j,t} - \hat{Y}_{j,t}^N - c \times \mathbb{I}[t \geq T_0]\right)^2 / (T - T_0)}{\sum_{t=1}^{T_0}\left(Y_{j,t} - \hat{Y}_{j,t}^N - c \times \mathbb{I}[t \geq T_0]\right)^2 / T_0}} \tag{6}$$

while the p-value in equation (5) becomes:

$$p^c = \frac{\sum_{j=1}^{J+1} \mathbb{I}\left[RMSPE_j^c \geq RMSPE_1^c\right]}{J+1} \tag{7}$$

Note that Ferman, Pinto, and Possebom also allow for country-weights in this ratio to vary using some sensitivity parameter $\phi \in \mathbb{R}_+$ and a vector $\boldsymbol{\nu} = \left(\nu_1, \ldots, \nu_{J+1}\right)$. Here, we focus on the case where $\phi = 0$ and $\boldsymbol{\nu} = (1, \ldots, 1)$, extending the equal-weight inference procedure in Abadie et al (2010) to test for any sharp hypothesis.[32]

Inverting the test statistic allows us to estimate confidence sets, where a general $(1-\alpha)$ confidence set can be constructed as follows:

$$CS_{(1-\alpha)} = \left\{f \in \mathbb{R}^{\{1,\ldots,T\}} : f(t) = c \; and \; p^c > \alpha\right\}$$

This set contains all constant-in-time intervention effects whose associated null hypotheses are not rejected by the inference procedure. In some cases, a one-sided test may be desirable (for example, isolating only negative effects post-treatment).[33]

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[32] Sensitivity analysis could be performed by varying ϕ and $\boldsymbol{\nu}$**.**

[33] A one-sided null hypothesis may be given by $H_0^c : \delta_{j,t} < c$ where a mean prediction error test statistic could be used, $MPE_j^c = \frac{\sum_{T_0+1}^{T}\left(Y_{j,t} - \hat{Y}_{j,t}^N - c \times \mathbb{I}[t \geq T_0]\right) / (T - T_0)}{\sum_{t=1}^{T_0}\left(Y_{j,t} - \hat{Y}_{j,t}^N - c \times \mathbb{I}[t \geq T_0]\right) / T_0}$, where the p-value p^c can be calculated as $p^c = \frac{\sum_{j=1}^{J+1} \mathbb{I}\left[MPE_j^c < MPE_1^c\right]}{J+1}$.

4 Data Selection

Box 4. Data Selection Summary

Single malt export data obtained from HMRC contains both value and quantity. Supplementary data – predictors – were also obtained, primarily from OECD. This includes consumption expenditure, exchange rates, interest rates, and alcohol consumption. The donor pool was narrowed down to OECD countries with no change in single malt tariff or major alcohol tax policy – this left 28 countries.

4.1 Sources

The monthly value (in GBP) and quantity (in litres of pure alcohol) of single malt exports for January 2010 – December 2020 are obtained from HMRC's Overseas Trade Statistics[34]. The OECD database was used to obtain quarterly nominal private consumption expenditure for Q1 2010 – Q4 2020, monthly exchange rates and monthly long-term interest rates for January 2010 – December 2020, as well as annual per-capita alcohol consumption between 2010-2018[35]. The distance between London and partner countries' capitals was obtained from CEPII[36] and serves as a proxy for freight and time-associated costs. Annual population data between 2010-2020 was obtained from OECD while tariff data was obtained from WTO.

Some variables, including export value and quantity, were available at a monthly frequency, while two predictors were not: quarterly private consumption expenditure and annual population. Population itself is not used as a predictor (see below); it is used to transform other variables into per capita values.

For this reason, both quarterly and monthly specifications were explored. In each of these, population interpolation to a quarterly or monthly frequency was also explored (see Table A4 and Table A5 in the Annex). Additionally, disaggregation of quarterly consumption was also explored in the case of the monthly specification.

4.2 Variable Selection and Transformation

4.2.1 Dependent variable(s)

- **Export value and quantity:** Since the synthetic control will be a weighted average of the donor pool (in terms of the dependent variable), export values

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[34] Accessed 12 March 2021, available at: https://www.uktradeinfo.com/trade-data/

[35] Accessed throughout March 2021, available at: https://data.oecd.org/

[36] Accessed 23 March 2021, available at: http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=8

and quantities were scaled before analysis – this consisted of using per capita export values/quantities as opposed to total values/quantities.

These values and quantities were then logged due to periods of large variances (mostly in countries with smaller populations, who in some months import small amounts of single malt). Months with export values/quantities of £0 or 0 LPA for a given country were imputed by the smallest monthly value in that country's time series.[37]

4.2.2 Population

- **Population:** This was not used as a predictor or dependent variable but rather to transform values into per-capita values where possible. Annual population data consisted of historical data (2010-2018) and projections (2019-2020). This data is based on mid-year population estimates – for the sake of this analysis, these are assumed to be in June. Linear extrapolation (forwards and backwards) to cover January 2010 to December 2020 was explored (to avoid step-changes having disproportionally large impacts on results) but this was found to have no major impact on final results.

4.2.3 Independent variables (predictors)

- **Private consumption:** nominal final private consumption data was available from OECD on a quarterly basis (non-seasonally adjusted). Consumption data was chosen over GDP since this was deemed to have a more 'direct' impact on exports or imports of a final consumption good such as single malt.

  Consumption values were transformed into per-capita consumption values using the population variable mentioned above and transformed into GBP by using the local-USD and USD-GBP exchange rates.

  In the case of the monthly specification, disaggregation of quarterly values into monthly values was also explored using the **`tempdisagg`** package in R, described in more detail in Sax and Steiner (2013).[38] This disaggregation, like the interpolation of population values, was also not found to have a major impact on final estimates.[39]

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[37] This affected roughly 3% of observations in our donor pool. The simple imputation method chosen here is not the only option, see for example Rob Hyndman's blog post here: https://robjhyndman.com/hyndsight/transformations/. Given the small frequency of these observations, it was deemed a simple imputation approach was sufficient for this analysis.

[38] Christoph Sax and Peter Steiner, 2013. "Temporal Disaggregation of Time Series," The R Journal vol 5(2), pages 80-87. Available at: https://journal.r-project.org/archive/2013/RJ-2013-028/index.html

[39] In short, the Denton-Cholette method was used to disaggregate quarterly series to monthly series subject to the constraint that each quarter's disaggregated values sum to the actual quarter's values.

- **Exchange rate:** values expressed in a local currency were transformed to GBP using the monthly average nominal exchange rate (obtained from the OECD). This was done in two stages: transforming local currency to USD, and then transforming USD to GBP (there was no comprehensive database of GBP to local currencies on the OECD database). The local-GBP exchange rate itself was also used as a predictor.

- **Alcohol consumption**: alcohol consumption data was only available on an annual basis from 2010 to 2018 (litres per capita per year). This was averaged over 2010-18, resulting in a time-invariant predictor.

- The **distance** between London and the export destination's capital was also used as a time-invariant predictor.

- Four different **lagged dependent variable** specifications were explored: no lag, the first lag of one month (or one quarter), a seasonal lag of twelve months (or four quarters), or both the first and seasonal lags. Results were similar in most lagged specifications, with the best pre-tariff fit most commonly found in the first-lag specification.

- A **monthly or quarterly dummy** was included in the no-lag and first-lag specifications to account for any seasonality in single malt exports not accounted for by seasonality in consumption.

Comparisons of final model results with disaggregated consumption data and interpolated population data (for the per capita variables) are included in the Annex.

4.3 Donor Pool Selection

4.3.1 Tariffs and alcohol tax policy changes

The collection of countries considered in this analysis consists of OECD nations without a change in tariff on any whisky imports from the UK, including Scotch whiskies, and full data availability. Sixty-nine countries (out of 152) had no change in tariffs during the pre-treatment period.[40] Thirty of these nations had full data availability in both the outcome and predictor variables (the US also had this).

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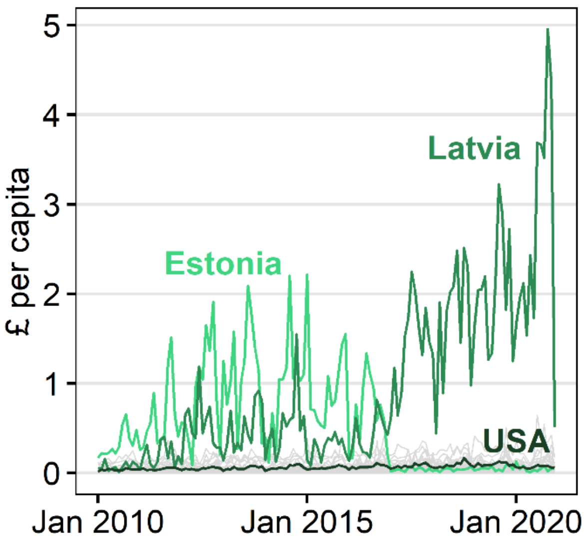
[40] Preferential or MFN applied tariffs, for which the data was obtained from the World Trade Organization (see Annex A – Donor Pool and Model Specifications).

Estonia and Latvia were both removed from these thirty countries because exports to those nations were likely affected by major changes in alcohol taxes in Estonia. This is especially evident when looking at single malt export value per capita (Figure 5).[41]

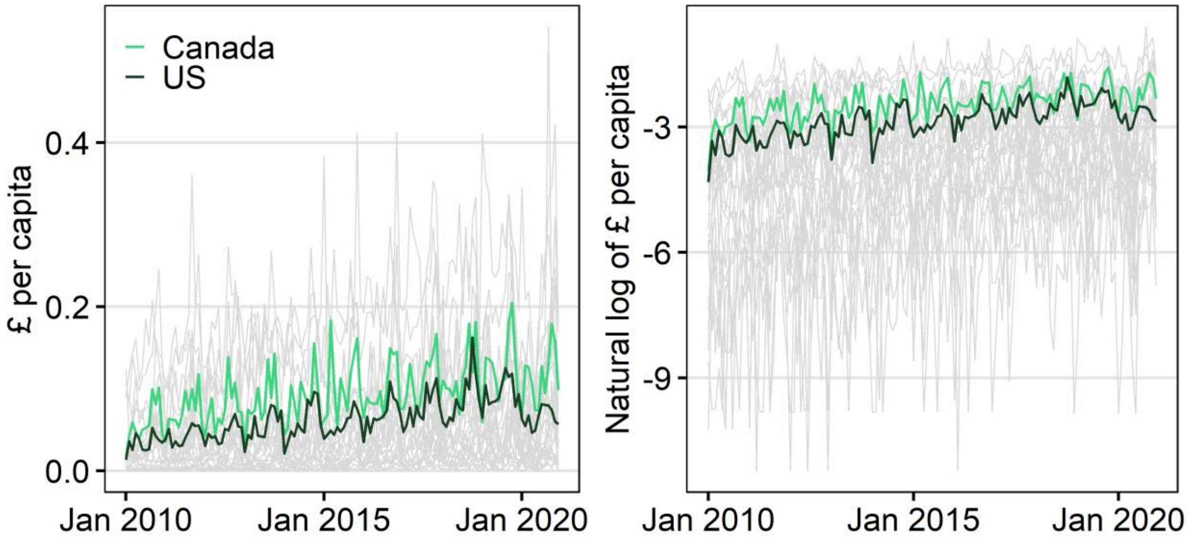
This left 28 countries in our donor pool which all had (a) no change in the whisky tariff in the pre-treatment period and (b) full data availability. This donor pool plus the United States accounted for 71% of single malt exports in 2018.[42]

Figure 6 shows the monthly export value per capita and the logged value per capita, respectively, where the grey



Source: HMRC OTS, OECD, RESAS calculations

Figure 5. UK exports of SMSW (£/cap) to countries with full data availability and no change in tariff



Source: HMRC OTS, OECD, RESAS calculations

Figure 6. Monthly UK exports of SMSW (£/cap and logged £/cap) to countries in the donor pool (excluding Estonia and Latvia)

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[41] In June 2017, Estonia increased the duties charged on many alcoholic beverages, potentially giving rise to increased cross-border alcohol trade with Latvia and Finland, for example (which would at least partially explain the increase in exports to Latvia following 2017). Although estimates of this effect are scarce, anecdotal accounts are given in various news reports. See for example BBC, 2017. "Estonian tax threat to Finns' booze cruises" and the excise duty page on the Ministry of Finance of the Republic of Estonia, 2019.

[42] See Table A1 in the Annex a full list of countries in the final donor pool, and Table A2 for a breakdown of countries not selected.

lines and Canada constitute the final donor pool. Figure 7 shows the same using quarterly data, where the similarity in trends and seasonality between the US and the donor pool becomes more apparent. The synthetic control can draw on the full range of the donor pool to more closely approximate exports to the US (as opposed to a simple average).

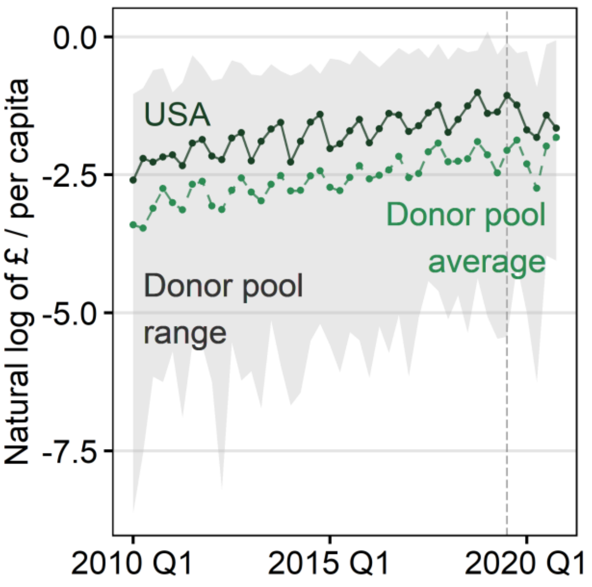
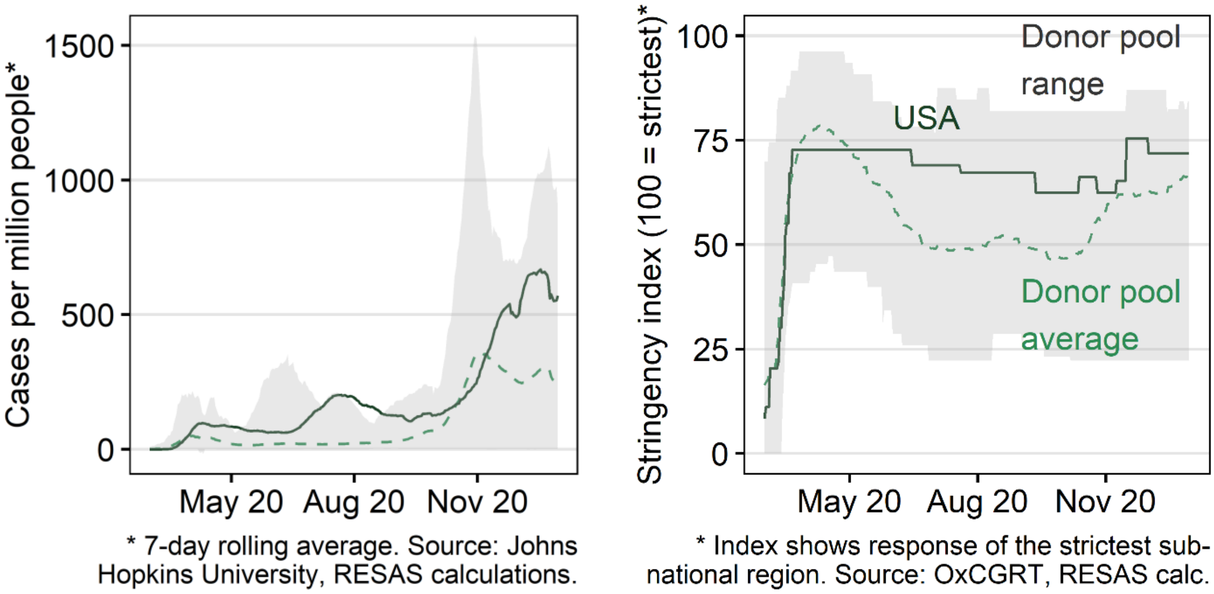


Figure 7. Quarterly UK exports of SMSW (logged £/cap) to the US and the donor pool

4.3.2 Covid-19

Covid-19, a major contributor to the dampened demand for food and drink exports during 2020, may not have impacted our donor pool and the US in a similar way.

Comparing Covid-19 cases in the US to our donor pool average suggests cases were particularly high in the US during late 2020. However, the Oxford COVID-19 Government Response Tracker[43] suggests that the US' government response to Covid-19 was within the range covered by our donor pool and exceeding the donor pool average from May to December 2020.



* 7-day rolling average. Source: Johns Hopkins University, RESAS calculations.

* Index shows response of the strictest sub-national region. Source: OxCGRT, RESAS calc.

Figure 8. Comparing new Covid-19 cases and the Covid-19 stringency index for the donor pool average (and range) and the US from March 2020

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[43] T. Hale et al, 2021. "*A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker)*," Nature Human Behaviour.

5 Synthetic Control Weights

The synthetic control methodology described in Section 3.1 consists of an optimisation process with two parts: (i) finding a combination of countries in the donor pool that best resembles the pre-treatment predictor values of the US (inner optimisation), and (ii) finding the optimal weights on these predictors so as to best resemble the export value of the US (outer optimisation). In practice, we end up with a set of weights put on both countries and predictors.

The various sets of specifications tested – quarterly and monthly specifications with or without a first or seasonal lagged dependent variables included – all lead to slightly different country and predictor weights. The weights for the ‘headline’ (quarterly first-lagged) specifications are presented here (with value, quantity, or price as the dependent variables).

Table 3. Country and predictor weights for the first-lag quarterly specification

Dependent variable	Top country weights		Top predictor weights	
Value	Canada	24.8%	Lagged dep. var.	> 99.9%
	France	22.8%	GBP exchange rate	< 0.01%
	Australia	16.4%	Interest rate	0.0%
	Further 9 countries	35.9%	Other predictors	0.0%
Quantity	Canada	56.0%	Alcohol cons.	78.7%
	South Korea	15.3%	Lagged dep. var.	21.2%
	Australia	9.8%	Interest rate	< 0.01%
	Further 8 countries	18.9%	Other predictors	< 0.01%
Price	Switzerland	37.9%	Lagged dep. var.	96.3%
	Australia	13.6%	GBP exchange rate	3.3%
	Lithuania	11.8%	Final consumption	0.4%
	Further 7 countries	36.7%	Other predictors	< 0.01%

Note that not all countries in the donor pool (or predictors) will necessarily have a weight associated with them.

In many cases, the weights obtained were similar between these specifications and those with other lagged dependent variables. A more complete set of weights associated to the quarterly specifications can be found in Annex B – Intermediate Synthetic Control Outputs.

6 Results

6.1 Overview

A wide range of model specifications were explored, many of which resulted in similar results. In general, the specifications using quarterly data provided a better pre-tariff fit than those using monthly data, which is why the quarterly results are presented as the primary sets of results and the focus of Sections 6.2, 6.3, and 6.4. Monthly export data may simply be too volatile (or vary too much between countries in the donor pool) to be able to accurately mimic exports to the US.

Frequency of data was not the only variation between specifications – value, quantity, or price as a dependent variable were all explored. Different lagged dependent variables were explored as predictors, as well as the interpolation and extrapolation of mid-year population estimates and disaggregation of quarterly consumption data (in the case of the monthly specifications).

This section shows an overview of results for the quarterly and monthly model specifications with a 'first' lagged dependent variable (i.e. the previous quarter or month) and no population interpolation or consumption disaggregation. Here, results are presented in per-capita terms. Aggregated impacts are presented in Section 0 – these show total tariff impacts over the course of the Q4 2019 – Q4 2020 post-tariff period.

Results for other lagged model specifications are shown in the Annex (see e.g. Table A4 for a list of all specifications explored, and Table D1 and Table D2 for results for these specifications).

6.1.1 Quarterly data

Results using quarterly export data are shown below, in Table 4. These show the average quarterly impact of the tariff on per-capita exports of single malt to the US, in terms of proportion of export value, quantity, and price. Confidence sets and p-values are also provided through the use of placebo tests (see Section 3.2.1).

Table 4. Results using a quarterly first-lagged specification

Dependent variable	**Estimated quarterly tariff effect**	**p-value**	**26/29 confidence set (~90%)**	
	Proportion (%)		Lower (%)	Upper (%)
Value (£/cap)	-18.3**	0.069	-100.0	-4.7
Quantity (mLPA/cap)	-10.3**	0.069	-19.6	-9.5
Price (£/LPA)	-10.2	0.345	-64.7	+17.9

Without population interpolation. Key: *** p < 2/29; ** p < 3/29; * p < 4/29.

The confidence sets[44] above suggest a strictly negative impact on both value and quantity, with the estimated impacts on export value and quantity given by [-100.0%, -4.7%] and [-19.6%, -9.5%], respectively. The estimated impact on average export price is non-significant and could be negative or positive as shown by the [-64.7%, +17.9%] confidence set.

6.1.2 Monthly data

Monthly specifications were also explored (using monthly trade data and monthly predictors where possible). Table 5 below shows the estimated per-capita impact of the tariff for the first-lagged monthly specification, along with 90% confidence sets.

Table 5. Results using a monthly first-lagged specification

Dependent variable	**Estimated monthly tariff effect**	**p-value**	**26/29 confidence set (~90%)**	
	Proportion (%)		Lower (%)	Upper (%)
Value (£/cap)	-17.4	0.207	-87.0	+1.2
Quantity (LPA/cap)	-10.7	0.448	-34.9	+16.8
Price (£/LPA)	-11.9	0.414	-56.7	+3.8

Without population interpolation or consumption disaggregation

The results above suggest a less clear picture than those obtained by using quarterly data: here, we are no longer confident that the impact on export value or quantity was different from zero – despite similar point estimates. The impact on average export price is similarly non-significant. A stated earlier, this may be because monthly export data is too volatile (including to countries with zero or near-zero export values during some months).

6.2 Results by Quarter

6.2.1 Value

The synthetic control and the observed UK-US export values are shown in Figure 9. The ‘gaps’ between the actual and synthetic values before and after the introduction of the tariffs can be compared, where the difference in the average gaps would provide a (point) estimate of the impact of the tariff. This is shown in Table 6 (this uses the same first-lag quarterly specification as above).

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[44] Since we have 28 countries in the donor pool, the smallest ‘p-value’ obtainable is $1/29 \approx 0.034$. To obtain this p-value, we would require that the US has the largest test statistic amongst all 29 countries – see equation (5). For this reason, we settle on a $3/29 \approx 0.103$ significance level (the closest we can get to a 10% significance level based on the low power) and a $26/29$ confidence set.

The point estimates suggest that, across the post treatment period, the average value of per-capita export was roughly 18.3% less than what it otherwise would have been without a tariff (calculated from the log tariff impact[45]).

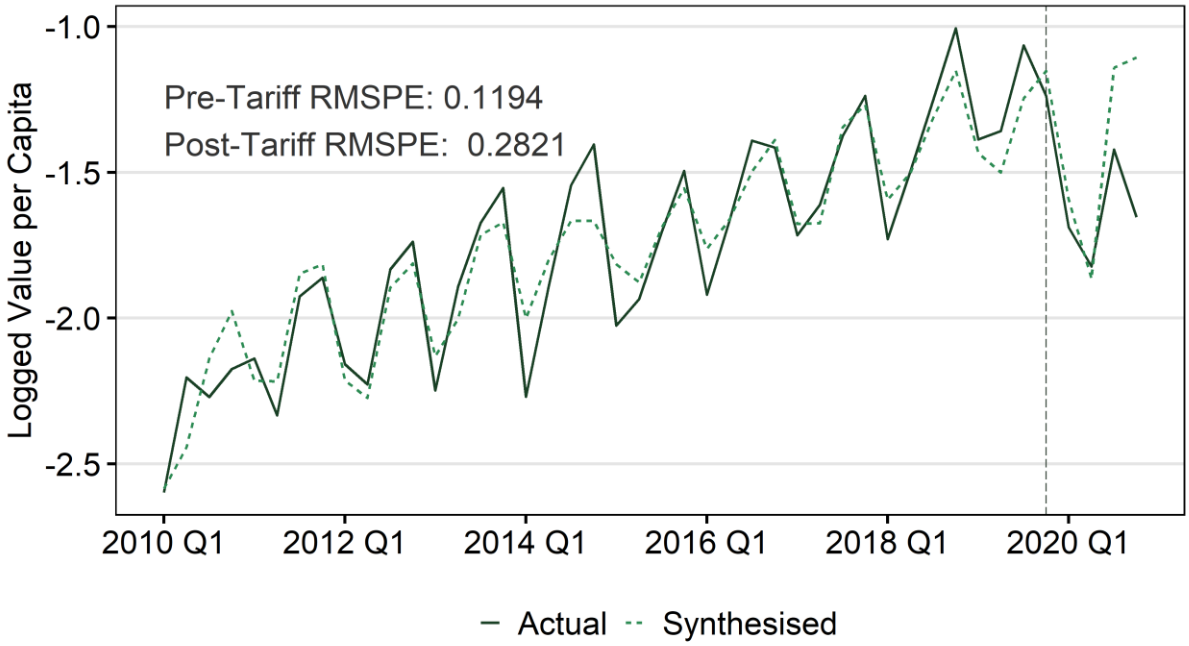

Figure 9. The observed single malt export value to the US between 2010-2020 and the constructed weighted average (synthetic control) during the same period

Table 6. Comparing export value between actual and synthetic US

	Log Exports per Capita Natural log of £/capita			**Exports per Capita** £/capita			**Tariff Impact**
Period	Actual	Synth.	Gap	Actual	Synth.	Gap	%
Pre-Tariff (Q1 2010 – Q3 2019):							
Average	**-1.762**	**-1.770**	**+0.008**	**0.18**	**0.18**	**+0.00**	**..**
Post-Tariff (Q4 2019 – Q4 2020):							
Q4 2019	-1.238	-1.152	-0.086	0.29	0.32	-0.03	..
Q1 2020	-1.688	-1.593	-0.095	0.18	0.20	-0.02	..
Q2 2020	-1.823	-1.866	+0.043	0.16	0.15	+0.01	..
Q3 2020	-1.422	-1.141	-0.281	0.24	0.32	-0.08	..
Q4 2020	-1.653	-1.105	-0.548	0.19	0.33	-0.14	..

---

[45] This is done using a series of linear approximations in the form of: $\left(1+\frac{1}{10^6}\right)^{\beta*10^6}$, where β is the difference in logs between the post-tariff and pre-tariff gap. See Annex C – Inference and Confidence Sets for more information.

Average	**-1.565**	**-1.372**	**-0.194**	**0.21**	**0.26**	**-0.05**	**..**
Tariff Impact (Post-Tariff less Pre-Tariff):							
Average	**0.197**	**0.399**	**-0.202**	**0.03**	**0.09**	**-0.06**	**-18.3**

Showing rounded values

It is apparent from both Figure 9 and Table 6 that large gaps are seen during Q4 2020, and that Q2 2020 saw a marginally positive gap. These quarterly gaps do not take into account the average pre-tariff fit and should therefore not be interpreted as quarterly tariff impact estimates. Additionally, any quarterly tariff impact estimates would have their own associated p-values and confidence sets which are not presented here (see Annex C – Inference and Confidence Sets. Instead, confidence sets for the average quarterly tariff impact are presented in Section 6.1.1.

6.2.2 Quantity

All outputs reported for value above are available for quantity as well. Table 7 below shows that the tariff resulted in an estimated -10.3% change in the average quantity of single malt exported per quarter. Table 4 shows that this result is statistically significant (meaning if we replicate the synthetic control for other countries, we find very few similar estimated impacts of ‘placebo’ tariffs).

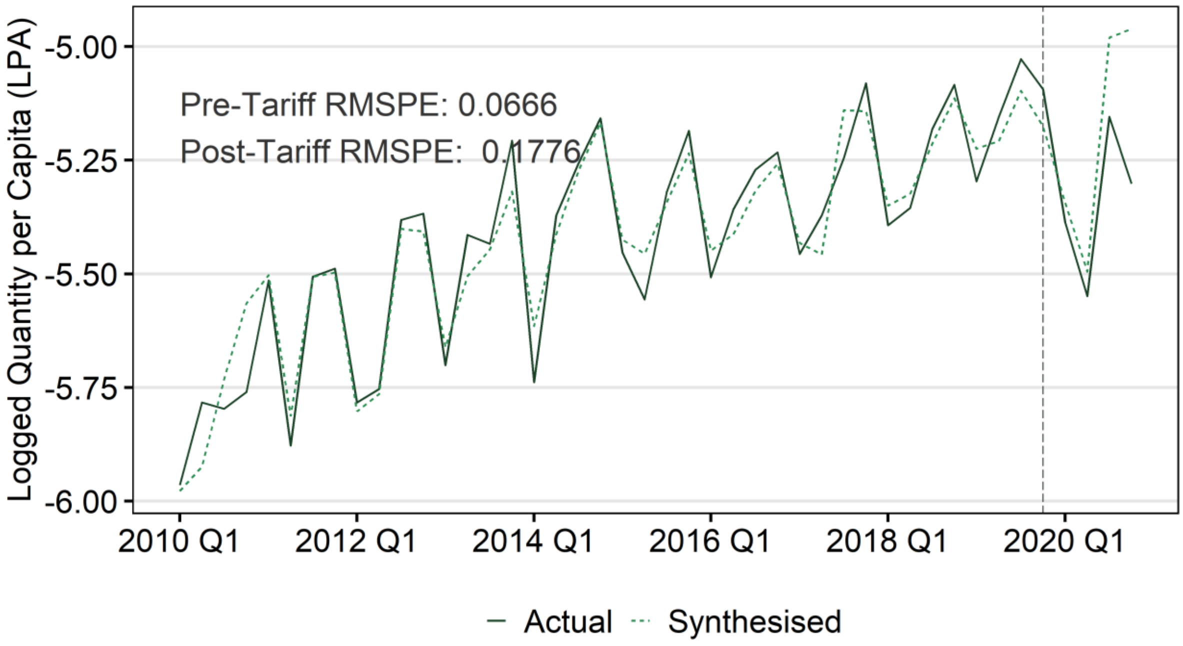

Figure 10. The observed single malt export quantity to the US between 2010-2020 and the constructed weighted average (synthetic control) during the same period

Table 7. Comparing export quantity between actual and synthetic US

	Log Exports per Capita Natural log of LPA/capita			**Exports per Capita** mLPA/capita			**Tariff Impact**
Period	Actual	Synth.	Gap	Actual	Synth.	Gap	%
Pre-Tariff (Q1 2010 – Q3 2019):							
Average	**-5.430**	**-5.433**	**+0.003**	**4.50**	**4.47**	**+0.03**	**..**
Post-Tariff (Q4 2019 – Q4 2020):							
Q4 2019	-5.094	-5.175	+0.081	6.13	5.66	+0.48	..
Q1 2020	-5.387	-5.344	-0.043	4.58	4.78	-0.20	..
Q2 2020	-5.549	-5.495	-0.054	3.89	4.11	-0.22	..
Q3 2020	-5.155	-4.980	-0.174	5.77	6.87	-1.10	..
Q4 2020	-5.302	-4.961	-0.341	4.98	7.01	-2.02	..
Average	**-5.297**	**-5.191**	**-0.106**	**5.07**	**5.68**	**-0.61**	**..**
Tariff Impact (Post-Tariff less Pre-Tariff):							
Average	**0.133**	**0.242**	**-0.109**	**0.57**	**1.21**	**-0.64**	**-10.3**

Showing rounded values

As with Table 6, the gaps presented in Table 7 should not be interpreted as tariff impact estimates in their own right. However, we can see a similar pattern where Q4 2020 is the quarter where the synthetic control and US deviate the most.

6.2.3 Price

Table 8 shows that the tariff resulted in an estimated -10.2% change in the average price of single malt exported. Additionally, the (negative) gaps are the largest in Q1 2020 and Q4 2020. However, as shown in Table 4, the estimated tariff impact is not statistically significant (meaning that if we replicate the synthetic control for other countries in our donor pool, we find that more than 10% of our total sample of countries show equal or larger estimated impacts of ‘placebo’ tariffs).

Table 8. Comparing export price between actual and synthetic US

	Log Price Natural log of £/LPA			**Exports** £/LPA			**Tariff Impact**
Period	Actual	Synth.	Gap	Actual	Synth.	Gap	%
Pre-Tariff (Q1 2010 – Q3 2019):							
Average	**3.668**	**3.656**	**0.012**	**39.734**	**38.988**	**0.745**	**..**
Post-Tariff (Q4 2019 – Q4 2020):							

Q4 2019	3.856	3.839	0.017	47.28	46.48	0.80	..
Q1 2020	3.698	3.882	-0.183	40.38	48.50	-8.11	..
Q2 2020	3.726	3.764	-0.038	41.51	43.12	-1.61	..
Q3 2020	3.732	3.828	-0.096	41.77	45.97	-4.20	..
Q4 2020	3.648	3.825	-0.177	38.40	45.82	-7.42	..
Average	**3.732**	**3.827**	**-0.095**	**41.868**	**45.977**	**-4.110**	**..**
Tariff Impact (Post-Tariff less Pre-Tariff):							
Average	**0.064**	**0.172**	**-0.108**	**2.134**	**6.989**	**-4.855**	**-10.2**

Showing rounded values

6.3 Sensitivity Analysis

6.3.1 Removing countries

The three countries with the most weight in the synthetic control were removed from the donor pool, one by one. Results for these estimations, using a quarterly first-lag specification[46] without population interpolation, are reported in Table 9. This is similar in some ways to the sensitivity analysis conducted by Abadie et al (2015). The resulting confidence intervals for these estimations use a donor pool of 27 countries (as opposed to 28). This means that a 26/29 confidence set cannot be constructed any longer – instead, a 25/28 confidence set is used, where 25/28 is now closest to 90%.

Clearly, the results are sensitive to the removal of the top three countries with the most weight in the synthetic control – particularly for quantity, which relies heavily on Canada’s time series. This perhaps suggests that the initial choice of donor pool is important, and that increasing the size of the donor pool further could be beneficial (while limiting it to countries that are similar to the US in some way).

Table 9. Results when removing countries from the donor pool

Dependent variable	Estimated quarterly tariff effect	p-value	26/29 (no removal) or 25/28 confidence sets(a)	
			Lower	Upper
	%		%	%
Value (£/cap)	**-18.3****	**0.069**	**-100.0(b)**	**-4.7**
Removed from donor pool (and original weight):				
1 Canada (25%)	-20.0**	0.071	-66.4	-7.9
2 France (23%)	-20.0**	0.071	-100.0(b)	-3.3

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[46] This single specification was selected to save computing time.

3 Australia (16%)	-13.4*	0.107	-100.0(b)	-1.2
Quantity (LPA/cap)	**-10.3****	**0.069**	**-19.6**	**-9.5**
Removed from donor pool (and original weight):				
1 Canada (56%)	-13.6*	0.107	-35.5	-2.4
2 S. Korea (15%)	-16.2*	0.107	-41.2	-0.7
3 Australia (10%)	-8.2**	0.071	(c)	(c)
Price (£/LPA)	**-10.2**	**0.345**	**-64.7**	**+17.9**
Removed from donor pool (and original weight):				
1 Switzerland (38%)	-12.9	0.321	-83.9	+22.9
2 Australia (14%)	-10.6	0.321	-71.7	+18.3
3 Lithuania (12%)	-11.1	0.321	-74.2	+18.8

Showing results for a quarterly first-lag specification. Key: (a) the 25/28 confidence set was the closest to 90% given a donor pool of 27 countries (plus the US); (b) truncated to -100%; (c) no 90% confidence set was obtained due to low power (however, for Australia's quantity, a 26/28 confidence set was given by [-13.7%, -11.7%]); *** p < 2/29 or 2/28; ** p < 3/29 or 3/28; * p < 4/29 or 4/28.

6.3.2 Covid-19

Although the synthetic control method tries to account for post-tariff fluctuations experienced in the US and the control states, it is only an assumption that these variations are identical. Covid-19, a major contributor to the dampened demand for whisky and many other food and drink exports during 2020, may not have impacted our synthetic control and the US in a similar way.

- Comparing new confirmed Covid-19 cases in the US to cases in our weighted average[47] suggests cases were particularly high in the US during November and December 2020. If this did have a major impact on demand for whisky not reflected in our synthetic control estimate, the tariff impact would be overestimated.

- The Oxford COVID-19 Government Response Tracker[48], however, suggests this rise in cases did not result in a major deviation in government response between the US and our weighted average. Nonetheless, importers and consumers of Scotch whisky may have been more cautious regardless of state-level restrictions.

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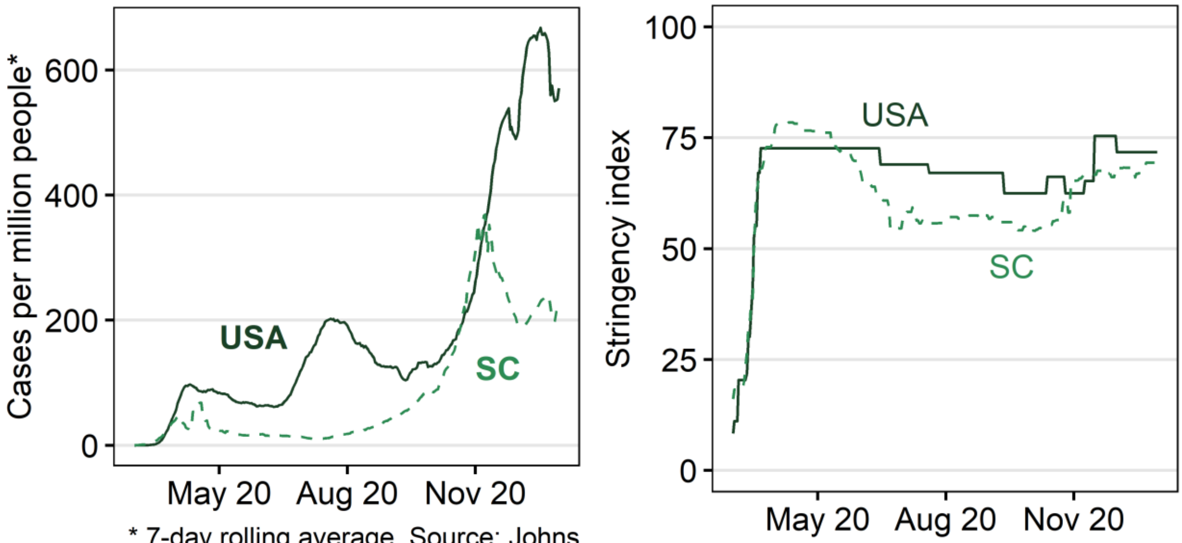
[47] The synthetic control obtained when using value as a dependent variable and a first-lag specification (**Error! Reference source not found.**).

[48] T. Hale, N. Angrist, R. Goldszmidt, B. Kira, A. Petherick, T. Phillips, S. Webster, E. Cameron-Blake, L. Hallas, S. Majumdar, and H. Tatlow, 2021. "*A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker)*," Nature Human Behaviour.

The comparison between the US and our synthetic control for both of these metrics is shown in Figure 11. The country weights used were those of the quarterly first-lag synthetic control described in Section 6.1.1.



* 7-day rolling average. Source: Johns Hopkins University, RESAS calculations.

Source: OxCGRT, RESAS calculations

Figure 11. Comparing the synthetic control (SC) obtained using the quarterly first-lag specification with new Covid-19 cases and the Covid-19 stringency index (100 = strictest)

6.3.3 Scotch Whisky Sales

The same IWSR data as shown in Table 2 was used to construct a change in (Scotch) whisky sales for the synthetic control (using the same quantity first-lag specification's country weights as above for volume, and the value first-lag specification's country weights for value).

These results suggest that the synthetic control saw an increase in Scotch whisky sales between 2019 and 2020, both in terms of volume (+1.6%) and value (+5.4%). This is in contrast the to the US' decline in Scotch whisky sales, shown in Table 10 below. These results are somewhat in line with expectations, suggesting that Scotch whisky sales in our combination of countries fared better than in the US. Similarly, sales of all whisky saw increases in both the US and our weighted average, although the increase seen in the latter was more muted.

Table 10. Scotch whisky sales in the United States and the synthetic control, 2019-20

	United States		Synthetic Control	
	Volume[(a)]	Value[(b)]	Volume[(a)]	Value[(b)]

		millions of 9-litre cases	$ billions	millions of 9-litre cases	$ billions
Scotch whisky	2019	8.51	3.47	9.42	6.89
	2020	8.38	3.36	9.57	7.26
	Growth (%)	**-1.5**	**-3.1**	**+1.6**	**+5.4**
All whisky	2019	74.77	19.90	36.86	12.45
	2020	78.40	21.16	37.09	13.01
	Growth (%)	**+4.9**	**+6.4**	**+0.6**	**+4.5**

Source: IWSR Drinks Market Analysis Ltd. (via the Scotch Whisky Association), RESAS calculations. (a) Using the first-lag quarterly quantity specification's country weights; (b) Using the first-lag quarterly value specification's country weights.

Note however that this is sales of all Scotch whisky, not just single malt. Other varieties, e.g. blended Scotch whiskies, will make up a large proportion of sales. Additionally, data on sales value from the IWSR includes sales tax, duty, and other mark-ups, while the export value obtained from HMRC excludes these. The IWSR data therefore also includes the tariff duty paid from October 2019 onwards.[49]

The data includes both on- and off-trade sales, with the US showing a high proportion of off-trade Scotch whisky sales (82.2%) compared to the global average (78.1%) in 2019. Splitting the Scotch whisky sales volume data into on- and off-trade parts, we note that the increase in off-trade sales between 2019 and 2020 was more pronounced in the synthetic control (+20.9%) than in the US (+6.3%), while the decrease in on-trade sales was less pronounced (-49.0% in the synthetic control versus -55.5% in the US).

6.4 Aggregated Results

The estimated per-capita tariff impacts on value and quantity shown in Section 6.1 can be aggregated using US population data.

Using the original proportional impacts and 90% confidence sets, we can obtain approximate tariff impacts over the entire Q4 2019 – Q4 2020 post-tariff period. As shown in Table 11, the quarterly tariff impact of 18.3% in value and 10.3% in quantity translates to a quarterly reduction of £18.5m or 213.6 thousand LPA per quarter. When totalled over the five observed post-tariff quarters, this amounted to £92.4

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[49] Further differences could be due to the exclusion of duty free sales in these figures, the different comparison we are making (2019 vs. 2020 as opposed to pre-tariff and post-tariff), and the different quantity unit used in this data (volume of whisky as opposed to volume of pure alcohol). Note also that the volume and value of US retail sales are not mimicked by the synthetic control particularly well. This is because the US had one of the highest per-capita sales of whisky when compared to countries in the donor pool (and the countries with higher sales did not have much weight put on them).

million or 1,068 thousand LPA. The wide confidence set for value means the total impact could be as small as £23.7m, while quantity's more narrow confidence set suggests a minimum impact of 985,700 litres of pure alcohol.

Table 11. Estimated total tariff impact on single malt export value and quantity

Unit	Estimated tariff impact	Average quarterly impact		Total impact (Avg. x 5)
	%	£/cap	£m	£m
Value	**-18.3****	**-0.06**	**-18.5**	**-92.4**
90% conf. set	[-100.0, -4.7]	[-0.31, -0.01]	[-101.3, -4.7]	[-506.3, -23.7]
	%	mLPA/cap	000's LPA	000's LPA
Quantity	**-10.3****	**-0.64**	**-213.6**	**-1,068.0**
90% conf. set	[-19.6, -9.5]	[-1.22, -0.59]	[-405.8, -197.1]	[-2,028.8, -985.7]

Showing results for the quarterly first-lag specifications without population interpolation.
Key: *** p < 2/29; ** p < 3/29; * p < 4/29.

When looking at the quantity exported, we could transform 'litres of pure alcohol' to quantities of single malt by assuming an alcohol content of 40% (by volume). This would lead to an estimated tariff impact of 2.7 million litres of single malt, with the 90% confidence interval given by [-5.1 million litres, -2.5 million litres].

7 Conclusion

Results

Comparing our constructed weighted average ('synthetic control') with observed single malt exports to the US shows clear evidence of decreases in both value and quantity of quarterly single malt exports to the US due to the introduction of the tariff.

It is clear from the results in Sections 6.1 and 6.4 that the estimated impact on export quantity is more 'defined' than the impact on export value. The analysis suggests a reduction of between 19.6% and 9.5% on export quantity, totalling between 5.1 and 2.5 million litres of single malt (assuming 40% ABV). This is in contrast to the estimated reduction in export value – given by the range -100.0% to -4.7%, a total decrease of between £506.3m to £23.7m.[50]

This wider range for tariff impacts on export value could be due to the fact that we are using total (quarterly) export value. This could mask changes in the per-unit price as well as changes in export mixes – e.g. a change in varieties exported due to importers switching to cheaper varieties of single malt. Estimated tariff impacts on the (average) export price are also non-informative, with the 90% confidence interval covering both negative and positive values.

While the quarterly specification is showcased above, it is useful to highlight the results of the monthly specification shown in Section 6.1.2. The monthly specification did not find a strictly negative impact on export value, quantity, or price – indicating an inconclusive average monthly impact on exports (i.e. either negative, positive, or zero).

This difference in results could be due to a variety of factors – for example, a change in seasonality because of Covid-19 which is reflected in monthly trade but less so in quarterly trade (i.e. did US importers delay or hasten their usual orders because of stock effects or due to hospitality restrictions being introduced in the US). It could also simply reflect the more volatile nature of monthly trade, or the fact that different lagged dependent variables were used (last quarter vs. last month).

It is important to note that the method used here is fairly novel, and that these are only provisional estimates of the tariff impact. Other methods are likely to provide slightly different answers, and even the synthetic control method as we used it can

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[50] It is clear from the data that a 100% reduction is impossible. The actual lower bound of the range is given by a number somewhere between 95% to 100%. Calculating the exact number was deemed too computationally intensive.

be augmented and changed – see Section 2.1.3 for some possible ways the method can be extended.[51]

Sector Intelligence

It should be highlighted that the tariff on single malt was far from the only factor impacting on Scotch whisky exports from the UK, and that the drink and hospitality industries overall have faced a tumultuous period since October 2019 (whether that is because of tariffs, Covid-19, EU Exit, or other factors).

Crucially, total export value and quantity is not the sole indicator of the whisky sector's success. Anecdotal evidence suggests that some exporters may have absorbed (some of) the costs associated with the tariff, resulting in lower profit margins or even losses[52]. Others may have chosen to export lower cost varieties of (single malt) Scotch whisky, potentially resulting in less revenue. Exporters of other varieties of Scotch whisky may have also seen negative impacts following the tariff introduction. In addition to this, there are likely to be longer-term impacts like a loss of market share to other spirit varieties. Similar industry effects were seen in the US whiskey sector following the tariffs imposed by the UK/EU in June 2018.[53]

All of these impacts are not explored here, meaning the 'true' impact of the tariff on the Scottish whisky sector is underestimated in this analysis (instead, we focus on impacts on exports). The increased demand for whisky in the US, shown in Section 1.4.2, highlights this further. While Scotch whisky producers and exporters were dealing with impacts of the tariff in a variety of ways, total sales of whisky in the US actually increased – meaning some other varieties of whisk(e)y saw more success.

Tariff Suspension

The USTR suspended the tariffs on single malt for four months as of 4 March 2021, with a further five-year suspension announced on 17 June 2021.[54] This analysis could serve as a starting point in estimating the full impact of the tariff throughout its enforcement. The same methods could also potentially be used in estimating impacts of the introduction of other tariffs as well (or indeed the removal of tariffs).

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[51] One example not mentioned in this section is the option to model multiple dependent variables simultaneously in the `MSCMT` R package by Becker and Klößner (2019).

[52] See for example https://whiskycast.com/u-s-tariff-trouble-hits-scotch-whisky-industry/.

[53] See for example https://www.thespiritsbusiness.com/2021/06/american-whiskey-tariffs-is-relief-in-sight/.

[54] See the joint statements by the UK and US governments here: https://ustr.gov/about-us/policy-offices/press-office/press-releases/2021/march/joint-us-uk-statement-suspension-large-civilian-aircraft-tariffs and https://ustr.gov/about-us/policy-offices/press-office/press-releases/2021/june/joint-us-uk-statement-cooperative-framework-large-civil-aircraft.

Further Discussion

This analysis serves as a discussion paper – it is meant to showcase analytical techniques and provide a starting point for discussions. We welcome any queries regarding the methodology or results presented in this paper. These can be directed to agric.stats@gov.scot.

Annex A – Donor Pool and Model Specifications

Donor Pool

The table below shows the countries in the donor pool. The choice was based on data availability and tariff. Any country with missing data for any of the predictors was discounted, as was any country with a change in tariff during Jan 2010 – Dec 2020.[55] Table A1 shows the countries in the final donor pool.

Table A1. Countries for use in donor pool in synthetic control method

Tariff	**Donor Pool (25+3 Control Countries)**			
No	Austria	Germany	Netherlands	South Africa
	Belgium	Hungary	New Zealand	Spain
	Canada	Iceland	Norway	Sweden
	Czechia	Ireland	Poland	Switzerland
	Denmark	Italy	Portugal	
	Finland	Japan	Slovakia	
	France	Lithuania	Slovenia	
Yes (no change)	Australia (ad-valorem equivalent tariff of 5%)			
	Chile (6%)		South Korea (20%)	

The total number of countries initially considered for the donor pool was 152. The majority of these (126) were indeed nations without any change in whisky tariff between 2010 – 2019. This was further narrowed down to 28 countries due to data availability of predictors (see Table A2).

These 28 countries accounted for 44.6% of total single malt export value in 2018, with the United States accounting for a further 26.4%. In total, this represented 71.0% of total exports in 2018; 16% came from countries not selected due to limited data availability, and the remaining 13% came from countries not selected due to changes in tariffs during 2010-2020 (or major changes in alcohol duty policies in the case of Latvia and Estonia).

Note that tariff data did not include tariffs introduced as a result of trade disputes, only those agreed upon as part of goods schedules in bilateral or multilateral trade negotiations (e.g. the 1994 WTO Uruguay Round or so-called '1980 procedures') . This means that even the United States was reported to have a 0% ad-valorem equivalent tariff for the HS6 category '220830 – Whiskies' in the WTO tariff data.

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[55] This information was obtained using the WTO'S Tariff Analysis Online facility.

Data on tariffs introduced as a result of trade disputes is scarce. The trade disputes available on WTO's trade dispute gateway[56] was carefully examined for trade disputes where the respondent was either (i) the United Kingdom or (ii) the European Union (pre-2021), and retaliation was granted at any point between 2010-2020.[57] The only trade dispute that met these criteria was DS316, the Airbus-Boeing dispute which resulted in tariffs on single malt.

Table A2. UK exports of single malt in 2018

	Countries	Value (£m)	Prop. (%)
Donor pool	28	583	44.6
United States	1	344	26.4
Total selected	**29**	**927**	**71.0**
Not selected due to data availability	69	207	15.8
Top five export destinations:			
08 Singapore	1	83	6.4
12 China	1	32	2.5
18 United Arab Emirates	1	17	1.3
19 India	1	17	1.3
25 Hong Kong	1	9	0.7
Not selected due to changing tariffs	54	173	13.2
Top five export destinations:			
06 Taiwan	1	101	7.7
11 Latvia (tax policy change)	1	39	3.0
24 Mexico	1	10	0.7
28 Israel	1	7	0.5
30 Vietnam	1	6	0.4
Total not selected	**123**	**379**	**29.0**
Total exports	**152**	**1,306**	**100.0**

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[56] See here: https://www.wto.org/english/tratop_e/dispu_e/find_dispu_cases_e.htm

[57] There were 88 relevant disputes for the EU, where DS316 (European Communities and Certain member States — Measures Affecting Trade in Large Civil Aircraft) was the only dispute for which retaliation (by the United States) was granted. Authorisation to retaliate was requested by the United States regarding DS291 (European Communities — Measures Affecting the Approval and Marketing of Biotech Products) with no further updates since 17 January 2008. Similarly, 3 relevant disputes existed for the United Kingdom, with DS316 being the only dispute where retaliation was granted.

The average monthly values of each predictor and export value in the pre-tariff period (Jan 2010 to Oct 2019) is shown below.

Table A3. Average predictor values for the pre-tariff period

		Export Value	Local Private Final Cons.	UK Private Final Cons.	Population (a)	Interest Rate	Local-GBP Exchange Rate	Avg. Alcohol Consumption 2010-18	Distance Between Capitals
Unit		£ per capita	£000's per capita	£000's per capita	Millions	%	Local currency / £	Litres per cap	000's km
Frequency		M	Q	Q	A	M	M	..	..
	US	**0.06**	**6.5**	**4.7**	**319.4**	**2.42**	**1.48**	**8.8**	**5.9**
1	Australia	0.06	5.7	4.7	23.6	3.32	1.74	9.9	17.0
2	Austria	0.04	4.4	4.7	8.6	1.51	1.20	12.3	1.2
3	Belgium	0.08	4.0	4.7	11.2	1.82	1.20	10.0	0.3
4	Canada	0.09	4.7	4.7	35.6	2.09	1.70	8.2	5.4
5	Chile	0.00	1.6	4.7	17.9	4.91	852.87	7.7	11.7
6	Czechia	0.01	1.7	4.7	10.6	1.97	31.27	11.6	1.0
7	Denmark	0.09	4.7	4.7	5.7	1.21	8.93	9.6	1.0
8	Finland	0.04	4.4	4.7	5.5	1.38	1.20	8.9	1.8
9	France	0.18	3.8	4.7	66.2	1.61	1.20	11.9	0.3
10	Germany	0.07	4.1	4.7	81.7	1.09	1.20	11.1	0.9
11	Hungary	0.00	1.2	4.7	9.9	4.91	361.91	10.9	1.5
12	Iceland	0.05	5.0	4.7	0.3	5.68	176.32	7.2	1.9
13	Ireland	0.01	3.9	4.7	4.7	3.22	1.20	11.1	0.5
14	Italy	0.03	3.5	4.7	60.2	3.23	1.20	7.3	1.4
15	Japan	0.01	4.0	4.7	127.1	0.47	148.16	7.2	9.6
16	S. Korea	0.01	2.4	4.7	50.8	2.96	1,652.65	8.8	8.9
17	Lithuania	0.02	1.7	4.7	2.9	2.58	1.20	13.6	1.7
18	Netherlands	0.18	3.9	4.7	16.9	1.36	1.20	8.6	0.4
19	New Z.	0.04	4.0	4.7	4.6	3.66	1.98	9.1	19.1
20	Norway	0.04	6.2	4.7	5.1	2.19	10.33	6.2	1.2
21	Poland	0.01	1.4	4.7	38.4	3.93	5.04	10.5	1.5
22	Portugal	0.02	2.4	4.7	10.4	4.82	1.20	10.4	1.6
23	Slovakia	0.00	1.7	4.7	5.4	2.19	1.20	10.0	1.3
24	Slovenia	0.01	2.2	4.7	2.1	2.92	1.20	10.5	1.2
25	South Africa	0.02	0.7	4.7	54.5	8.54	16.12	7.3	9.0
26	Spain	0.04	2.9	4.7	46.6	3.00	1.20	10.0	1.3
27	Sweden	0.14	4.4	4.7	9.8	1.37	11.27	7.2	1.4
28	Switzerland	0.13	7.6	4.7	8.2	0.46	1.41	9.6	0.7

(a) Population is not a predictor in itself – instead, it was used to convert export value (or quantity) and private final consumption into per-capita values. These predictors were subsequently logged.

Model Specifications

Data Transformation

The following data transformations and combinations were explored, each with either no lagged dependent variable, a first-lag dependent variable, a seasonal-lag dependent variable, or both a first- and seasonal-lag as a predictor (along with other predictors) – making for a total of 48 monthly specifications and 24 quarterly specifications (where only the first-lagged specifications with no consumption disaggregation or population interpolation are reported in the final report).

The price dependent variable was constructed by taking the monthly export value to a given country and dividing it by the monthly export quantity. For cases where the quantity was reported as zero, the next-smallest non-zero quantity for that country between 2010-2020 was used. Where both value and quantity were zero, a missing value was generated. None of the 29 countries had one of these missing values.

Table A4. Different monthly model specifications and pre-tariff fit

Dependent variable*	**Consumption[a]**	**Population[b]**	**RMSPE[c] (prior to tariff introduction)**			
			No Lag	First Lag	Seasonal Lag	First & S. Lag
Value (£)	Q	A	0.23836	0.19924	0.20298	0.19917
Value (£)	Q	IM	0.23853	0.19918	0.20294	0.19912
Value (£)	DM	A	0.23836	0.19924	0.20298	0.19917
Value (£)	DM	IM	0.23853	0.19918	0.20294	0.19912
Quantity (LPA)	Q	A	0.22948	0.16004	0.16304	0.16004
Quantity (LPA)	Q	IM	0.22944	0.16007	0.16306	0.16007
Quantity (LPA)	DM	A	0.22948	0.16004	0.16304	0.16004
Quantity (LPA)	DM	IM	0.22944	0.16007	0.16306	0.16007
Price (£/LPA)	Q	A	0.14120	0.12383	0.12499	0.12383
Price (£/LPA)	Q	IM	0.14120	0.12383	0.12499	0.12383
Price (£/LPA)	DM	A	0.14120	0.12383	0.12499	0.12383
Price (£/LPA)	DM	IM	0.14120	0.12383	0.12499	0.12383

(a) Dependent variable was logged per capita for value/quantity, logged for price. (b) Key: Q = Quarterly; DM = Disaggregated into Monthly; A = Annual (mid-year); IM = Interpolated to Monthly. (c) Root Mean Squared Prediction Error (comparisons between different dependent variables should not be made). The model(s) including a seasonal lagged dependent variable did not include a monthly dummy. Rounded to five decimal places.

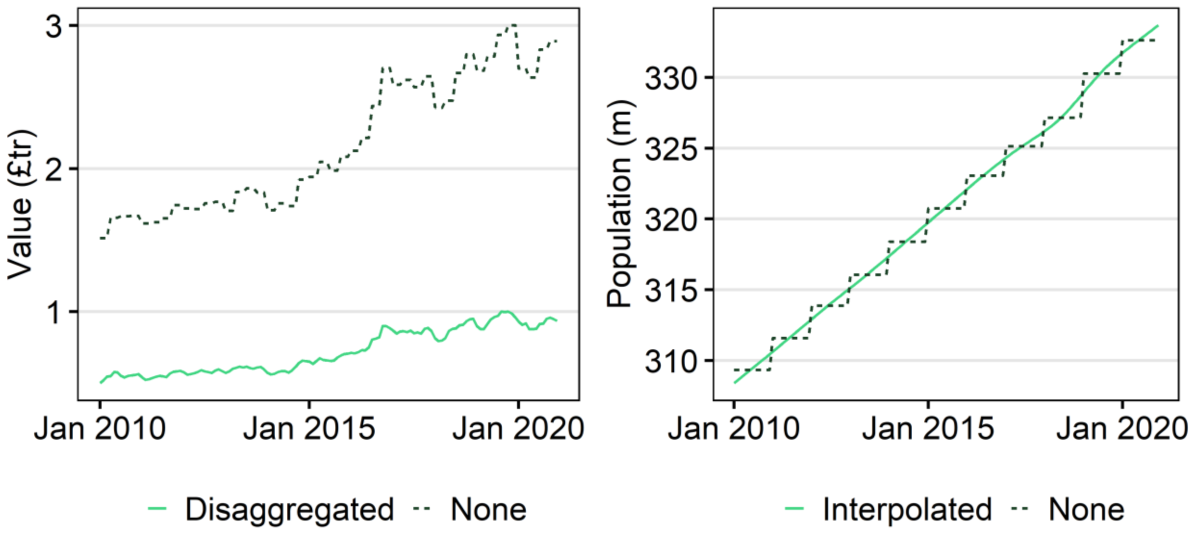
Table A5. Different quarterly model specifications and fit

Dependent variable*	**Consumption[(a)]**	**Population[(b)]**	**RMSPE[(c)] (prior to tariff introduction)**			
			No Lag	First Lag	Seasonal Lag	First & S. Lag
Value (£)	Q	A	0.17703	0.11943	0.12009	0.11943
Value (£)	Q	IM	0.17711	0.11923	0.11995	0.11923
Quantity (LPA)	Q	A	0.14457	0.06657	0.06709	0.06656
Quantity (LPA)	Q	IM	0.14434	0.06657	0.06710	0.06656
Price (£/LPA)	Q	A	0.10643	0.09301	0.09453	0.09301
Price (£/LPA)	Q	IM	0.10643	0.09301	0.09453	0.09301

(a)(b) See Table A4 for key; (b) The model(s) including a seasonal lagged dependent variable did not include monthly dummy, other specifications did. Rounded to five decimal places.

Interpolation and Disaggregation

Population interpolation and consumption disaggregation, as shown above, do not majorly affect the fit of the synthetic control (and where they do, this affects the post-tariff fit the same way and therefore the tariff impact estimates are similar). Figure A1 below shows this for the United States – quarterly consumption disaggregated into monthly values, and annual mid-year estimates interpolated to a monthly frequency. Population interpolation was also explored for quarterly specifications.



Source: OECD, RESAS calculations

Source: OECD, RESAS calculations

Figure A1. Visual representation of quarterly-to-monthly consumption disaggregation (left) and monthly population interpolation for the US (right)

Annex B – Intermediate Synthetic Control Outputs

Synthetic Control Weights

Table B1 and Table B2 below show the country and predictor weights for the different lag specifications using value and quantity as the dependent variable at a quarterly frequency. Results for specifications using the price dependent variable and/or a monthly frequency are available upon request.

Table B1. Optimal country weights W with different lag specifications

Country		Value				Quantity			
		No Lag	First Lag	Seas. Lag	First & S. Lag	No Lag	First Lag	Seas. Lag	First & S. Lag
1	Australia	..	0.164	0.161	0.164	0.172	0.098	0.096	0.099
2	Austria	0.132	..	..	..	..	..	..	..
3	Belgium	..	..	..	..	..	..	..	..
4	Canada	0.577	0.248	0.276	0.248	0.430	0.560	0.563	0.557
5	Chile	..	..	..	0.009	..	0.003	0.002	0.003
6	Czechia	..	0.017	..	0.017	..	..	..	..
7	Denmark	..	..	..	..	..	..	0.021	..
8	Finland	0.086	..	..	..	..	..	..	..
9	France	..	0.228	0.235	0.228	..	0.033	0.013	0.031
10	Germany	..	..	..	..	..	..	..	..
11	Hungary	..	..	..	..	..	..	..	..
12	Iceland	..	0.015	..	0.015	..	..	0.005	..
13	Ireland	..	..	..	..	..	..	..	..
14	Italy	0.095	..	..	..	..	..	..	..
15	Japan	..	..	..	..	..	0.063	0.038	0.061
16	Lithuania	..	0.019	..	0.019	..	0.153	0.164	0.156
17	Netherlands	..	0.039	0.047	0.039	..	0.048	0.048	0.048
18	N. Zealand	..	0.016	..	0.016	..	0.021	0.025	0.023
19	Norway	0.109	..	..	..	..	..	..	..
20	Poland	..	..	..	..	0.398	..	..	..
21	Portugal	..	0.105	0.126	0.105	..	0.004	0.009	0.004
22	Slovakia	..	..	..	..	..	..	..	..
23	Slovenia	..	..	..	..	..	..	..	..
24	South Africa	..	..	..	..	..	..	..	..
25	South Korea	..	..	0.013	..	..	..	..	..
26	Spain	..	0.081	0.114	0.081	..	..	..	..
27	Sweden	..	0.057	0.027	0.057	..	0.003	..	0.004
28	Switzerland	..	..	..	..	..	0.013	0.017	0.014

.. : no weight placed (0.000); using the quarterly specifications with no population interpolation. Rounded to three decimal places.

Table B2. Optimal predictor weights V with different lag specifications

Dependent Variable	Independent Variables	No Lag	First Lag	Seas. Lag	First & S. Lag
Logged Export Value per Capita	First Lagged Dependent Variable	..	1.000	..	1.000
	Seasonal Lagged Dependent Variable	..	..	0.051	..
	Long-Term Interest Rate	..	..	..	..
	GBP Exchange Rate	0.032	..	0.898	..
	Logged Private Final Consumption (per cap) (Local)	..	..	..	..
	Logged Private Final Consumption (per cap) (UK)	0.323	..	0.051	..
	Monthly Dummy	0.323	..	..	..
	Average Alcohol Consumption (per cap) (2010-18)	0.323	..	..	..
	Distance between Capitals	..	..	..	..
Logged Export Quantity per Capita	First Lagged Dependent Variable	..	0.212	..	0.124
	Seasonal Lagged Dependent Variable	..	..	0.078	0.033
	Long-Term Interest Rate	0.027	..	0.001	..
	GBP Exchange Rate	0.321	..	..	..
	Logged Private Final Consumption (per cap) (Local)	0.006	..	..	..
	Logged Private Final Consumption (per cap) (UK)	0.321	..	0.078	0.124
	Monthly Dummy	0.321	..	..	..
	Average Alcohol Consumption (per cap) (2010-18)	..	0.787	0.843	0.719
	Distance between Capitals	0.005	..	..	..

.. : no or little weight placed (0.000 or < 0.0005); Using the quarterly specifications with no population interpolation. Rounded to three decimal places.

Post- to Pre-Treatment RMSPE Ratios

The following tables show ratios of the post-tariff fit to the pre-tariff fit (for the US). A ratio of > 1 would show that our synthetic control has a worse fit after the tariff, while a ratio of < 1 would show the opposite. These ratios themselves do not have much meaning without also looking at the ratios obtained from countries unaffected by the tariff (the placebo studies). Comparing these ratios with those obtained by the US would provide us with a p-value.

Table B3. Ratio of post- to pre-treatment RMSPEs with different monthly lag specs.

Dependent Variable	Period*	No Lag	First Lag	Seas. Lag	First & S. Lag
Logged Export Value per Capita	US Pre-Tariff	0.23836	0.19924	0.20298	0.19917
	US Post-Tariff	0.26765	0.30455	0.30911	0.30151
	US Ratio**	**1.12291**	**1.52859**	**1.52289**	**1.51386**
	Countries with Ratio ≥ US	15/29	6/29	5/29	6/29
Logged Export Quantity per Capita	US Pre-Tariff	0.22948	0.16004	0.16304	0.16004
	US Post-Tariff	0.35667	0.20361	0.18330	0.20361
	US Ratio*	**1.55429**	**1.27221**	**1.12426**	**1.27221**
	Countries with Ratio ≥ US	3/29	13/29	19/29	13/29
Logged Export Price	US Pre-Tariff	0.14120	0.12383	0.12499	0.12383
	US Post-Tariff	0.13269	0.14933	0.15302	0.14933
	US Ratio*	**0.93975**	**1.20595**	**1.22430**	**1.20595**
	Countries with Ratio ≥ US	15/29	12/29	12/29	12/29

Using the monthly specifications with no interpolation or disaggregation. Rounded to five decimal places. * Pre-tariff is Jan 2010 to Oct 2019, post-tariff is Nov 2019 to Dec 2020; ** Larger ratios show larger differences between post- and pre-tariff fit, see equation (4).

Table B4. Ratio of post- to pre-treatment RMSPEs with different quarterly lag specs.

Dependent Variable	Period*	No Lag	First Lag	Seas. Lag	First & S. Lag
Logged Export Value per Capita	US Pre-Tariff	0.17703	0.11943	0.12009	0.11943
	US Post-Tariff	0.21071	0.28206	0.28489	0.28206
	US Ratio**	**1.19022**	**2.36168**	**2.37217**	**2.36168**
	Countries with Ratio ≥ US	13/29	2/29	2/29	2/29
Logged Export Quantity per Capita	US Pre-Tariff	0.14457	0.06657	0.06709	0.06656
	US Post-Tariff	0.31616	0.17758	0.17290	0.17787
	US Ratio*	**2.18689**	**2.66753**	**2.57719**	**2.67245**
	Countries with Ratio ≥ US	2/29	2/29	2/29	2/29
Logged Export Price	US Pre-Tariff	0.10643	0.09301	0.09453	0.09301
	US Post-Tariff	0.10326	0.12301	0.10881	0.12301
	US Ratio*	**0.97021**	**1.32256**	**1.15109**	**1.32256**
	Countries with Ratio ≥ US	16/29	10/29	14/29	10/29

Using the quarterly specifications with no interpolation. Rounded to five decimal places. * Pre-tariff is Q1 2010 to Q3 2019, post-tariff is Q4 2019 to Q4 2020; ** Larger ratios show larger differences between post- and pre-tariff fit, see equation (4).

Synthetic Control Predictor Values

The table below shows the average value of each variable for the particular weighted average of countries (synthetic control) for the pre-tariff period. Some of these values may be heavily skewed (for example, in the case of the exchange rate) due to certain countries being included in the weighted average. This is not necessarily a concern – only the difference in export value, quantity, or price is used in estimating the impact of tariff.

Table B5. Average synthetic control predictor values for the pre-tariff period

	Export Value, Quantity, or Price	**Local Private Final Consumption**	**UK Private Final Consumption**	**Population** [(b)]	**Interest Rate**	**GBP Exchange Rate**	**Avg. Alcohol Consumption 2010-18**	**Distance Between Capitals**
	See (a) for unit	£000's per capita	£000's per capita	Millions	%	Local currency / £	Litres per cap	km
Monthly average for the Jan 2010 – Oct 2019 pre-tariff period								
US								
Value	0.06	6.4	4.7	319.4	2.42	1.48	8.8	5.9
Quantity	0.001	6.4	4.7	319.4	2.42	1.48	8.8	5.9
Price	39.02	6.4	4.7	319.4	2.42	1.48	8.8	5.9
Synthetic control predictor averages								
Value	0.06	3.8	4.7	..	2.27	46.10	9.6	5.1
Quantity	0.001	4.1	4.7	..	2.10	137.34	8.9	6.7
Price	38.53	4.5	4.7	..	1.59	10.94	9.2	3.0
Synthetic control weights (excl. lagged dep. vars. and/or monthly dummy)								
Value	..	0.000	0.000	..	0.003	0.001	0.000	0.000
Quantity	..	0.000	0.000	..	0.001	0.000	0.000	0.000
Price	..	0.000	0.330	..	0.000	0.011	0.000	0.000

Quarterly average for the Q1 2010 – Q3 2019 pre-tariff period

US								
Value	0.17	6.4	4.7	319.3	2.42	1.48	8.8	5.9
Quantity	0.004	6.4	4.7	319.3	2.42	1.48	8.8	5.9
Price	39.17	6.4	4.7	319.3	2.42	1.48	8.8	5.9
Synthetic control predictor averages								
Value	0.17	3.5	4.7	..	2.53	45.57	9.9	4.9
Quantity	0.004	3.9	4.7	..	2.24	267.11	8.8	6.8
Price	38.69	4.7	4.7	..	2.18	21.99	9.8	5
Synthetic control weights (excl. lagged dep. vars. and/or monthly dummy)								
Value	..	0.000	0.000	..	0.000	0.000	0.000	0.000
Quantity	..	0.000	0.000	..	0.000	0.000	0.787	0.000
Price	..	0.004	0.000	..	0.000	0.033	0.000	0.000

(a) Export value is measured in £ per capita, export quantity is measured in litres of pure alcohol per capita, price is measured in £/LPA. (b) Population is not a predictor in itself – instead, it was used to convert export value or quantity and private final consumption into per-capita values. These variables were subsequently logged.

Annex C – Inference and Confidence Sets

Choice of Test Statistic

The ratio of post- to pre-tariff $RMSPE$ test statistic was used as opposed to the post-tariff $(R)MPE$ test statistic because the pre-treatment fit for nearly all the synthetic controls' placebo tests was poor.

Using the latter option for the p-value (Section 3.2.1.1) would likely lead to restricting the donor pool to single digits. This was deemed too restrictive, and so the second option was used instead (Section 3.2.1.2). This ratio RMSPE test statistic performs well, only surpassed by the t-test statistic in the Monte Carlo studies ran by Ferman, Pinto, and Possebom (2018).

In the case of the first-lag quarterly value specification, this leads to a p-value of 0.069 (Figure C1).

This effect varies over time when looking at the absolute post-treatment gaps (i.e., root squared prediction errors) on a quarter-to-quarter (or month-to-month) basis, compared to the pre-treatment RMSPE. Figure C2 shows the p-values obtained for each quarter using either method (here dubbed 'Method 1' and 'Method 2').

This shows that the 2020 Q4 period saw particularly large deviations from the synthetic control (due to the tariff or some other US-specific deviation compared to the synthetic control) using the ratio test statistic ('method 2').

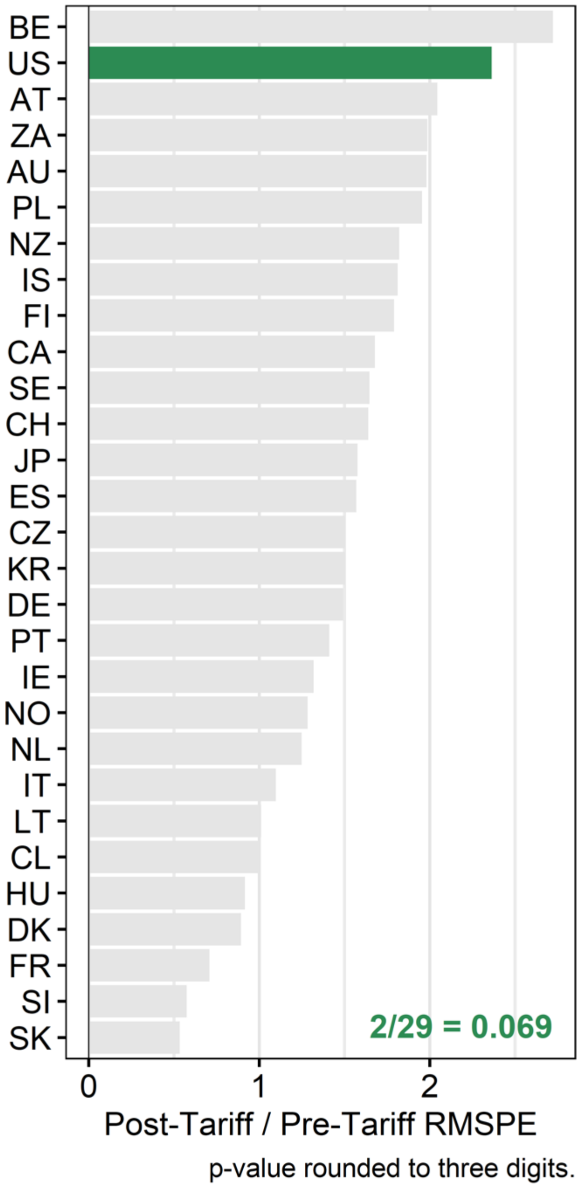


Figure C1. The ratio of post- to pre-tariff fit for the first-lagged quarterly value specification

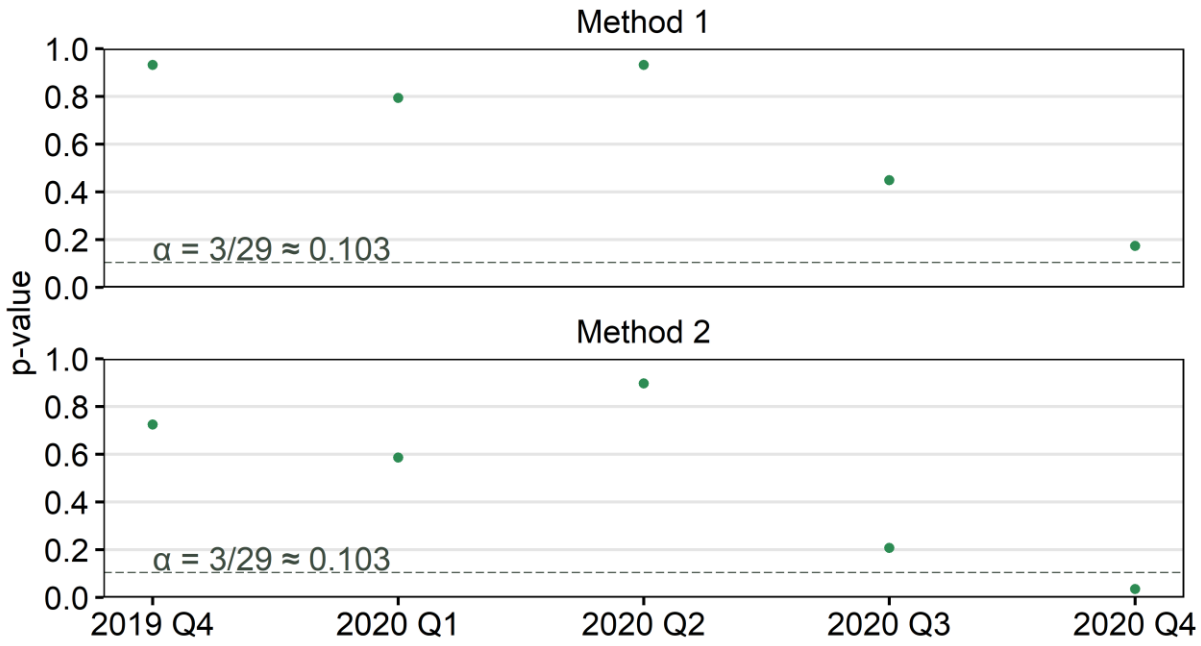


Figure C2. P-values obtained from the post-tariff RMSPE test statistic (upper) and ratio RMSPE test statistic (lower) by post-tariff quarter

Impact Estimates

The estimated tariff impact is given by the post-treatment gap (of averages) less the pre-treatment gap (of averages). Since the dependent variable is in logged per-capita terms, these averages are calculated as follows:

Pre-tariff:

$$\frac{1}{T_0}\sum_{t=1}^{T_0} log(Y_t^I) - log(Y_t^N) = \frac{1}{T_0}\sum_{t=1}^{T_0} log\left(\frac{Y_t^I}{Y_t^N}\right) = \frac{1}{T_0} log\left(\prod_{t=1}^{T_0}\frac{Y_t^I}{Y_t^N}\right)$$

Post-tariff:

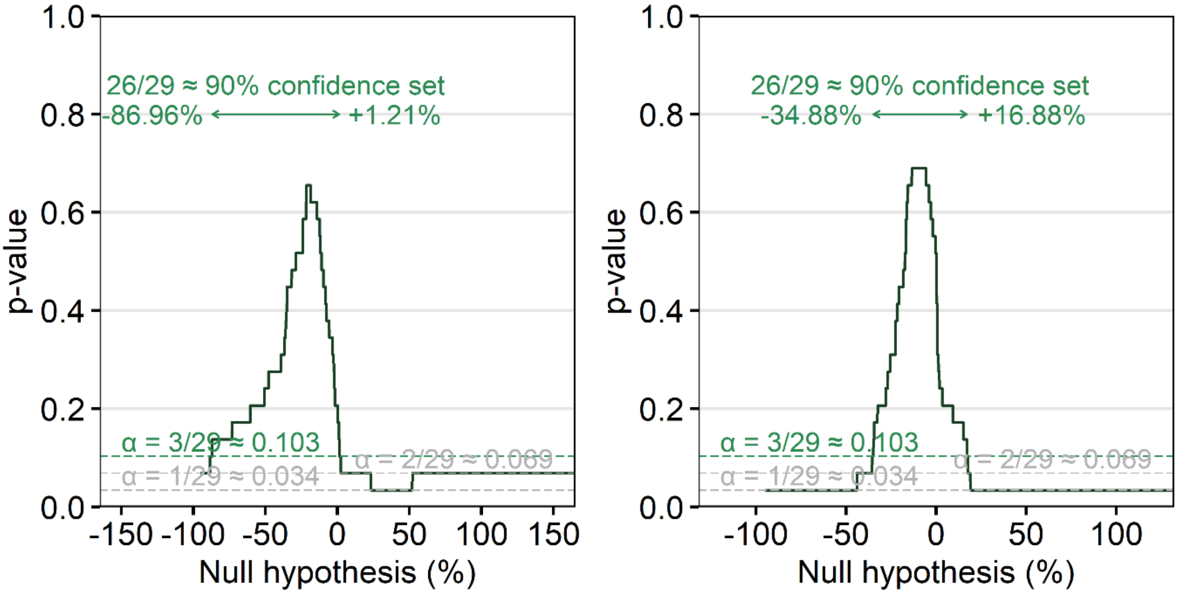
$$\frac{1}{T-T_0}\sum_{t=T_0+1}^{T} log(Y_t^I) - log(Y_t^N) = \frac{1}{T-T_0}\sum_{t=T_0+1}^{T} log\left(\frac{Y_t^I}{Y_t^N}\right) = \frac{1}{T-T_0} log\left(\prod_{t=T_0+1}^{T}\frac{Y_t^I}{Y_t^N}\right)$$

where Y_t^I is the observed export value, Y_t^N is the counterfactual export value (synthetic control), and $t = 1, \dots, T_0$ and $t = T_0 + 1, \dots, T$ refer to the pre-treatment and post-treatment periods.

Were we to calculate proportional differences using averages of the original per-capita values (or total values), we'd arrive at slightly different proportions. Since the above logged proportional differences are also used for hypothesis testing (by adding or subtracting c to the left-hand-side of the post-tariff equation above), the other proportional differences are not explored.

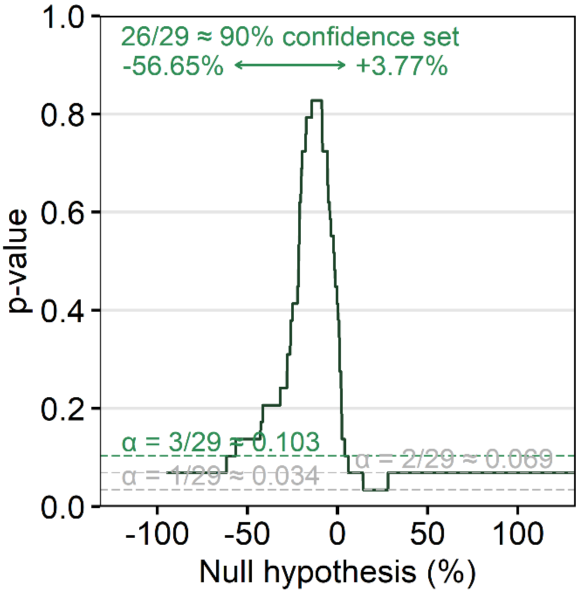
Confidence Sets

Two-sided confidence sets were constructed using the $RMSPE$ test statistic described in Section 3.2.2. Results for (a) value, (b) quantity, and (c) price are shown below (using a first-lag specification) for both the monthly and quarterly specifications.



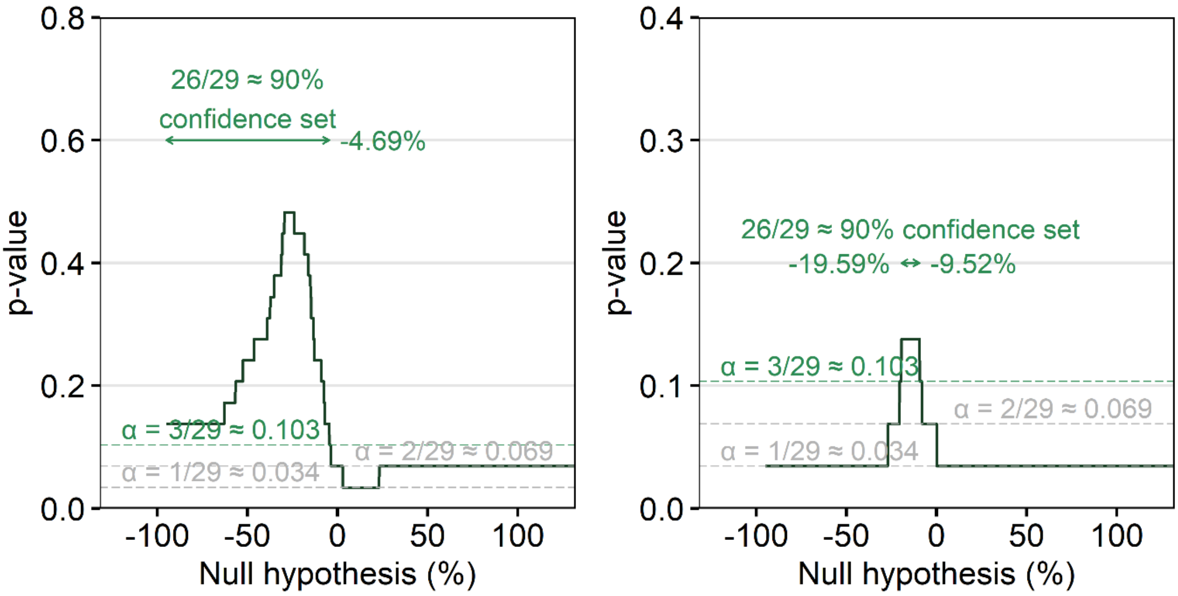
(a) Value

(b) Quantity



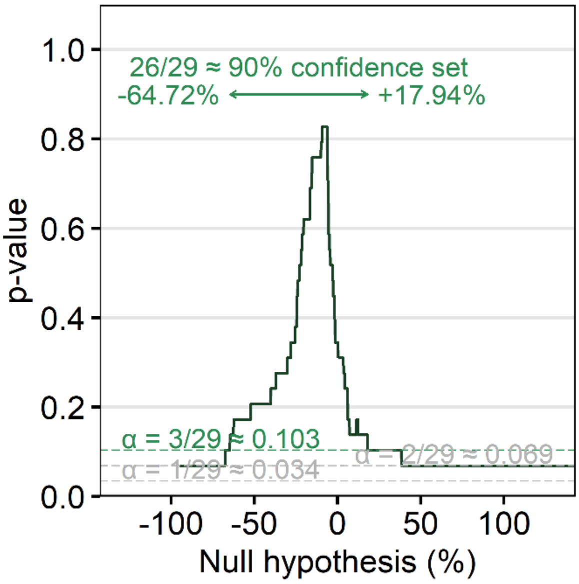
(c) Price

Figure C3. 26/29 confidence sets for the first-lagged monthly specifications with value, quantity, and price as dependent variables



(a) Value

(b) Quantity



(c) Price

Figure C4. 26/29 confidence sets for the first-lagged quarterly specifications with value, quantity, and price as dependent variables

Annex D – Final Results

Monthly Specifications

The table below shows results for all tested specifications without population interpolation or consumption disaggregation. Generally, results were similar whether this was done or not.[58]

Table D1. Final set of results for monthly specifications

Dependent variable*	**Lag**	**Estimated monthly tariff effect**		**p-value**	**26/29 confidence set (~90%)**	
		Unit(a)	Prop. %		Lower %	Upper %
Value	No lag	-0.01	-7.1	0.517	-87.9	+19.4
Value	**First lag**	**-0.02**	**-17.4**	**0.207**	**-87.0**	**+1.2**
Value	Seasonal lag	-0.02	-18.1	0.172	-88.8	+1.4
Value	First and seas. lag	-0.02	-17.2	0.207	-86.4	+1.5
Quantity	No lag	-0.40*	-16.5	0.103	-62.5	-0.8
Quantity	**First lag**	**-0.24**	**-10.7**	**0.448**	**-34.9**	**+16.9**
Quantity	Seasonal lag	-0.21	-11.4	0.655	-32.5	+26.6
Quantity	First and seas. lag	-0.24	-12.9	0.448	-34.8	+17.5
Price	No lag	-2.98	-6.2	0.517	-38.0	+29.6
Price	**First lag**	**-5.72**	**-11.9**	**0.414**	**-56.6**	**+3.8**
Price	Seasonal lag	-5.88	-12.2	0.414	-57.5	+3.8
Price	First and seas. lag	-5.72	-11.9	0.414	-56.7	+4.0

Without population interpolation or consumption disaggregation (results for these specifications were similar if not identical). Key: (a) Logged value (£/cap), quantity (millilitres of pure alcohol / cap) and price (£/LPA); *** p < 2/29; ** p < 3/29; * p < 4/29.

Quarterly Specifications

The same synthetic control method was applied on a quarterly trade series, with the tariff assumed to be introduced in Q4 2019. Using a quarterly series may limit the effects of seasonality and would more closely align with the quarterly consumption series. The monthly interest rate and exchange rates were averaged over the quarter, while trade value/quantity was summed. Quarterly population interpolation was also explored but not found to have a major impact.

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[58] Interpolation of annual population estimates did slightly increase the impact estimate across the board, e.g., a larger negative tariff impact on value, but only by c.a. 0.4% (this also resulted in the lower bound of the 90% confidence set being roughly 1% lower).

While the quarterly series may limit seasonality, it would also reduce the power of any hypothesis test by reducing the number of observations. The total number of observations for each country decreases from 132 months to 44 quarters, with only 5 post-tariff observations (2019 Q4 to 2020 Q4).

Although the estimated quarterly effect of the tariff on the export value and quantity appears to be strictly negative at a 10% significance level, the lower bound for the value confidence set is still somewhat non-informative at [-100.0%, -4.7%].

Table D2. Final set of results for quarterly specifications

Dependent variable	**Lag**	**Estimated quarterly tariff effect**		**p-value**	**26/29 confidence set (~90%)**	
		Unit(a)	Prop. %		Lower %	Upper %
Value	No lag	-0.03	-8.5	0.448	-100.0	(a)
Value	**First lag**	**-0.06****	**-18.3**	**0.069**	**-100.0**	**-4.7**
Value	Seasonal lag	-0.06**	-18.9	0.069	-100.0	-5.2
Value	First and seas. lag	-0.06**	-18.3	0.069	-100.0	-4.7
Quantity	No lag	-1.38**	-20.2	0.069	-69.4	-4.6
Quantity	**First lag**	**-0.64****	**-10.3**	**0.069**	**-19.6**	**-9.5**
Quantity	Seasonal lag	-0.57**	-9.0	0.069	(b)	(b)
Quantity	First and seas. lag	-0.64***	-10.2	0.034	-19.2	-9.8
Price	No lag	-3.89	-8.3	0.552	-49.7	+32.8
Price	**First lag**	**-4.86**	**-10.2**	**0.345**	**-64.7**	**+17.9**
Price	Seasonal lag	-4.27	-9.1	0.483	-62.5	+25.5
Price	First and seas. lag	-4.86	-10.2	0.345	-64.7	+17.9

Without population interpolation (results for these specifications were similar if not identical). Key: (a) Logged value (£/cap), quantity (millilitres of pure alcohol / cap) and price (£/LPA); (b) no lower/upper bound was found due to lower power; *** p < 2/29; ** p < 3/29; * p < 4/29.

Table D3. Comparison between different first-lag frequency specifications

Frequency	Dependent variable	Estimated monthly or quarterly tariff effect		p-value	26/29 confidence set (~90%)	
		Unit[(a)]	Prop. %		Lower %	Upper %
Quarterly	Value	-0.06**	-18.3	0.069	-100.0	-4.7
Monthly	Value	-0.02	-17.4	0.207	-87.0	+1.2
Quarterly	Quantity	-0.64**	-10.3	0.069	-19.6	-9.5
Monthly	Quantity	-0.24	-10.7	0.448	-34.9	+16.9
Quarterly	Price	-4.86	-10.2	0.345	-64.7	+17.9
Monthly	Price	-5.72	-11.9	0.414	-56.6	+3.8

Without population interpolation or consumption disaggregation. Key: (a) Logged value (£/cap), quantity (millilitres of pure alcohol / cap) and price (£/LPA); ** p < 3/29.

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