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From global economy-wide modelling to modelling a small product market: The case of wine

Kym Anderson

and

Glyn Wittwer

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Contact details:
Wine Economics Research Centre
School of Economics
University of Adelaide
SA 5005 AUSTRALIA
Email: wine-econ@adelaide.edu.au

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From global economy-wide modelling to modelling a small product market: The case of wine

Kym Anderson

University of Adelaide and Australian National University

kym.anderson@adelaide.edu.au

and

Glyn Wittwer

Victoria University, Melbourne

Glyn.Wittwer@vu.edu.au

October 2018 (revision)

Revision of a chapter for a Festschrift in honor of Tom Hertel.

Abstract

Under Tom Hertel's guidance, GTAP's myriad contributions in providing databases and models for economy-wide analysis of the world's markets have been enormous, and deservedly well recognized. Less appreciated by the policy community and many economists has been the additional contribution GTAP has made to improving the modelling of global markets for individual product markets. The smaller the national and global markets for a particular product, the less sense it makes to model them as part of the overall economy. But several of the features of CGE models nonetheless can be incorporated usefully into global product market models. This paper reports on one such attempt, namely to model the world's winegrape and wine markets. Building on a prototype first reported by Wittwer, Berger and Anderson (2003), a much-improved model was developed by Anderson and Wittwer (2013) and has now been further revised with its database updated to 2014 and projected to 2025. Both the model and the new database are described and, to illustrate the model's usefulness, we compare the 2025 baseline with alternative scenarios chosen to illustrate the empirical importance of possible additional shocks to those markets. One is a more-than-expected strengthening of the US dollar. Another is a set of possible Brexit scenarios, bearing in mind that the UK has been one of the world's biggest wine-importing countries. We conclude the paper by mentioning fruitful areas for further work such as expanding the model to include other beverages and analysing possible increases in beverage taxes as health lobby groups in many countries strengthen their anti-alcohol and anti-sugar drives.

Author contact:

Kym Anderson
School of Economics
University of Adelaide
Adelaide, SA 5005 Australia

Phone +61 8 8313 4712
kym.anderson@adelaide.edu.au

From global economy-wide modelling to modelling a small product market: The case of wine

GTAP's myriad contributions in providing databases and models for economy-wide analysis of the world's markets has been enormous, and deservedly well recognized. Less appreciated by the policy community and many economists has been its additional contribution in improving the modelling of global markets for individual product markets. The smaller the national and global markets for a particular product, the less sense it makes to model them as part of the overall economy. But several of the features of CGE models nonetheless can be incorporated usefully into global product markets.

This chapter reports on one such attempt, involving a model the world's winegrape and wine markets. Building on a prototype first published in 2003, we developed a much-improved model in 2013 that has since been further revised with its database updated to 2014 and is ready for projecting a decade or so forward.

Both the model and the new database are described in the next section. The following section explains how we project the model to 2025. We then report the results of two sets of alternative scenarios chosen to illustrate the empirical importance of possible additional shocks to those markets. First, we compare the 2025 baseline with a more-than-expected strengthening of the US dollar. Then we examine possible Brexit scenarios, bearing in mind that the UK has been one of the world's biggest wine-importing countries. We conclude the paper by mentioning fruitful areas for further work such as expanding the model to include other beverages and analysing possible increases in beverage taxes as health lobby groups in many countries strengthen their anti-alcohol and anti-sugar drives.

The model and database

Our model of the world's wine markets, first published by Wittwer, Berger and Anderson (2003) and revised by Anderson and Wittwer (2013), is summarized in the Appendix. It disaggregates wine markets into four types, namely non-premium, commercial-premium and super-premium still wines, and sparkling wine.[1] There are two types of grapes, premium and non-premium. Non-premium wine uses non-premium grapes exclusively, super-premium wines use premium grapes exclusively, and commercial-premium and sparkling wines use both types of grapes to varying extents across countries. Wine is also differentiated into red and white. The world is divided into 44 individual nations and 7 composite geographic regions that capture all other countries.

A recent enhancement has been the inclusion of bilateral exchange rates. This enables modelling of the impacts of real exchange rate movements in the partial equilibrium framework. Such movements were important in the 1980s and 1990s as some New World producers expanded their export bases. We have used this feature to model the ground lost by some producers, notably Australia, due to the real exchange rate impacts of the global mining boom which impacted particularly strongly in Australia for nearly a decade from 2005 (Anderson and Wittwer 2013).

This global model has supply and demand equations based on the original ORANI model's theory (see Dixon et al. 1982) and hence quantities and prices and price elasticities for each of the grape and wine products and for a single composite of all other products in each country. There are also income elasticities of demand for each final product. Grapes are assumed to be not traded internationally, but wine and other products are both exported and

[1] Commercial-premium still wines are defined by Anderson, Nelgen and Pinilla (2017) to be those between US$2.50 and $7.50 per litre pre-tax at a country's border or wholesale.

imported. Wine trade follows the Armington (1969) assumption, as used in the ORANI and GTAP models. Margins are used as in the ORANI school of CGE models to distinguish between prices by type of sale. They are important because retail mark-ups are a large proportion of the total value of a wine, particularly in the case of on-premise consumption. Another margin relates to transport costs. Each market is assumed to have cleared before any shock, and to find a new market-clearing outcome following any exogenously introduced shock.

The model's database is calibrated to 2014, based on the comprehensive wine market volume and value data and trade and excise tax data provided in Anderson and Pinilla (2017) and Anderson, Nelgen and Pinilla (2017). It is projected forward assuming aggregate national consumption, population, and real exchange rates change between 2014 and 2025 to the extent shown in Appendix Table 1, as projected by Anderson and Strutt (2016) using the GTAP model and database.[2] The alternatives to that baseline that are explored below also are projected to 2025.

Projecting Global Wine Markets to 2025

Global wine production and exports are projected in the baseline from 2014 to 2025 consistent with past trends. In our baseline scenario both grape and wine industry total factor productivity is assumed to grow at 1% per year everywhere, while grape and wine industry capital is assumed to grow net of depreciation at 1.5% per year in China but zero elsewhere. Concerning preferences, there is assumed to continue to be a considerable swing towards all wine types in China and a swing away from non-premium wines in all other countries

[2] The real exchange rate changes over the projection period are the changes expected in the nominal value of country i's currency relative to the US dollar times the expected ratio of the GDP deflator for the US versus that for country i.

through to 2025. With these assumptions, the model's global volumes of production and consumption rise little over that 11-year period (9%), made up of a 6% decline in non-premium wine and a one-sixth rise in commercial and super-premium wine. In real (2014 US$) value though, global wine output and consumption increase by about 50% in total and 60% in the two premium categories. The international trade projections are similar although a little larger, with the share of global wine production exported (= share of global consumption imported) rising two percentage points between 2014 and 2025.

The baseline projection does not alter greatly the 2014 shares of various countries in global wine production, apart from China because we assume vineyard expansion is faster there than elsewhere. In value terms that means China moves from 5th to 4th by 2025 behind France, the US and Italy. Spain remains barely ahead of Australia and they with Germany take the next three places (Figure 1(a)). In total wine production volume terms, China moves from 6th to 5th place, and Argentina drops from 5th to 8th (and from 8th to 9th in value terms).

When sub-divided into fine wine (super-premium still plus sparking), commercial premium wine and non-premium wine, France and the US retain the highest two places on the global ladder for fine wine production, and Spain and Italy retain the top two places for non-premium wine. As for commercial premium wine production (defined to be those between US$2.50 and $7.50 per litre pre-tax at a country's wholesale level or national border), Italy retains the top ranking over our projections period but, at least in terms of value, China challenges France for the 2nd place.

The country rankings by projected value of total wine consumption change somewhat more than those for production by 2025, with China taking second place after the US ahead of France and Germany, and then the UK slightly overtaking Italy to slip into fifth place (Figure 1(b)). The US, France and Germany retain the top three rankings for consuming fine wine, but Canada slightly overtakes Italy for 4th place, in terms of value at least. In the case of

commercial wine consumption, China strengthens its number one position ahead of the US and the UK does likewise vis-à-vis Germany for 3rd place.

As for the projected changes in consumption volumes, China is projected to dominate the increase in aggregate, although the US is projected to lead the increase in consumption of fine wine. In Western Europe and the Southern Hemisphere's New World countries, fine wines are projected to substitute for commercial wines (defined as the sum of commercial premium and non-premium wines) with almost no change in total wine consumption. Sub-Saharan Africa is the next region that is projected to take off, with its growth accounting for more than one-third of the rest of the world's increase in volumes consumed.

Those differences in production versus consumption rankings are reflected in international trade. Figure 2 shows that France, Italy and Spain remain the three dominant exporters of wine in aggregate value, but that the rankings of the next few change to Australia being slightly ahead of Chile, and then the US, Germany and New Zealand being almost equal 6th place in value terms. France and then Italy are even more dominant in fine wine exports, and remain so by 2025, while Italy outranks France in the commercial premium export category, and Spain outranks Italy, Australia and then Chile in the non-premium export class.

Among the importers the US and UK are projected to continue to hold the first two places in 2025 in value terms, but China moves into third place slightly ahead of Germany, followed well behind by Canada, Hong Kong, Belgium-Luxembourg, Netherlands and Japan (Figure 2b)). Other Africa (excluding South Africa) is projected to experience the largest increase in imports of all the other regions, followed by Other Asia which becomes as big as Germany in value terms (Figure 3(a)). In terms of total volume of wine imports, Germany and the UK held the top two shares in 2014 but by 2025 the UK is projected to be well ahead of Germany in our baseline projection (Figure 3(b)).

Given this baseline, we now illustrate the model's usefulness by considering alternative scenarios to 2025. One relates to exchange rates: how do these markets alter if the Euro's real exchange rate (RER) is 10% stronger in 2025 than we've assumed in the baseline? The other relates to the UK's exit from the European Union and various trade agreements it might enter into between now and 2025. Consider these in turn.

Alternative scenarios: a 10% appreciation of the Euro

The baseline projection assumes the Euro devalues in real terms by just under 10% against the US dollar and UK Pound between 2014 and 2025 (Appendix Table A1). How much different would the wine market projections to 2025 look if that did not happen? That is, what would be the impact of shocking that baseline with a 10% appreciation of the Euro against the US dollar? The estimated impact of that shock is just as theory would lead us to expect: the Euro prices of wines in the Eurozone go down and prices in other countries go up in local currency terms; quantities produced go down and quantities consumed go up in the Eurozone, and the opposite changes occur in the rest of the world. Since the former are net exporters and the latter (including the UK) are net importers, international trade in wine shrinks. In 2025 global wine trade would be less by almost 100 ML or just over US$1 billion, with a decline of Eurozone exports of $1.56 billion. However, within the rest of the world there would be a gain in New World wine exports of $425 million.

The 10% Euro appreciation would cause producer prices in the Eurozone to be 3-5% lower in our four different wine quality categories (and the quantity produced would be 1% lower), and consumer prices there to be 2-4% lower (and quantities consumed 1-3% higher). In the rest of the world, by contrast, producer prices would be 2-4% higher (and the quantity produced 0.5-1% higher) while consumer prices there would be 1-2% higher (and quantities

consumed 1-2% lower). Global production and consumption would change very little, by just -0.2%.

The largest effect of such a currency change would be a decline in the wine self-sufficiency ratio (production divided by consumption) of the Eurozone countries and an increase in that ratio in countries in the rest of the world. That change is estimated to be less than 5 percentage points for both groups of countries in this simulation.

However, these results beg the question as to *why* this real currency appreciation occurred. If it was because of macro or sectoral or trade policy reforms that boosted economic growth in Eurozone countries, there would be a change in real household incomes in those countries, and some spillover effects on incomes and real exchange rates in the rest of the world. In principle, the macro effects of such policy reform could be simulated using the economywide GTAP model to generate new income and exchange rates for all countries (as was done to provide the initial projections for the baseline in 2025 in our global wine model by drawing on Anderson and Strutt 2016), and those could then have also been included in the present simulation experiment. That would have further boosted domestic wine consumption in the Eurozone and hence raised wine prices globally (as that region accounts for more than two-fifths of global wine consumption), and so added to the decline in the Eurozone's wine self-sufficiency, and further increased that ratio for the rest of the world.

Alternative scenarios: How might wine markets be affected by the UK exiting the EU?

The UK's planned withdrawal from the European Union (Brexit), following a referendum on 23 June 2016 and a general election on 8 June 2017, will affect markets for many products, including wine. True, very little wine is produced in the UK (although the volume is now five times what it was in the 1980s), and wine has accounted on average for just 0.5% of UK

merchandise imports since World War I. Over the past six decades, though, wine's share of UK alcohol consumption has steadily risen from 5% to more than one-third, so wine traders, distributors and retailers as well as wine consumers are concerned about Brexit's potential impact on them. To wine producers and consumers *outside* the UK, Brexit is attracting considerable attention too, because the UK has always accounted for a major share of the world's wine imports.

To examine how wine markets might be affected by an exit of the UK from the EU, it is necessary to look beyond just the immediate trade-reducing and trade-diverting effects of altering bilateral import tariffs that are the focus of the standard comparative static economic theory of (withdrawal from a) customs unions. Since the process of exiting, establishing new trading arrangements and adjusting to the altered incentives is expected to spread over many years, and initially to slow the growth of UK incomes and devalue the pound, one needs to compare the projection of how wine markets would have looked in several years without Brexit with projections of how it would look under various Brexit scenarios and then a replacement trade agreement between the UK and EU27.[3] We assume these are two discrete steps with no agreed arrangements to smooth the transition between them.

Two alternative scenarios are considered ('large' and 'small') for the initial impact of Brexit, to provide a range of results. We assume that, because of the UK's decision to exit the EU, the rate of UK real GDP growth is only one-third or two-thirds as fast over the projection period (0.9% or 1.8% per year instead of 2.6%), and the UK pound will be 20% or 10% lower

[3] As of mid-2017 and even in late 2018 it was not certain that the UK would leave the Single Market or alternatively form a UK-EU27 customs union, but both would require the UK to retain the EU's tariff policy and the former would require the UK also to continue to allow freedom of movement of labour and to remain under the European Court of Justice, none of which Brexiteers want. We therefore ignore these two possibilities and, following Rollo et al. (2016) and Smith (2017), assume that the UK will commit to the current EU tariff schedule at the WTO in the first instance and then seek a free trade agreement (FTA) with the EU27. Presumably other trading partners would want to wait and see what that FTA looked like before signing on to a bilateral FTA of their own with the UK. Deep FTAs normally take several years to negotiate and get ratified by the relevant parliaments, even when a sufficient number of experienced negotiators are on each side of the table. A new and expanded set of FTA options are explored in Anderson and Wittwer (2018).

in real terms than in our model's core baseline projection.[4] In both alternative scenarios it is assumed the UK applies the EU's external tariffs on wine from 30 March 2019, at the end of the 2-year period following the UK's formal triggering of Article 5.

We then consider a subsequent impact of Brexit, presumed to result from the negotiating, signing, implementing and responding to, by 2025, of a free trade agreement (FTA) with the EU27. (Chile and South Africa both currently have preferential access to EU wine markets, but we continue to assume in this scenario that the UK does not implement new bilateral FTAs with them or others in our time frame).[5] This subsequent scenario assumes the pound returns to what it would have been in 2025 in the absence of Brexit, and that real UK incomes return two-thirds of the way back to what they would have been without Brexit as compared with our 'small' initial Brexit scenario.

A. Initial impact of Brexit

Since the pound dropped by one-sixth against the US dollar in the four months following the Brexit vote in June 2016 and the UK's average real wage fell 1% between November 2016 and April 2017 (latest available data, from ONS 2017), we assumed our 'large' scenario was considered more likely soon after the Brexit vote. But we compare those results with ones from our 'small' initial impact scenario, since it has become more likely following the June 2017 general election as 'softer' options are now being considered by the new Government.

[4] The nominal US$ price of the pound in the fortnight following the Brexit vote on 23 June 2016 dropped 13% to US$1.30, and a year later the pound sat at the same rate, having dropped to an average of $1.24 (an 18% devaluation) during Oct 2016 and April 2017. Our choice of a low of 10% and a high of 20% aims to capture future possible rates while uncertainties remain. The average real wage in the UK fell in the first half of 2017, and projected real GDP growth during 2018-20 has been revised down to 1.7% in the UK's latest Budget (HM Treasury 2017).

[5] South Africa currently has duty-free access to the EU28 for just 50 ML of wine per year, beyond which the MFN tariff rate applies. South Africa currently exports around 320 ML to the EU, one-third of which initially goes to the UK. How that quota of 50 ML is divided between the UK and EU27 is subject to future negotiation (Rollo et al. 2016; Swinbank 2017). In what follows we assume none of it is accepted by the UK so that all South African wine imports pay the UK's MFN tariff under Brexit.

Generally the results are about half as big in the 'small' scenario, with the exception of the bilateral trade effects. To show the sensitivity of results to our assumptions, we point out the differences when the 'small' results are not close to half the results shown for the 'large' scenario.

Before turning to those results, we first present a 'free trade' scenario, which assumes the UK chooses the radical option of becoming the Hong Kong of Europe. Unlikely though this scenario is, the results provide assurance that our global wine model generates the standard types of effects of exiting a customs union. In this 'free trade' scenario, the UK is assumed to move to zero tariffs on all wine imports. Thus the current preferences on EU, Chilean and South African wine imports disappear as all other wine exporters enjoy the same free access to UK wine markets. We assume in this scenario that Brexit has no impact on the UK's real income or consumption growth rates by 2025, and that by then the pound has returned to its 2014 value relative to other currencies (similar to the real exchange rate assumed in our baseline scenario to 2025, see Appendix Table A1).[6] Under these assumptions, EU/Chile/South African wine exports to the UK in 2025 are 0.03% less than in the no-Brexit baseline, UK imports from other wine exporters are 0.25% larger, but the UK's total imports of wine are hardly any different (since local wine prices have fallen by only 0.5% and incomes are unchanged). In this scenario UK consumers expand their volume of consumption by just 0.5%, while the EU27 exports more and other countries export less to the rest of the world such that world wine exports are almost unchanged. In short, all these effects are in the direction that comparative static customs union theory would predict, but they are small because we assumed the UK's real income and currency would be the same as in our baseline for 2025 described in the previous section.

[6] If this was seen as a credible long-run trade policy, it would encourage more investment that would eventually raise UK incomes, but not without major structural changes that would initially disrupt the economy. Implicitly we are assuming in our free trade scenario that these two opposite impacts on real incomes and the pound offset each other by 2025.

In the ‘large’ alternative initial scenario involving Brexit, as compared with the baseline scenario to 2025, the consumer price of wine in 2025 would be 22% higher in the UK in local currency terms (20% because of real depreciation of the pound, 4% because of the new tariffs on EU, Chilean and South African wines, and -2% because of slower UK income growth). The volume of UK wine consumption would be 28% lower: 16% because of slower UK economic growth, 7% because of real depreciation of the pound, and 5% because of the new tariffs. Super-premium still wine sales would be the most affected, dropping by two-fifths, while sparkling and commercial wines would drop a bit less than one-quarter. Since the average price rises by more than the fall in the volume sold, the aggregate value of UK sales even in local currency terms would fall under this ‘large’ Brexit scenario. Under the ‘small’ Brexit scenario, the consumer price of wine in 2025 would be 11% higher in the UK and its volume of wine consumption would be 17% lower.

The volume of projected UK imports in 2025 is 427 million litres (ML) or nearly one-quarter lower in the ‘large’ scenario than in the baseline scenario, comprising 58 ML less sparkling, 31 ML less super-premium still wine, and 339 ML less commercial wine. World imports would be lower by just 239 ML because imports by other countries would be 189 ML higher in response to the international prices of wines being lower in this scenario. In value terms UK imports are $1.75 billion (or 27%) lower in 2025 because of ‘large’ Brexit: $1.13 billion because of lower incomes, $0.38 billion because of the fall in the pound, and $0.14 billion because of the rise in wine import tariffs (Table 3). These aggregate trade impacts are a little more than half as large under the ‘small’ Brexit scenario.

Despite the levels of imports falling because of raised import tariffs, domestic consumption of all three quality categories of UK-produced wine is lower with than without Brexit, because of the shrunken demand for all wines resulting from the lowered UK incomes and their raised local price because of the devaluation of the pound. The pound’s devaluation

does make it easier for the UK to sell wines abroad though: their exports are 7 ML or nearly 5% higher in 2025 in the 'large' Brexit scenario, and UK production is 3% higher. Those UK exports (or re-exports of imported bulk wine after it is bottled in the UK) that go to EU27 countries are reduced though because of the tariff now imposed at the new EU border.

Without Brexit, the UK's shares of global wine imports would have been slightly higher in volume terms in 2025 than in 2010-15, but 2 percentage points lower in value terms thanks to East Asia's expanding demand for imports of premium wines. With 'large' Brexit, however, that value share would be a further 2 percentage points lower, and the volume share would be almost 5 points lower. The net effect of these impacts on global trade are shown in Figure 4: most of the initial trade effect of Brexit is a large decline in net imports of wine by the UK with very little offsetting positive effect on trade in the rest of the world. The 'small' Brexit numbers are a bit more than half these for 'large' Brexit.

The aggregate effect of 'large' Brexit on the market shares of various wine-exporting countries in the UK is almost indiscernible even with one decimal point. The projected 2025 shares are quite different from the actual 2014 shares for several countries. They are much smaller in 2025 for South Africa, Australia and New Zealand (and the US in volume terms), and are much larger in volume for Spain and in value for Italy. This is because wine-exporting countries benefit differentially from the varying rates of growth in net import demand for wine in non-UK countries over this projection period. The most important projected changes are the increase in the real value of annual wine imports between 2014 and 2025 by China (200% or $3 billion), Other Asia (110% or $2.2 billion) and Africa (270% or $1.6 billion). More than half of Australia's increase in annual exports from 2014 to 2025 go to Asia, and more than half of South Africa's increase in exports go to other Africa.

Table 3 reveals that European, Chilean and South African wine exports are lowered by 'large' Brexit, by 150 ML or US$1.2 billion in the case of the EU, with some of their

exports diverted from the UK to EU27 and other markets in competition with New World exporters. While the US, Australia and Argentina sell only a little less into the UK, they sell less also to other countries. For Chile and South Africa, who lose their preferential access to UK (but not to EU27) markets in this Brexit scenario, some of their exports are re-directed from the UK to EU27 countries but again they export less overall. Global wine trade in 2025 would be less under this 'large' Brexit scenario by 240 ML (1.9%) or $1.8 billion (3.5%). The percentage by which wine exporters' trade shrinks is greater for values than for volumes because of changes in relative prices of different-quality wines. Those differences are shown in the numbers in parentheses in Table 3.

Three other points are worth making about Table 3. One is that Australia sells slightly more to the UK in the 'small' Brexit scenario, rather than slightly less as in the 'large' Brexit case. Evidently the negative income and price (devaluation) effects in the 'large' scenario do not more than offset the positive trade-diverting effect on Australian exports to the UK of removing preferences in the 'small' scenario. Second, New Zealand sells slightly more to non-UK countries under Brexit, despite greater competition from EU27, Chile and South Africa. This anomaly is due to changes in the relative prices of different qualities of wine in global wine markets, bearing in mind that New Zealand has the world's highest average price for still wine exports. And third, the value (but not the volume) of exports of 'Other' countries to markets other than the UK is higher under Brexit. This too is due to changes in the relative prices of different qualities of wine in global wine markets.

B. Subsequent impact of Brexit from a UK-EU27 FTA

The next most-likely step in the Brexit process is for the UK to negotiate a new trade arrangement with the EU27. We therefore assume that a UK-EU27 FTA with free bilateral

wine trade is implemented and adjusted to by 2025, and that progress toward that end occurs soon enough that the adverse macroeconomic shocks from the initial impact of uncertainty over the Brexit process are confined to those assumed in our 'small' scenario outlined above. In this subsequent scenario we assume the pound returns to what it would have been in 2025 in the absence of Brexit (i.e., reversing the 10% devaluation assumed in our 'small' initial Brexit scenario), and that real incomes in the UK return two-thirds of the way back to what they would have been without Brexit-related uncertainty (and so are 8% higher in 2025 than in our 'small' scenario).

This subsequent development in the Brexit process would reverse most of the initial effects of Brexit by 2025, but not fully because of our assumption that the lost growth in the initial years of uncertainty following the Brexit vote are only partly recovered by 2025 following the implementation of a UK-EU27 FTA. Moreover, the longer it takes before this FTA is finalized and implemented, the longer will the estimated initial adverse effects persist and so the larger will be the cumulative cost of Brexit to UK wine consumers and to grape and wine producers in wine-exporting countries.

Table 4 summarizes the subsequent trade effects for 2025. It suggests that all but one-tenth of the loss in value of world trade in wine from the initial 'small' impact would be restored, most of it because of a smaller reduction in the UK's wine imports following the FTA. Most of that improved outcome is because of recovered imports from EU27, commensurate with the latter's high share of UK imports. Even though Chile and South Africa are assumed in this scenario to have not yet signed an FTA with the UK, they export slightly more to the UK (and even more to all other countries) than in the initial 'small' scenario.

Within the UK, this FTA would bring down the local currency consumer price of wine by 9%, largely offsetting the 11% rise in the initial 'small' Brexit scenario; and it would

raise the volume consumed in the UK by 18%, fully offsetting the 17% fall in the initial 'small' Brexit scenario.

In short, this subsequent step in the Brexit process can be expected to restore much of the initial adverse effects in the UK of the Brexit vote by 2025. For the wine exporters in the EU27, Chile and South Africa, they too lose less in this as compared with the initial 'small' scenario, while other key exporters sell nearly as much in 2025 in this scenario as they were projected to in the baseline. That is, they are beneficiaries of the reduced discrimination in global wine markets in this case where Chile and South Africa no longer enjoy preferential access to the UK market (and even though EU27 producers would again be allowed to do so). Keep in mind, though, that while the estimated losses in the initial scenarios are reported just for 2025, they are expected to be felt throughout the preceding years of uncertainty. Hence the longer it is before the uncertainty abates and the UK's current preferential trading arrangements are replaced by new ones such as a UK-EU27 FTA, the higher will be the cumulative cost of the Brexit vote to the wine trade.

Caveats and Conclusions

The above Euro exchange rate shock and Brexit simulations are just a few of many scenarios that could be modelled. Obvious additional ones relating to Brexit could also assume FTAs are reached between the UK and other trading partners including Chile and South Africa, and also countries such as Australia and New Zealand. Some of those other countries are already exploring the European Commission's invitation (see EC 2015) to negotiate an FTA with what will be the EU27. The sequence in which FTAs are signed and the speed with which they are implemented will matter (as was also the case with the sequential signing over the

past decade of bilateral FTAs with Northeast Asian countries by Chile, Australia and New Zealand, see Anderson and Wittwer 2015). Even if the UK were able to sign additional bilateral FTAs and begin implementing them before 2025, it would make very little difference to the above results (since wine tariffs are a very minor contributor to them) unless those FTAs were to accelerate UK economic growth and the rise in the value of the pound before 2025.

Clearly there will be great uncertainly for some time yet over the possible policy outcomes to flow from Brexit, and of their consequent sequential impacts on UK household disposable incomes, foreign exchange rates, and bilateral wine tariffs. Meanwhile, the above projections under explicit assumptions provide some idea of how wine markets might be affected by the most-likely first two stages of the Brexit process (agreeing on a new tariff schedule at the WTO, and agreeing to and implementing a UK-EU27 FTA). In particular, they make clear that there could be non-trivial initial impacts on the domestic wine market, effects that are likely to be larger than just the direct impact of changes in bilateral tariffs. If the UK were to be successful in getting agreement to transition arrangements that delayed the changes in tariffs until new FTAs were agreed and ratified, the initial effects would be less dramatic than in our first scenarios, but it remains to be seen whether any such agreements can be reached. In any event, the net effect of Brexit on the welfare of the world's consumers and producers of wine as a whole will be negative not just initially but permanently unless new trade policy commitments by the UK with major wine-exporting countries are sufficiently more liberal than current arrangements.

A fruitful area for further work would be to broaden the world wine model to include not only other alcoholic drinks but also soft drinks, global expenditure on which is similar in retail value to expenditure on alcoholic beverages. The inclusion of carbonated category of soft drinks could be particularly useful because many health lobbies are calling not only for

higher taxes on alcoholic beverages but also for taxes on the sugar content of non-alcoholic beverages, the effects of which could be estimated with such an extended model.

Appendix: Key equations in the Global Wine Markets Model

A model of the world's wine markets was first published by Wittwer, Berger and Anderson (2003) and much improved by Anderson and Wittwer (2013). Several significant enhancements have been to that original model. Wine types have been disaggregated into more types, namely non-premium (including generic bulk), commercial-premium and super-premium still wines, and sparkling wine.[7] As in the original model, there are two types of grapes, premium and non-premium. Non-premium wine uses non-premium grapes exclusively, super-premium wines use mainly premium grapes, and commercial-premium and sparkling wines use both types of grapes. In the regional dimension, the number of countries and country groups has expanded from ten in the original model to 51 now: 44 individual nations and 7 composite regions. The model's database is calibrated to 2014 for this paper, based on data in Anderson, Nelgen and Pinilla (2017), trade data for which are downloaded from https://comtrade.un.org/. The model is implemented using GEMPACK software (Harrison et al. 2014).

An enhancement of importance to the present study is the inclusion of exchange rate variables in the model. This allows a distinction between price impacts as observed in local currency units and those observed in 2014 US dollars.

[7] Commercial-premium still wines are defined by Anderson and Nelgen (2011) to be those priced between US$2.50 and $7.50 per litre pre-tax at a country's border or wholesale.

In the model, the grape and wine sectors minimize costs of intermediate inputs subject to weak CES substitutability between inputs. By assumption, no intermediate inputs are imported from other countries.[8] Hence:

$$X_{id}^{c} = f(X1_{id}, CES[P_{id}^{c} / P1_{id}]) \quad (1)$$

$$P1_{id}.X1_{id} = \sum_{c} X_{id}^{c}.P_{id}^{c} \quad (2)$$

where X_{id}^{c} is the quantity demanded of commodity *c* by grape or wine industry *i* in region *d*, P_{id}^{c} is the corresponding price, and $X1_{id}$ and $P1_{id}$ are the respective intermediate composite quantities and prices.

There are two primary factors employed in the sector: labour (the quantity of which is endogenous with perfectly elastic supply) and capital. Capital is usually treated as exogenous in quantity, with rates of return bearing all the adjustment in the various scenarios. This reflects the fact that both grapes (a perennial crop), and wine plant capacity, adjust slowly to market signals:

$$L_{id} = f(F_{id}, CES[W_{id} / PF_{id}]) \quad (3)$$

$$K_{id} = f(F_{id}, CES(R_{id} / PF_{id}]) \quad (4)$$

$$PF_{id}.F_{id} = L_{id}.W_{id} + K_{id}.R_{id} \quad (5)$$

Grape and wine producers are assumed to minimize costs subject to CES substitution between capital and labour. Equations (3) to (5) show primary factor demands for the labour composite L_{id} and capital K_{id} subject to a composite factor demand F_{id} by industry *i* in region *d*. The factor prices are W_{id} for labour, R_{id} for capital rentals and PF_{id} for composite factor prices.

[8] An exception concerns bulk wine imports used mainly in the bottling of commercial premium wine in the UK, USA, Canada, Japan and Germany.

The composite factor demand F_{id} is proportional to total output Q_{id} subject to a primary-factor-using technology A_{id}. Hence

$$F_{id} = Q_{id}.A_{id} \tag{6}$$

The perfectly competitive zero pure profit condition is that total revenue, valued at the output price P_i^{0s} multiplied by Q_{id}, equals the total production cost:

$$P_i^{0s}.Q_{id} = \sum_c P_{id}^c.X1_{id}^c + \sum_o W_{id}^o.L_{id}^o + R_{id}.K_{id} \tag{7}$$

Household demands follow a linear expenditure system in each region. We reduce the optimizing problem for household consumption of each commodity, subject to a budget constraint, to equations describing subsistence and discretionary demands. Aggregate subsistence expenditure $WSUB_d$ depends only on consumer prices $P3_{cd}$ for each commodity, and the number of households N, as per capita subsistence quantities $XSUB_{cd}$ subject to given preferences are constant.

$$WSUB_d = \sum_c P3_{cd}.XSUB_{cd}.N_d \tag{8}$$

Discretionary expenditures for each commodity (the left-hand side of equation (9)) are equal to the marginal budget share (β_{cd}) of aggregate discretionary expenditure. This aggregate is the bracketed term on the right-hand side of equation (9), where $W3TOT_d$ is aggregate nominal expenditure:

$$P3_{cd}(X3_{cd} - XSUB_{cd}.N_d) = \beta_{cd}(W3TOT_d - WSUB_d) \tag{9}$$

Since real aggregate consumption is usually exogenous in our partial equilibrium simulations, the linear expenditure system determines the consumption shares of individual final commodities (i.e., the five wine types plus a composite of all other consumption items), driven by changes in relative prices as faced by domestic consumers. The income elasticity of demand for each commodity is equal to the marginal budget share divided by the expenditure share. This varies from 0.5 for non-premium wine to 1.7 for super-premium still wine. The

income elasticity of demand for other consumption is very close to 1.0, because wine accounts for an average of only 0.3 percent of aggregate expenditure globally and no more than 1.1 percent in any country (Anderson and Nelgen 2011, Table 166).

A feature of our revised model of world wine markets is the inclusion of nominal exchange rates. These appear directly in the equation linking retail prices ($P3^{s}_{cd}$) to producer prices by country of origin (P^{0s}_{c}) where *c* denotes the wine type:

$$P3^{s}_{cd} = P^{0s}_{c} \frac{\phi_d}{\phi_s} T^{tar}_{cd} T^{tax}_{cd} + P^{m}_{cd} \tag{10}$$

The exchange rates in the consuming and producing regions are ϕ_d and ϕ_s respectively, expressed as local currency units per $US. T^{tar}_{cd} is the power of the tariff in the consuming region and T^{tax}_{cd} the power of the domestic consumption (or excise) tax prior to any generic value-added or goods-and-services tax. P^{m}_{cd} is the price of margin *m*, assumed to be locally supplied, non-tradable and therefore unaffected by the exchange rate.

A given level of consumption for wine type *c* ($X3_{cd}$) is satisfied using the Armington (1969) assumption, in which wine from different countries of origin are imperfectly substitutable. First, domestic wine is imperfectly substitutable with a composite of imports:

$$X3^{ss}_{cd} = f(X3_{cd}, CES(P3^{ss}_{cd} / P3_{cd})) \quad ss = \text{domestic, imports} \tag{11}$$

and then imports by origin ($X3^{s}_{cd}$) are determined in a second CES equation:

$$X3^{s}_{cd} = f(X3^{ss="imports"}_{cd}, CES(P3^{s}_{cd} / P3^{ss="imports"}_{cd})) \tag{12}$$

The model enables us to show how changes in international competitiveness affect the world's wine markets. A crucial part of this exercise is explaining how prices determined outside the grape and wine markets influence these markets. Since the model is partial equilibrium, in order to depict the impacts of changes in international competitiveness, outside price changes need to be imposed as shocks on the model. The price of intermediate

inputs other than grapes and wine shown in equations (1) and (2) is set equal to the price of GDP (P_d^g) multiplied by a shifter F_d^c .

$$P_{id}^c = F_d^c P_d^g \tag{13}$$

If no specific price observations are available, the shifter F_d^c remains exogenous and unshocked, with the change in price being determined by a shock to the price of GDP. If observations are available for specific input price movements, the shifter F_d^c becomes endogenous, with P_{id}^c now exogenous and shocked.

$$W_{id} = F_d^w P_d^g \tag{14}$$

Wage rates are treated similarly. In equation (14), if the wage shifter F_d^w is exogenous, changes in wage rates W_{id} are determined by changes in the price of GDP. If wage rate data are available, F_d^w becomes endogenous and wage rates are shocked directly.

$$P_{cd}^m = F_d^m P_d^g \tag{15}$$

The prices of trade and transport margins are also determined by the price of GDP if the shifter F_d^m in equation (15) is exogenous.

Changes in international competitiveness depend on changes in relative price levels and changes in nominal exchange rates. In equation (16), ϕ_s^R denotes real exchange rate movements relative to the US dollar:

$$\phi_s^R = P_s^g / [P_{"USA"}^g * \phi_s] \tag{16}$$

In (16), the nominal exchange rate for the United States is always unchanged, because nominal and real exchange rates are expressed relative to the US currency.

Changes in international market conditions may have impacts in one direction on producer prices as expressed in US dollars P_i^{0s} and potentially in the opposite direction in

local currency units. Hence, we calculate real producer prices $P^{0s}_{i,loc}$ in local currency terms (i.e., the price most relevant to domestic producers):

$$P^{0s}_{i,loc} = P^{0s}_{i} * \phi_s \ / \ P^{g}_{s} \tag{17}$$

To obtain real price changes in local currency terms, we convert US dollar prices ($P3^{s}_{cd}$ for source-specific and $P3_{cd}$ for the source-composite price) to real local currency prices ($P3^{s}_{cd,loc}$ and $P3_{cd,loc}$) using the CPI (P^{c}_{d}) as the deflator:

$$P3^{s}_{cd,loc} = P3^{s}_{cd} * \phi_d \ / \ P^{c}_{d} \tag{18}$$

and

$$P3_{cd,loc} = P3_{cd} * \phi_d \ / \ P^{c}_{d} \tag{19}$$

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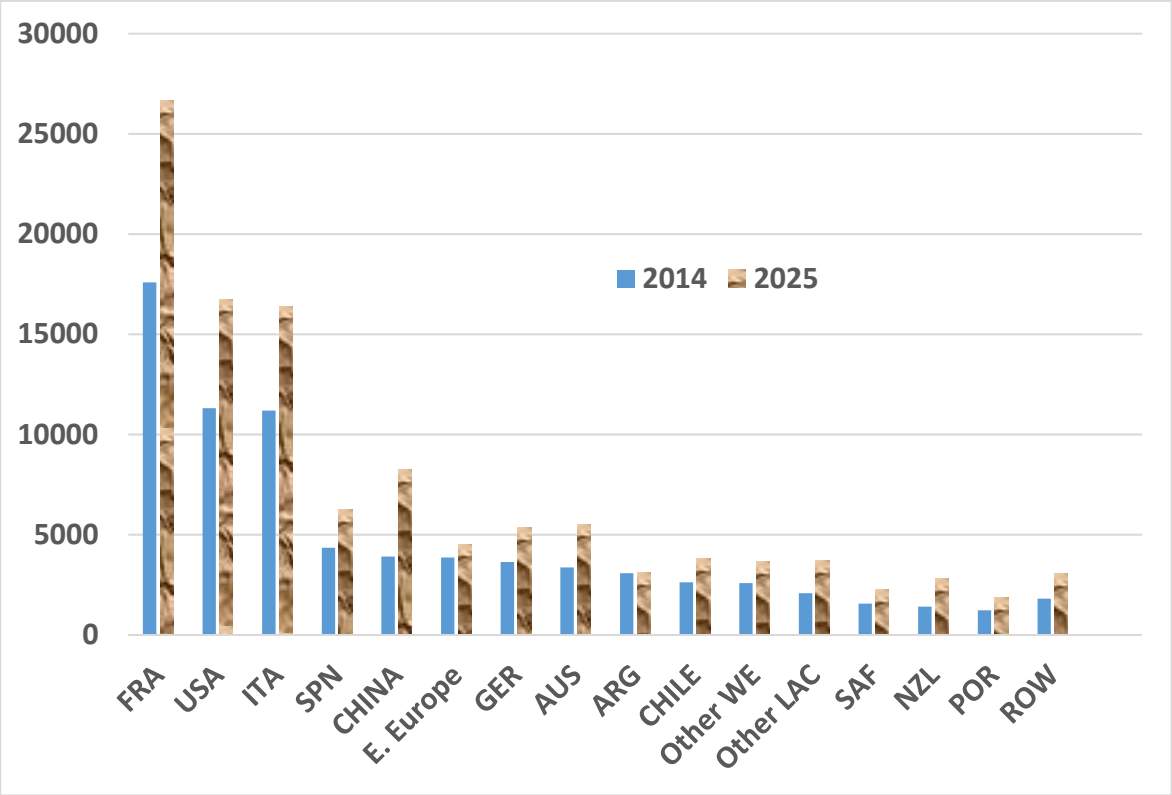
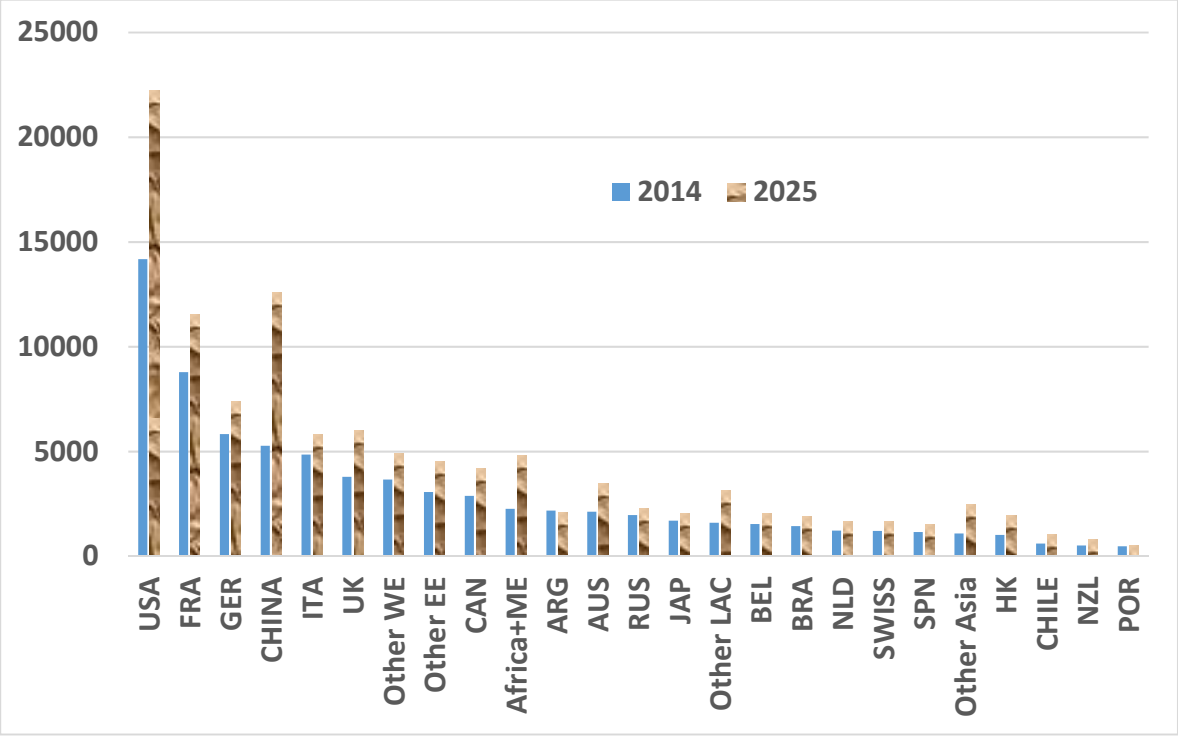
Figure 1: Value of wine production and consumption in key countries, 2014 and projected 2025 (2014 US$ million at winery/wholesale pre-tax prices)

(a) Production



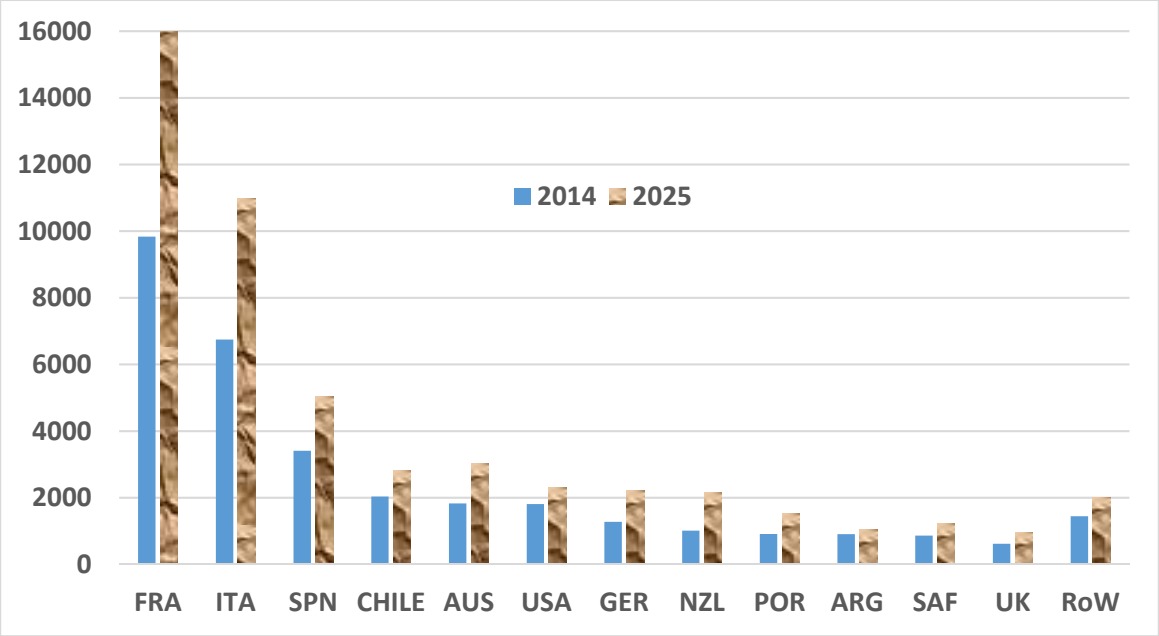
(b) Consumption



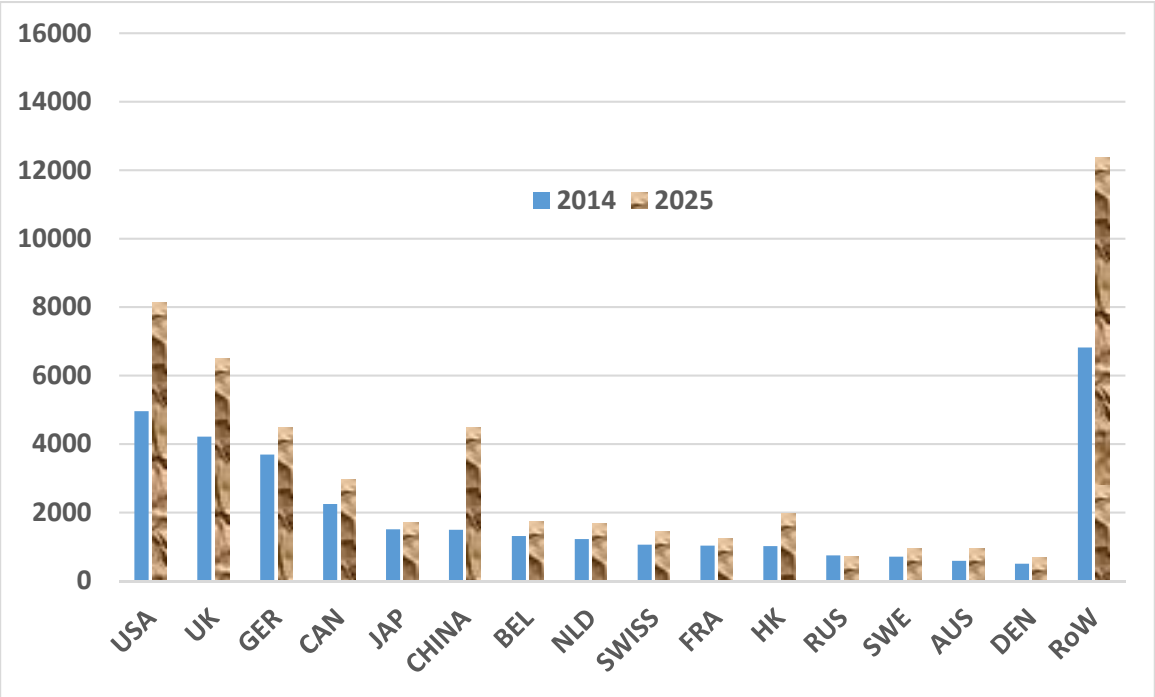
Source: Authors' model results.

Figure 2: Value of wine exports and imports, key wine trading countries, 2014 and 2025 (2014 US$ million)

(a) Exports



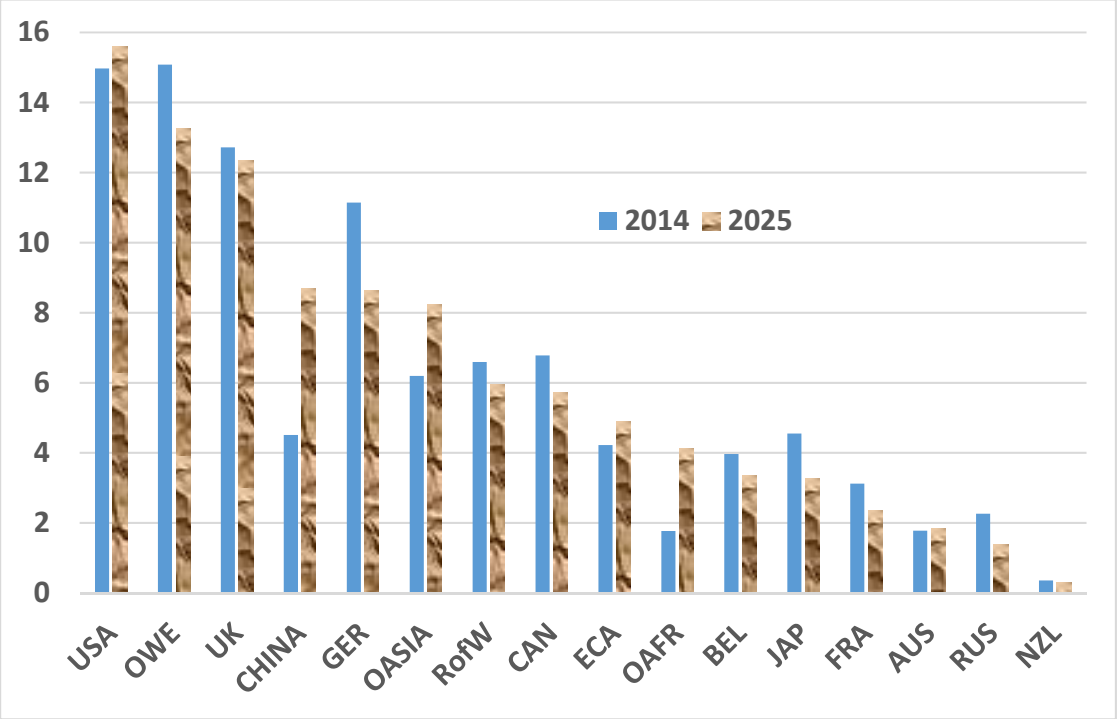
(b) Imports



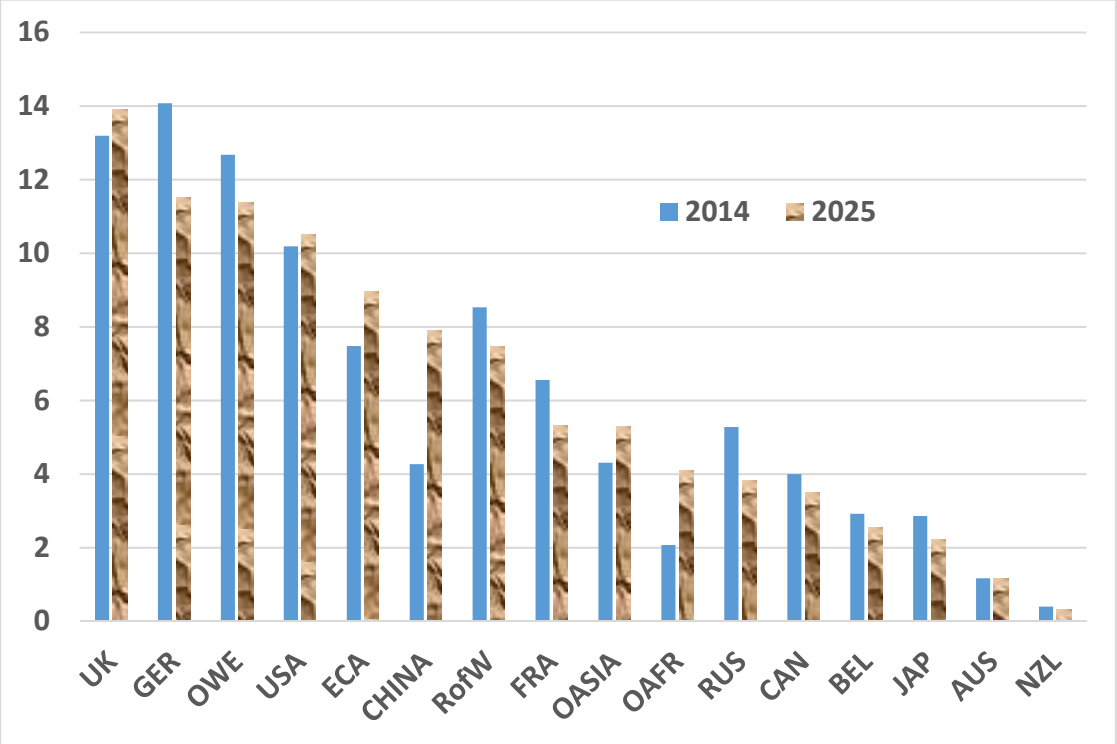
Source: Authors' model results.

Figure 3: National shares of global wine import value and volume, 2014 and 2025 (%)

(a) Value shares (%)

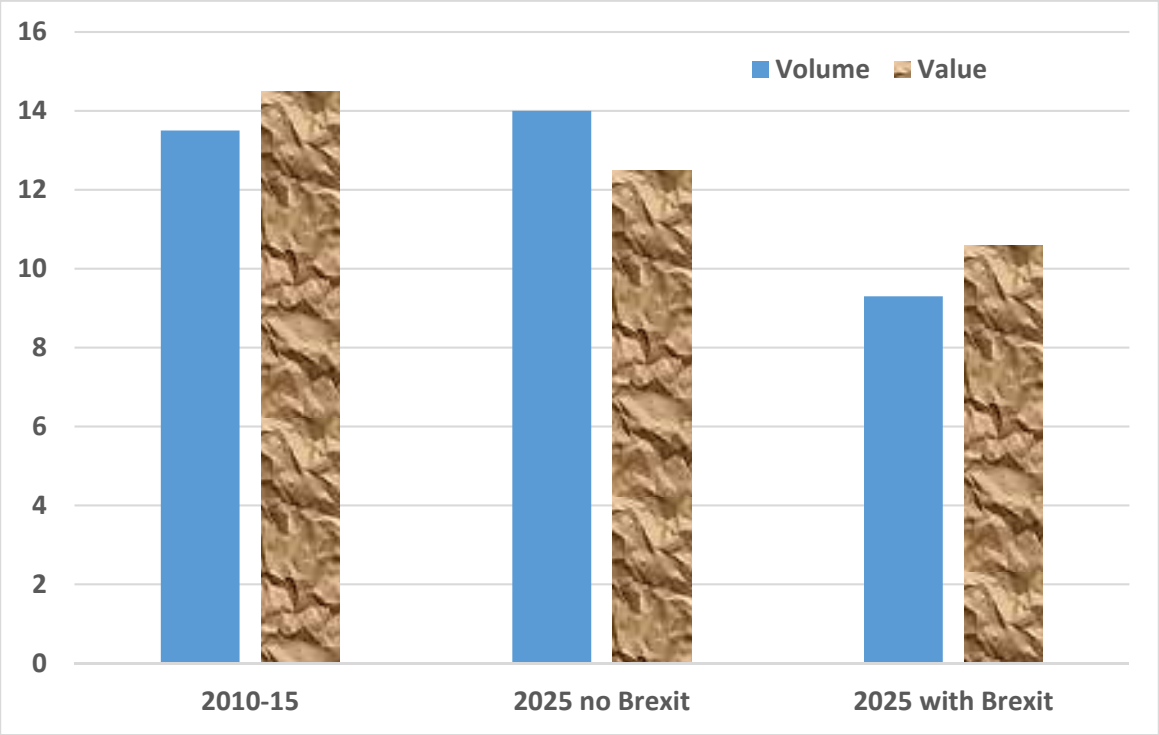


(b) Volume shares (%)



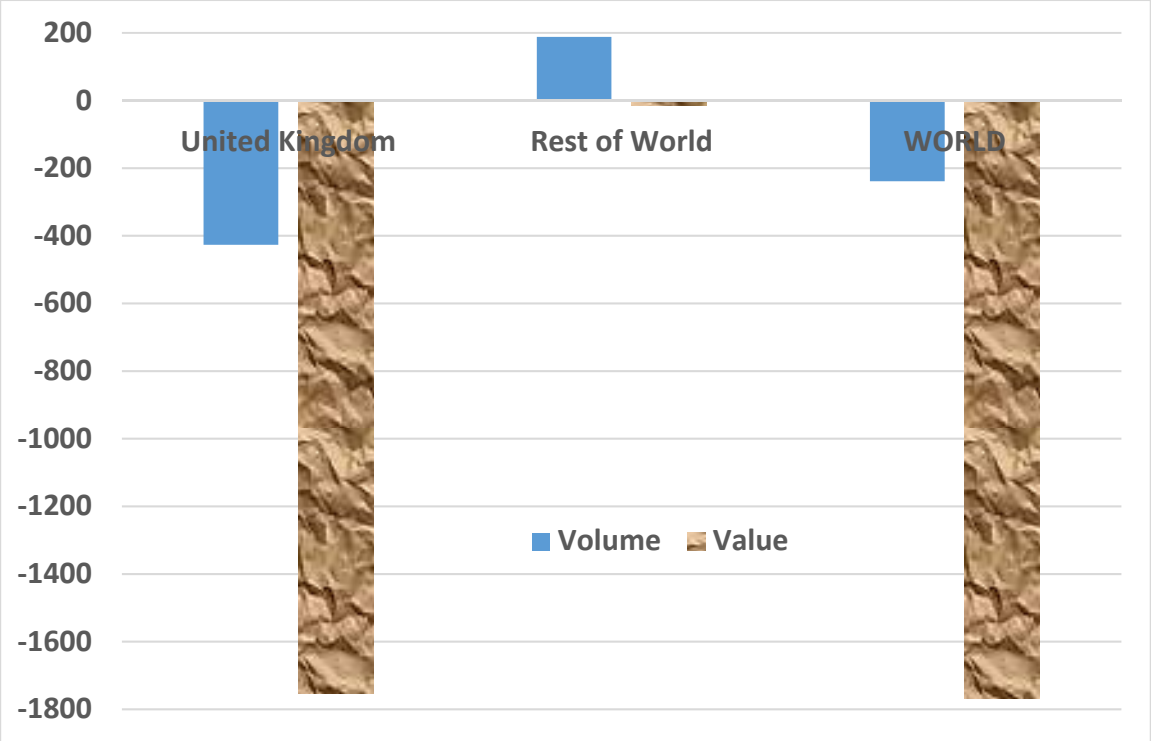
Source: Authors' model results.

Figure 4: UK shares of world wine imports, 2010-15 and projected to 2025 without and with the initial 'large' Brexit shock (%)



Source: Anderson and Pinilla (2017) and authors' model results.

Figure 5: Difference in 2025 wine import volumes and values as a result of Brexit (ML and US$ million in 2014 US dollars)



Source: Authors' model results.

Table 1: Shares of UK wine imports from today's key wine-exporting countries, 1675 to 2014 and projected 2025 without and with Brexit (%)

Volume:	France	Spain	Portugal	Italy	Germany	South Africa	Australia	United States	Chile	New Zealand	Argentina	Other countries	Total
1675-1696	25	42	23	1	9	0	0	0	0	0	0	0	100
1697-1862	5	26	49	1	3	2	0	0	0	0	0	14	100
1863-1919	26	26	22	0	0	0	2	0	0	0	0	25	100
1920-1940	12	18	32	0	0	5	14	0	0	0	0	20	100
1995:													
volume	32	10	3	18	14	3	7	3	2	1	0	7	100
value	43	9	4	13	10	2	8	3	2	1	0	5	100
2010-14:													
volume	15	9	1	17	4	8	21	10	8	4	1	2	100
value	35	8	2	15	4	4	11	5	6	6	1	2	100
Exporters' share of world wine exports, 2010-14:													
volume	*15*	*20*	*3*	*22*	*4*	*4*	*7*	*4*	*7*	*2*	*3*	*9*	*100*
value	*30*	*9*	*3*	*19*	*4*	*2*	*6*	*4*	*5*	*3*	*3*	*12*	*100*
2025 projected, no Brexit													100
volume	18.9	19.6	2.7	21.0	4.6	4.7	5.7	3.8	6.2	1.4	1.9	9.5	100
value	31.7	9.9	3.0	21.4	4.3	2.3	5.4	4.3	5.2	4.0	1.9	6.6	100
2025 projected, with Brexit													
volume	19.0	19.6	2.7	21.0	4.4	4.7	5.8	3.8	6.1	1.4	1.9	9.6	100
value	31.7	9.8	3.0	21.4	4.2	2.2	5.4	4.2	5.1	3.9	1.9	7.1	100

Source: Compiled from data in Anderson and Pinilla (2017) to 1940, United Nations COMTRADE, https://comtrade.un.org/data/ for 1995-2014, and authors' model results for 2025.

Table 2: Difference in 2025 projected volume and value of wine imports by the United Kingdom and the rest of the world as a consequence of the initial Brexit (ML and 2014US$ million)

	Volume (ML)					Value (US$ million)				
	PN + CP[a]	Super Pr[b]	Sparkling	TOTAL	*%*	PN + CP[a]	Super Pr[b]	Sparkling	TOTAL	*%*
ΔUK imports due to:										
Lower incomes	-199	-21	-29	-249	*58*	-636	-253	-232	-1121	*64*
Lower pound	-76	-10	-14	-100	*23*	-256	-126	-105	-488	*28*
Higher tariffs	-67	-1	-15	-83	*19*	-110	-9	-25	-143	*8*
TOTAL	**-342**	**-32**	**-58**	**-432**	*100*	**-1002**	**-388**	**-362**	**-1752**	*100*
% diff. from base	*23*	*33*	*33*	*25*		*24*	*32*	*32*	*27*	
% of total cuts	*79*	*7*	*14*	*100*		*57*	*22*	*21*	*100*	
ΔROW net imports	146	22	24	192		23	142	-181	-16	
ΔWORLD TRADE	**-196**	**-10**	**-34**	**-240**		**-978**	**-246**	**-543**	**-1768**	

[a] Non-premium plus Commercial Premium still wines [b] Super-premium still wines

Source: Authors' model results.

Table 3: Difference in 2025 bilateral wine import volumes and values from key exporters by the UK and rest of the world (RoW) as a result of initial Brexit shock (ML and 2014US$m)[a]

(a) 'large' scenario

	Volume (ML)				Value (2014US$m)			
	UK	RoW	WORLD	(%)	UK	RoW	WORLD	(%)
EU27	-287	136	-150	(-1.7)	-1187	-5	-1192	(-3.1)
Chile	-59	35	-25	(-3.0)	-169	31	-138	(-4.8)
Sth. Africa	-53	35	-18	(-3.2)	-105	20	-85	(-6.7)
USA	-7	-6	-13	(-2.4)	-75	-40	-115	(-5.0)
Australia	-4	-3	-7	(-0.9)	-25	-65	-90	(-3.0)
Argentina	-3	-9	-12	(-4.8)	-16	-39	-55	(-5.2)
NewZealand	-11	9	-2	(-0.9)	-162	71	-91	(-4.3)
Others	-2	-10	-12	(-0.2)	-11	-52	-63	(-4.4)
WORLD	**-427**	**187**	**-240**	**(-1.9)**	**-1750**	**-79**	**-1829**	**(-3.5)**

(a) 'small' scenario

	Volume (ML)				Value (2014US$m)			
	UK	RoW	WORLD	(%)	UK	RoW	WORLD	(%)
EU27	-178	82	-96	(-1.2)	-692	-43	-736	(-1.9)
Chile	-46	28	-18	(-2.4)	-128	36	-91	(-3.2)
Sth. Africa	-43	29	-14	(-4.2)	-82	23	-59	(-4.7)
USA	1	-6	-5	(-1.1)	-23	-28	-51	(-2.2)
Australia	5	-10	-5	(-0.6)	19	-56	-38	(-1.3)
Argentina	0	-6	-6	(-2.6)	-3	-25	-29	(-2.7)
NewZealand	-5	4	-1	(-0.6)	-80	34	-46	(-2.2)
Others	0	-9	-9	(-0.1)	-1	-33	-34	(-2.4)
WORLD	**-266**	**112**	**-154**	**(-1.3)**	**-991**	**-92**	**-1083**	**(-2.1)**

[a] Numbers in parentheses are the percentage difference between the Brexit and baseline scenarios for 2025 projected wine import volumes or values by source.

Source: Authors' model results.

Table 4: Difference in 2025 bilateral wine import volumes and values from key exporters by the UK and rest of the world (RoW) as a result of implementing a UK-EU27 FTA following initial 'small' Brexit shock (ML and 2014US$ million difference relative to initial 'small' Brexit scenario)[a]

	Volume (ML)				Value (2014US$m)			
	UK	RoW	WORLD	('small')[a]	UK	RoW	WORLD	('small')[a]
EU27	212	-112	100	(-96)	750	0	750	(-806)
Chile	1	3	4	(-18)	3	40	43	(-92)
Sth. Africa	3	2	5	(-14)	3	18	21	(-60)
USA	3	3	6	(-5)	26	21	47	(-50)
Australia	1	1	2	(-5)	8	38	46	(-33)
Argentina	1	4	5	(-6)	4	20	24	(-28)
NewZealand	4	-3	1	(-1)	61	-25	36	(-46)
Others	1	6	7	(-9)	5	-46	-41	(92)
WORLD	**226**	**-96**	**130**	**(-154)**	**860**	**66**	**926**	**(-1022)**

[a] Numbers in parentheses are the world trade differences between the 'small' initial Brexit scenario and the baseline scenario, copied from columns 3 and 7 of Table 5(b).

Source: Authors' model results.

Appendix Table A1: Cumulative consumption and population growth rates and changes in the real exchange rate (RER) relative to the US dollar, 2014 to 2025 without Brexit (%)

	Aggregate consumption	Pop'n	RER		Aggreg. consm	Pop'n	RER
France	18	4	-11	Australia	35	11	-17
Italy	11	2	-9	New Zealand	32	9	-26
Portugal	14	0	-9	Canada	27	8	-18
Spain	26	8	-9	United States	31	8	0
Austria	19	4	-7	Argentina	7	10	109
Belgium	20	7	-9	Brazil	16	8	-29
Denmark	22	2	-9	Chile	55	8	-2
Finland	21	3	-7	Mexico	42	12	-8
Germany	14	-2	-11	Uruguay	45	3	1
Greece	22	-1	-14	Other L. Am	60	10	-5
Ireland	42	12	-9	South Africa	36	12	-1
Netherlands	21	4	-9	Turkey	50	8	20
Sweden	24	9	-13	North Africa	53	11	0
Switzerland	18	8	-6	Other Africa	109	18	84
United Kingdom	32	6	1	Middle East	52	18	-12
Other W. Europe	21	10	-1	China	79	3	5
Bulgaria	41	-7	7	Hong Kong	42	3	2
Croatia	20	-2	-1	India	134	13	17
Georgia	35	0	23	Japan	11	-3	-24
Hungary	25	-3	-11	Korea	38	1	-9
Moldova	49	-11	13	Malaysia	62	15	-16
Romania	45	-4	22	Philippines	75	18	7
Russia	18	-2	-8	Singapore	44	21	-22
Ukraine	22	-5	14	Taiwan	29	1	-13
Other E. Europe	40	-5	48	Thailand	47	3	-9
				Other Asia	99	10	10

Source: Authors' compilation from projections by various international agencies and from global economy-wide modeling by Anderson and Strutt (2016).