January 2018

1. Methodology

We model the impact of leaving the EU on the Scottish and UK economy using the Scottish Government Global Econometric Model (SGGEM) a version of the National Institute Global Econometric Model (NiGEM), which is a multi-country structural econometric model, developed and owned by the National Institute of Economic and Social Research (NIESR). NiGEM is widely used for forecasting and policy analysis by many international and financial institutions, research organisations and governmental departments, including among them the Bank of England, H.M. Treasury, European Central Bank, OECD, and many more.

NiGEM has the additional advantage of being used in several unconnected studies by other institutions in their analysis of the long-run impact of leaving the EU on the UK. This is primarily because the global nature of the model, which includes explicit trade linkages, make it particularly well suited to modelling the impact shifts in trade policy can have on individual economies. It is also general equilibrium in nature allowing both prices and quantities to adjust over time whilst also being able to incorporate endogenously monetary and fiscal responses - all of which are clearly important for the adjustment process that leaving the EU may entail.

The Scottish Government's version of this model, which was commissioned from and built by NIESR, is referred to as SGGEM because it additionally includes Scotland as an explicit entity within the UK. The relationship between Scotland, the rest of the UK and other global countries is determined within the structural framework of the model. This is the main differentiation between SGGEM and NiGEM and other than the addition of Scotland they are largely the same model.

Using SGGEM allows the Scottish Government to perform medium to long-term policy analysis, including differential impacts that scenarios can have between Scotland and the UK as a whole. It is also particularly relevant to answering the questions set out by this paper regarding the impact leaving the EU has on Scotland. On top of this we can increase the transparency of our approach by adopting many of the assumptions and modelling approaches used by other institutions who have used NiGEM in their own analysis of the UK leaving the EU.

In our modelling we draw from the approach of other institutions and studies in focusing on six economic shocks likely to result from losing full EU membership: a reduction in total trade with other EU member countries; an increase in trade tariffs with the EU; a reduction in inward FDI flows; impacts on productivity as a result of lower trade openness; changes in migration and the repatriation of UK/Scotland's share of projected net contributions to the EU budget.

2. The Possible Scenarios

Figure 1 below summarizes some of the different forms that the relationship with the EU could take after Brexit.

Figure 1: Overview of economic aspects of alternative relationships

		Access to the single market in goods & services			Obligations		Influence
		Tariff-free trade	Customs union & external trade	Level playing field/ non-tariff barriers	Other policy and regulation	Financial Contributions	Votes on EU rules
EU Membership		Full	Full. No customs costs. Access to EU FTAs	Full	Full	Full EU budget contributions	Full
The UK's Special Status		Full	Full. No customs costs. Access to EU FTAs	Full	UK is not a member of the single currency	UK recieves rebate on EU budget contribution	Full
EEA (Norway)		Some tariffs remain on agriculture and fisheries	No Access. Customs costs apply. No access to EU FTAs	Agriculture & fisheries not substantially covered by the EEA agrreement	Accepts most EU rules, including market/product standards, free movement of people, environment, energy, climate & social policy	Pays for EEA grants, Norway Grants, admin costs & programme costs	None
Bilateral Agreements	Switzerland	Some tariffs remain on agriculture and fisheries	No Access. Customs costs apply. No access to EU FTAs	Minimises non-tariff barriers in sectors covered. Limited coverage for services. No financial services passport	Adopts EU rules in sectors covered. Participates in free movement of people & EU rules on e.g. environment, energy, climate and social policy	Gives grants to new EU member states. Pays admin & programme costs	None
	Turkey	Only applies to manufactured goods & processed agriculatural goods	No customs costs for manufactured goods. Obligation to align external trade policy with EU	Removes most other barriers to trade in goods. No special access for services. No financial services passport	Adopts EU product standards, committed to equivalent rules on competition, state aid etc. & complies with environmental standards linked to goods trade	Turkey is not in receipt of some EU funding	None
	Canada	Some tariffs remain on agriculture. Some tariffs on manufactured goods remain for a transitional period	No Access. Customs costs apply. No access to EU FTAs	Partial liberisation of services. No financial services passport	Firms trading into EU conform to EU standards. International agreements & standards apply	None	None
WTO Membership		EU external tariffs apply	No Access. Customs costs apply. No access to EU FTAs	International agreements and standards apply. No financial services passport	Firms trading into EU conform to EU standards. International agreements & standards apply	None	None

Source: *HM Treasury analysis: the long-term economic impact of EU membership and the alternatives* (2016)

Examples of three of the most significant bilateral trade agreements currently with the EU include Switzerland, Turkey and Canada. Currently none of these agreements allow complete access to the European Customs Union, financial passporting rights, 100% tariff-free trade or access to external EU Free-trade agreements. This suggests that if the UK government is successful in their negotiations to achieve a bilateral trade agreement, losing full EU membership status will still likely lead to some degree form of additional trade barriers with the EU.

The UK government has also stated that, should the negotiations become intractable, or if the price of a bilateral trade agreement becomes too high, they will resort to a WTO trade relationship with the EU. This would lead to a number of barriers arising on trade with the EU.

Given the uncertainty of the negotiation outcomes, in very broad terms we therefore consider a range of scenarios, from a WTO approach to a bilateral trade agreement along the lines of those similarly in existence is agreed. We also examine a scenario where Scotland and the UK gain access to the EEA, such as Norway.

As stated before we focus on six key shocks likely as a result from leaving the EU. The size and magnitude of these shocks are determined based on the different possible scenarios under consideration. In order to remain as transparent as possible we choose to follow, where possible, the approach prescribed either by independent institutions in their modelling of the UK leaving the EU, or by consensus in the literature. If a range of estimates for assumptions exist, we have tried to adopt the more conservative options available.

3. Modelling the Economic Implications of Leaving the EU

This section covers the six economic shocks that the literature and economic theory suggest are the main mechanisms for any impact leaving the EU may have. These are:

1. a reduction in total trade with other EU member countries;
2. an increase in trade tariffs with the EU;
3. a reduction in inward FDI flows;
4. impacts on productivity as a result of lower trade openness and FDI investment;
5. changes in migration; and
6. the repatriation of UK/Scotland's share of projected net contributions to the EU budget.

The simulated shocks described in this section are applied directly onto our model. When a shock is run, a new baseline is created and we then revert any model changes from any previous shocks back to the standard set of model equations. For example, some modifications are made to the model regarding the trade shock as described further on in this section. We then proceed to adjust the model as required for the next set of shocks and we repeat this step for every shock in question. Once all the set of shocks have been run, The final results are compared to the original baseline. This is exactly the same approach as that followed by NIESR in Ebell, Hurst and Warren (2016).

Currently the range of shocks are implemented to begin in 2019 when the UK is officially projected to leave the EU. In reality, the precise timing of any impacts will depend on any transition arrangement agreed with the EU.

3.1 The Impact on Trade

There is a broad consensus in economic theory and the academic literature that membership in a free trade area is associated with increased bilateral trade flows between member states. A thorough and comprehensive review of the literature is covered in Ebell and Warren (2016) who cite estimates for a range of scenarios, from a WTO to EEA style relationship with the EU. This large body of evidence suggests that leaving the EU, is likely to reduce the UK's (and therefore implicitly Scotland's) trade with Europe.

Applying a trade shock into the SGGEM model, we follow the approach applied by NIESR in their long-run analysis of the UK leaving the EU (see Ebell, Hurst and Warren 2016) by simulating a reduction in both the UK and Scottish exports by shocking the import demand of their trading partners.

Currently Scotland has its own explicitly modelled Export Market size variable "$S_{t,Scot}$". This variable is the weighted sum of imports, weighted by exports (to country n) relative to import market size (of country n). This variable is then modified in the same approach that NIESR adopt in their analysis. This can be seen in equation 1) below:

$$1) \quad S_{t,Scot} = \sum_0^{eu} \emptyset_{eu}\, \epsilon_{eu(Scot)} mvol_{t,eu} + \sum_0^{rw} \emptyset_{rw}\, mvol_{t,rw} + \emptyset_{rUK} mvol_{t,rUK}$$

Subscript *eu, rw* and *rUK* represent a country in the EU, the rest of the world or the rest of the UK. The term $\epsilon_{eu(Scot)}$ is the scaling factor applied to EU weightings only. This scaling factor allows us to mimic the effect of a fall in import demand from EU countries as a result of non-tariff barriers. Setting $\epsilon_{eu(Scot)}$ equal to 1 assumes no impact on Scottish export market share with the EU. As an example setting $\epsilon_{eu(Scot)}$ to a value of 0.5 represents a halving of the size of EU import markets for the EU from Scotland.

The rest of the UK likewise has a similar variable "$S_{t,UX}$" and it is amended in a similar manner as can be seen in equation 2) below. The variable governing the UK as a whole – "UKS" – is then the weighted summation of equation 1) and 2).

$$2) \quad S_{t,UX} = \sum_0^{eu} \emptyset_{eu}\, \epsilon_{eu(rUK)} mvol_{t,eu} + \sum_0^{rw} \emptyset_{rw}\, mvol_{t,rw} + \emptyset_{Scot} mvol_{t,Scot}$$

The "Ø" coefficients of both equations are inbuilt within the model and have been estimated by NIESR in the construction of the SGGEM model. These coefficients govern the trade relationships between countries. For example for Scotland $\emptyset_{rUK}$ governs the share of Scotland's imports from the rUK relative to all other imports. For Scotland $\emptyset_{rUK}$ is relatively high representing the fact that a large percentage of Scottish imports come from the rUK. Likewise the aggregated coefficients of $\emptyset_{eu}$ for Scotland are smaller relative than the coefficients for the rUK. This reflects the differing trade relationship Scotland and the rUK have with the EU, with the rUK being far more exposed to the EU in terms of overall trade, than Scotland is on its own.

To impose the assumption of a fall in trade for both Scotland and the rUK with the EU, we can set $\epsilon_{eu(rUK)}$ and $\epsilon_{eu(Scot)}$ to equal a value less than one.

3.2 Tariffs

The next assumption is that EU countries impose tariffs on Scottish and UK exports while tariffs with the rest of the world remain the same. To do so we again follow the approach outlines by NIESR in their approach by splitting the equation governing UK non-commodity export prices into EU (*pxnceu)* and rest of world (*pxncrw)*, equations 6) and 7) respectively. These equations simply state that export prices to the EU and the Rest of the World are governed by a function of the consumer expenditure deflator, the exchange rate and competitors export prices.

These two series are then weighted by the proportion of exports to the EU and the rest of the world in total trade to create the aggregate series *UKpxncom* and *Scotpxncom,* equations 8) and 9) respectively.

$$6)\ \Delta\log(pxnceu_t) = \beta_1\Delta\log(ced_t rx_t) + \beta_2\Delta\log(ced_{t-1}rx_{t-1}) - \lambda_1(\text{pxnceu} + \alpha_4\text{cpx})$$

$$7)\ \Delta\log(pxncrw_t) = \beta_3\Delta\log(ced_t rx_t) + \beta_4\Delta\log(ced_{t-1}rx_{t-1}) - \lambda_2(\text{pxncrw} + \alpha_4\text{cpx})$$

$$8)\quad rUKpxncom_t = 0.48(pxnceu_t) + 0.52\ (pxncrw_t)$$

$$9)\quad Scotpxncom_t = 0.16\ (pxnceu_t) + 0.84\ (pxncrw_t)$$

Applying a tariff shock is then done by permanently shocking the intercept of equation 6), governing the non-commodity export price to EU countries. This shock then filters through to both equation 8) and 9) for the UK and Scotland, although each will suffer a differential impact on total non-commodity export prices due to the different trade weightings.

3.3 Foreign Direct Investment

There is a large body of economic theory and literature analysing the effects free trade agreements have on inward flows of foreign direct investment (FDI). The three most

common methods for estimating this relationship are using gravity models; synthetic cohorts and regressions on FDI and trade openness.

A range of estimates exist on the impact EU membership has been for UK FDI but the consensus is that membership of the EU has generally significantly increased FDI via two main channels:

1. Free movement of capital makes it easier for firms from the other EU-28 countries to invest in Scotland and the UK.

2. Free trade in goods and services, including passporting and labour mobility across the EU, make Scotland and the UK a more attractive destination for FDI from outside of the EU.

The scenarios assumes that Scotland faces an identical FDI shock to that of the UK. This may be a slightly conservative approach, as there is some evidence that Scotland achieves a relatively higher share of FDI than the UK average, however as it is difficult to quantify this, an identical shock is modelled.

Modelling any impacts on FDI is done by calibrating a permanent shock to UK and Scottish private sector investment (PSI). This is done by calculating the change in FDI in nominal values then calculating the weight of this change as a share of total private sector investment. For example Ebell, Hurst and Warren (2016) find that in a WTO scenario a fall in UK FDI of 24% corresponds to a reduction in UK PSI of 3.5% within NiGEM.

The capital accumulation and corresponding investment flow equations within SGGEM are given as follows:

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10) $$\Delta \log(k_t) = \beta_1 \Delta \log(k_{t-1}) + \beta_2 \Delta y_t + \beta_3 \Delta y_{t-1} - \lambda_1 \left({}^{k_{t-1}}/_{ycap_{t+12}} \right) + sigma_t * user_t$$

11) $$inv_t = k_t - (1-\delta) k_{t-1}$$

---

where $user_{\mathrm{t}}$ is the user cost of capital and is a function of the long term real rate, and investment premia, $ycap$ is the potential output given by the mix of capital labour , labour augmented technological progress and energy given in the production function. Equation 11) shows that the capital stock adjusts to the new equilibrium path given the ratio between the capital stock un the previous period and expected potential output 3 years in the future. Investment then adjusts so the capital stock moves towards the desired equilibrium value.

The resultant PSI shock is applied as a small negative shift to the intercept of the capital accumulation equation 11) in each period for the entire simulation. The size of the shock is calibrated to achieve the assumed fall in PSI of each scenario.

3.4 Repatriation of Net Contributions to the EU

Both Scotland and the UK are net contributors to the EU budget, in the sense that both countries contribute more to the EU budget than they receive back in spending. From 2017 to 2020 the UK's contribution to the EU budget, net of both public and private sector receipts from the EU, is projected to average 0.3% of GDP.[1] Analysing the case for Scotland, in the 2015-16 Government Expenditure and Revenue Scotland (GERS) publication, net payments to the EU, excluding the North sea, are estimated to be £465 million pounds. Using the same source, Scottish GDP for 2015-16 excluding the North sea is estimated at £147,072 million pounds, resulting in net contributions to the EU estimated to be roughly 0.32% of GDP. For the sake of simplicity we make the assumption that both Scotland and the UK therefor receive a repatriation of EU budget contributions equal to 0.3% of GDP.

The base assumption in modelling this effect is to assume that both UK and Scottish Governments would use the repatriated contributions to increase spending - specifically government consumption. Using the baseline we calculate the nominal value of a 0.3% increase in GDP for each country for each period. We then positively shock the intercept of the Government consumption equation for each country by the nominal amount for each period.

In an EEA scenario, we assume that like other EEA countries, contributions to the EU would continue, and hence no repatriation of EU budget occurs..

3.5 Impact on Productivity

Productivity growth in the economy, generally referred to as Total Factor Productivity (TFP), has a significant impact on the wider economy, such as via the amount of output produced per person, which can affect things like levels of investment, and nominal wages. The European Union allows greater openness between its member states through the free movement of goods, services, capital and labour. Box 2 discusses the channels through which greater levels of openness to both trade and investment can affect TFP growth in the economy:

Box 2: Productivity and Trade Openness

[1] These projections are based on OBR and HM Treasury projections, as reported by Webb and Keep (2016), together with EU data on EU spending.

Innovation and Adoption

Fewer barriers to trade has been shown to increase the incentives for domestic firms to implement and adopt new technologies into their business. Higher levels of trade can increase the return a company generates from investment in new technology or capital spending. Increased trade can also improve the quality of inputs available and a more efficient adoption of technological innovations and practices from trading partners.

Increased Competition

Fewer trade barriers with the rest of Europe increases the level of competition domestic firms face from European counterparts. This creates a strong incentive for domestic firms to improve their productivity in order to maintain and expand their market share. Many academic studies have found that periods of time where competition is weak has significantly undermined productivity growth throughout the economy. Conversely when competition has strengthened, productivity growth has been boosted.

Other studies also have found evidence that being a member of the Single Market has led to a significant increase in the entry of foreign firms into the domestic market, increasing the levels of competition within the economy. Again this is found to have had a significant positive impact on productivity but also other positive external effects such as boosting the level of patenting in domestic firms[2].

Foreign Direct Investment

Foreign Direct Investment (FDI) can positively impact domestic firms by increasing investment in new technologies and improving working practices. These help to boost the productivity of firms through efficiency gains and applying the latest technology to either boost production quantity or cut the real cost of production. There are also positive externalities from FDI such as foreign firms transferring newer technologies and managerial practices via investment and through the supply chain. There is strong evidence that greater openness to trade and FDI boosts technology transfer between foreign and domestic firms across the economy.[3]

Scale and Specialisation

Access to the EU single market greatly increases the potential consumer base firms have to sell to. Access to a larger market allows the most productive and successful firms to expand, taking advantage of economies of scale in production to expand the range, variety and quality of products on offer. In particular there is evidence that

[2] *The effects of Entry on Incumbent Innovation and Productivity*, Aghion, Blundell, Griffith, Howitt and Prantl (2009).

[3] A summary of the evidence can be found in *EU membership and the Bank of England*, Bank of England (October 2015).

greater openness to international trade also improves productivity by encouraging firms to focus on their comparative advantage –the things they do best.[4]

Better Matching of Capital

Greater openness to international flows of factors of production can improve the allocation of resources, resulting in capital being allocated in a more efficient manner to projects likely to benefit the most from them.[5]

Box 2 describes some of the positive impacts greater openness to trade and investment can have on TFP. The possible implications of leaving the EU, and the subsequent fall in trade openness, may therefore reduce both the level and future growth of TFP in the UK and Scotland.

Applying a shock to TFP in our SGGEM model can be done relatively easily by shocking the Labour Augmenting Technical change variable – an exogenous variable that is part of the production function governing potential output in the economy. Shocking this variable acts as a proxy to shocking TFP for the economy as a whole with the shocks propagating themselves through the supply side of the economy.

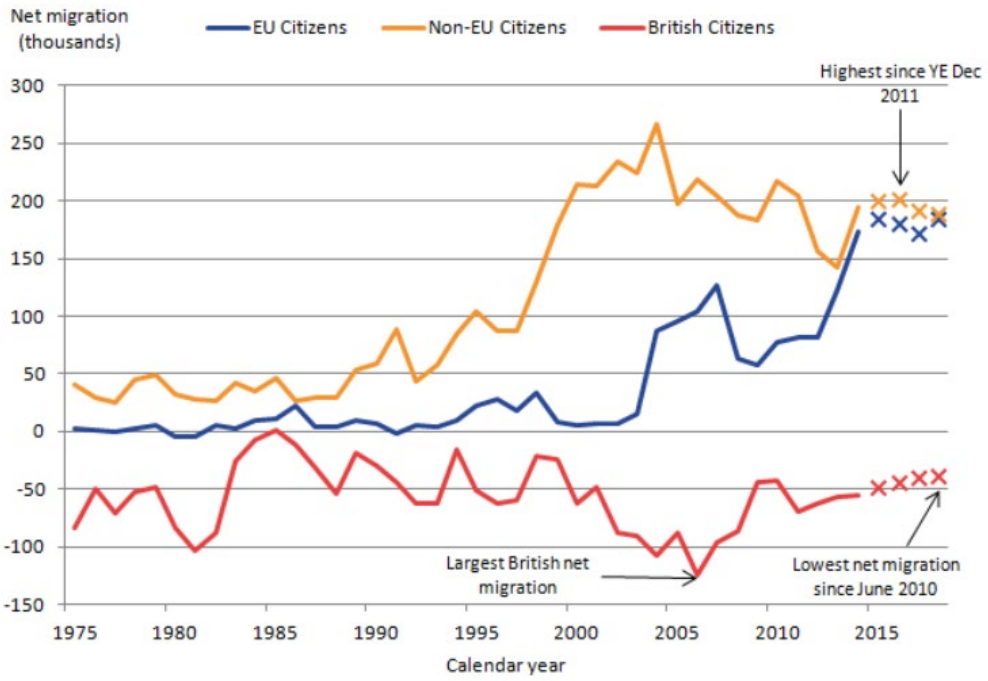
Naturally, given that we are effectively shocking the production function, the impact a fall in TFP can have is substantial. However given the strong empirical and theoretical reasons for accommodating a TFP shock as well as the fact that many other institutions have included productivity shocks in their analysis of leaving the EU, we choose to include it into ours. A more comprehensive review of the literature and an example of incorporating productivity into scenarios of leaving the EU is covered in the HM Treasury paper covering their long-run analysis (H.M.Treasury, 2016).

3.6 Changes in Migration

Full membership of the EU entails signing up to the free movement of labour between member states, which has had a significant impact on migration levels between both Scotland, the UK and the EU. This has been particularly evident since the expansion of the EU in 2004 as can be seen below:

Net Long-Term International Migration by citizenship, UK, 1975 to 2015 (YE December 2015)

[4] *Gains from Trade When Firms Matter,* Melitz and Trefler (2012); *How do firm-level responses to trade affect industry productivity and the gains from trade?*, Melitz and Redding (2013).
[5] *Financial Openness and Productivity,* Bekaert, Harvery and Lundbland (2011).



Source: Office for National Statistics, Long-Term International Migration

Given the uncertainty around the future of free movement of labour, we incorporate a migrationary shock into our analysis to accommodate for the impact lower net migration could impose. For example the Office of Budget Responsibility (OBR) state that in the absence of the UK leaving the EU they would have used the Office for National Statistics (ONS) High Migration population projections in their forecasts, but as a result of the EU referendum they have continued to adopt the ONS Principle Population Projections[6]:

ONS Population Projections

	Persons, thousands	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Scotland	High Migration	5,442	5,468	5,495	5,522	5,549	5,577	5,605	5,632	5,660	5,688	5,715	5,741	5,767
	Principle	5,412	5,428	5,445	5,462	5,480	5,497	5,514	5,532	5,548	5,565	5,581	5,596	5,610
	% Difference	**0.6%**	**0.7%**	**0.9%**	**1.1%**	**1.3%**	**1.5%**	**1.6%**	**1.8%**	**2.0%**	**2.2%**	**2.4%**	**2.6%**	**2.8%**
UK	High Migration	64,879	65,394	65,902	66,402	66,904	67,406	67,906	68,402	68,891	69,374	69,850	70,318	70,779
	Principle	64,603	65,034	65,456	65,869	66,281	66,691	67,098	67,497	67,889	68,273	68,648	69,015	69,373
	% Difference	**0.4%**	**0.6%**	**0.7%**	**0.8%**	**0.9%**	**1.1%**	**1.2%**	**1.3%**	**1.5%**	**1.6%**	**1.8%**	**1.9%**	**2.0%**

Source: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/

The High Migration scenario then can represent a scenario where free movement of labour remains. For example we assume that this would cover an EEA scenario. We then take the Principle Population projection as a baseline assumption for a scenario where free movement of labour is not attained, such as the Bilateral Trade Agreement and WTO scenarios.

Applying any such assumption into our model is achieved by reducing the future total population when we model a scenario where we assume that free movement of labour

[6] OBR – Nov 2016 report Paragraph 3.25

will not apply. The magnitude of the shock is the corresponding difference between the high migration and principle projection. For example, in a WTO scenario with no free movement of labour we assume that the total Scottish population would fall by 0.6% by 2018, 0.7% by 2019, 0.9% by 2020 and so on in that manner. A similar shock is applied to the rUK, this time using the UK % difference. As can be seen in the table above, the impact on Scotland is marginally greater than the UK as a whole and hence we would expect there to be a differential impact from changes in migration.

This shock to future total population leads to a reduction in the growth of the rUK and Scottish labour force. It is assumed that 75% of the forgone population from the high migration projections would have been in the labour force, consistent with evidence of the participation of recent EU immigration flows. This is also the same assumption imposed in the OECD's analysis of the UK leaving the EU when they model the impact of falling net migration (OECD, 2016).

4. Scenario Assumptions

This section sets out the different scenarios under consideration including the assumptions made for each of the shock mechanisms covered in Section 3.

The first scenario under consideration is a WTO relationship. The following scenario then considers a possible bilateral trade scenario. The final scenario considers where the Scotland and the UK remain a member of the European Economic Area (EEA).

4.1.1 WTO Relationship

Trade

Moving to a WTO relationship is assumed to reduce trade with the EU, due to increases in trade barriers. The size of the reduction in trade with EU member countries is based on evidence from gravity model estimates of the impact of leaving the EU, treating goods and services separately. NIESR - as explained in Ebell, Warren (2016) - follow the evidence presented in (Baier, Bergstrand, Egger, & McLaughlin, 2008), who have a wide range of estimates for WTO, Bilateral Trade agreement and EEA scenarios. The estimates for the WTO case imply that leaving the EU would be associated with a decline in EU goods trade of between 50% and 56%. The reduction in services trade with the EU is based on (Van der Marel & Shepherd, 2013), whose estimates imply that leaving a free trade area would lead to a reduction in services trade of 43%. NIESR then take a weighted average of these two estimates, which takes into account that as of 2014, 72.4% of trade with the EU was in goods, resulting in a decline in total UK trade in goods and services with the EU of 50%. It should also be noted that in (Ebell, Hurst, & Warren, 2016) NIESR also consider an alternative scenario, where total trade in goods and services with the EU declines by 72% based on other external analysis. However, we take the more conservative estimate of 50% for the WTO scenario.

We assume that this assumption applies equally to both Scotland and the UK. As discussed in Section 4, we apply a trade shock, beginning in 2019 Q1 (assuming this is the end of the two year negotiation period) by shocking the value of $\epsilon_{eu(Scot)}$ and $\epsilon_{eu(UK)}$, both initially set to equal 1, so that they both fall gradually in a linear fashion to equal 0.5 by 2021. This implies a halving of the size of EU import markets for the EU, from which point it remains at this new level to the end of the scenario period.

Adopting a WTO relationship would allow the UK to negotiate new trade deals with other countries, which may reduce trade barriers with non-EU countries in the future.

Since the nature and timescales for such agreements are currently unknown, they are not included in the modelling.

Tariffs

In addition if the UK no longer has a free trade agreement with the EU, we would expect tariff barriers to rise on trade with the EU. The average WTO most-favoured nation (MFN) import tariff is 9%. We again following NIESR in assuming a more conservative average tariff of 5% would be applied to trade in goods and services with the EU in a WTO scenario. They use the more conservative estimate to allow for some scope for the negotiation of a more preferential trading agreement with the EU being agreed over time. We again assume this tariff is applied in 2019 Q1 and is permanent for the entire scenario.

As discussed in Section 4, this 5% tariff shock is applied by permanently increasing the intercept of equation 6). This effectively raises the non-commodity export price to EU countries. This then feeds through to Scotland and the UK through equations 8) and 9) which are weighted by the respective trade relationship with the EU.

FDI

There is a broad consensus that leaving a free trade agreement leads to a fall in inward FDI flows. Taking the range of estimates from the literature we follow (Ramasamy & Yeung, 2010) 's central estimate of a decline in FDI of -24% for the UK as a whole as a result of leaving the EU in a WTO style scenario. Again this is the scenario assumed by NIESR in their analysis. This comes from the impact of openness on inward FDI flows along with declines in openness corresponding with the decline in trade flows from the gravity model literature. This is also in line with assumptions made by other institutions in their own FDI analysis such as (H.M.Treasury, 2016) whom for a WTO scenario suggest a range from -18% to -26%.

NIESR calculates that a corresponding fall in FDI flows of 24% is equivalent to a fall in total private sector investment (PSI) of 3.5%. This is effectively done by calculating the nominal value a fall in FDI flows would have as a percentage of the total private sector capital stock[7]. The 3.5% PSI shock is applied as a small reduction to the intercept of the capital accumulation equation 11) in each period for the entire simulation. This is done to achieve the desired fall in PSI of 3.5% by 2030. This shock is applied to begin in 2019 Q1 and lasts for the remainder of the scenario.

We apply this magnitude of shock equally to both Scotland and the rUK. There are arguments that Scotland may actually have a greater exposure to FDI, for example there is evidence that Scotland has performed strongly relative to the rest of the UK as a location for inward investment. A recent Ernst & Young Attractiveness Survey

[7] See Ebell and Warren (2016) for details on the calculation of these estimates.

suggested Scotland attracted more FDI projects than any part of the UK outside London for three of the past four years. However due to the limited data on this matter, particularly if this is investment from the EU or the rest of the world, and to reduce any subjectivity bias we follow the assumption that this shock is equal for Scotland and the UK as a whole.

Repatriation of EU Budget Contribution

As covered in Section 4, both Scotland and the UK are net contributors towards the EU budget, estimated roughly to be around 0.3% of GDP each. Following the approach of NIESR we assume that full repatriation of this net contribution occurs and we assume that all of this is filtered into government spending – specifically that Scottish and UK Government consumption grows by 0.3% of the nominal baseline GDP in each period. The positive shock is assumed to begin in 2019 Q1 to coincide with the projected end of exit negotiations with the EU and is permanent for the remainder of the scenario.

Productivity

As discussed in section 4, there is a large body of evidence around the relationship between openness and a direct impact on productivity levels in the economy. Both the (H.M.Treasury, 2016) and (OECD, 2016) analysis include such an analysis pulling from the literature as a basis for implementing direct shocks to productivity within NiGEM. NIESR do not initially include a productivity shock in their analysis, however when comparing their findings to others in the literature they go on to include a productivity shock for reasons of comparison.

While the (H.M.Treasury, 2016) do not give the size of the productivity shock directly, they report that its analysis is based on an elasticity of productivity to trade of between 0.2 to 0.3 - e.g. a 1% decline in trade would lead to a 0.2% to 0.3% fall in productivity. NIESR find estimates of a fall in *total* UK trade of around 20% - 30%, which equates to roughly a fall in TFP of 5% - which is the assumption NIESR then applies in their analysis. We follow this approach and assume that this shock applies equally to both Scotland and the UK.

Migration

In a WTO scenario we assume that the free movement of labour between the EU and UK no longer applies. As discussed in section 4 we therefor apply the appropriate shocks in line with the difference between the ONS High migration and Principle population projections.

A summary of the assumptions made for the WTO Scenario are outlined below:

Shock	WTO
Reduction in Scotland and rUK export market share in the EU	-50%
Increase in tariffs on Scotland and rUK trade with the EU	+ 5%
Productivity	-5%
Reduction in inward FDI flows and Private Sector Investment (PSI) to the rUK and Scotland	-24% (-3.5% PSI)
Population (impact of lower Net Migration)	-2% rUK -2.8% Scot
EU budget savings, % of GDP	+ 0.3%

4.1.2 A Bilateral Trade Agreement

We next consider a scenario under which the UK Government negotiates a bilateral trade agreement (*or Free-Trade Agreement; FTA*) with the EU for both the UK as a whole and for Scotland.

Trade

Similar to the WTO scenario the size of the reduction in trade with EU member countries is again based from the gravity model estimates. We again follow NIESR's example by drawing on the evidence presented in in (Baier, Bergstrand, Egger, & McLaughlin, 2008), whose estimates imply that leaving the EU in a Bilateral Trade/Free-Trade scenario would be associated with a decline in EU goods trade of between 25% and 38%. The reduction in services trade with the EU is based on (Van der Marel & Shepherd, 2013), whose estimates imply that leaving a free trade area in a Bilateral/Free-trade agreement scenario would lead to a reduction in services trade of 40%. Again following NIESR's example we take a weighted average of these two estimates resulting in a decline in total UK trade in goods and services with the EU of between 29% - 39%. We will again take the more conservative estimate of 29% for the bilateral trade agreement scenario. This is in contrast to the estimated fall of 50% for the WTO scenario.

We assume that this applies equally to both Scotland and the UK. As discussed in Section 4, we apply a trade shock, beginning in 2019 Q1 (assuming this is the end of the two year negotiation period) by shocking the value of $\epsilon_{eu(Scot)}$ and $\epsilon_{eu(UK)}$, both

initially set to equal 1, so that they both fall gradually in a linear fashion to equal 0.71 by 2021. This implies a reduction in the size of EU import markets for the EU by 29%, from which point it remains at this new level to the end of the scenario period.

Tariff

No-shock

EU Budget Repatriation

As stated previously, the initial bilateral trade agreement scenario assumes that the UK and Scotland do not retain the free movement of labour with the EU.

As covered in Section 3, both Scotland and the UK are net contributors towards the EU budget, estimated roughly to be around 0.3% of GDP each. Following the approach of NIESR we assume that full repatriation of this net contribution occurs and we assume that all of this is filtered into government spending – specifically that Scottish and UK Government consumption grows by 0.3% of the nominal baseline GDP in each period. The positive shock is assumed to occur in 2019 Q1 to coincide with the projected end of exit negotiations with the EU.

FDI

As mentioned in the WTO scenario, the analysis by (H.M.Treasury, 2016) offer a range of estimates for the likely fall in FDI flows for different scenarios leaving the EU would entail. This includes estimates for a WTO, Negotiated bilateral agreement (FTA) and EEA scenario. Their estimate for the Bilateral trade scenario range from -15% to -20%. Hence we take the central estimate of -17.5%. Applying a similar analysis as NIESR this would result in a net fall in private sector investment (PSI) of roughly 2.6%, relative to a fall of 3.5% in the WTO scenario. The calculations for this analysis can be found in (Ebell, Hurst, & Warren, 2016).

In a similar manner to before the 2.6% PSI shock is applied as a small negative shift to the intercept of the capital accumulation equation 11) in each period for the entire simulation. This is done to achieve the desired fall in PSI of 2.6% by 2030. This shock is applied to begin in 2019 Q1 and lasts for the remainder of the scenario. We again assume that this shock is equally applied to Scotland and the rUK.

Productivity

As stated before the (H.M.Treasury, 2016) and (OECD, 2016) analysis pull from the literature as a basis for implementing direct shocks to productivity within NiGEM for a range of scenarios. Again while the (H.M.Treasury, 2016) do not give the size of the productivity shock directly, they report that its analysis is based on an elasticity of

productivity to trade of between 0.2 to 0.3 - e.g. a 1% decline in trade would lead to a 0.2% to 0.3% fall in productivity. NIESR find estimates of a fall in total UK trade of around 13% - 18% for the Bilateral scenario this equates to roughly a fall in TFP of 3.5% which is the assumption we then apply. Again we assume this is the same for both the UK and for Scotland.

Migration

As stated above, we assume the Bilateral scenario does not include an agreement for the free movement of labour. Hence as in the WTO scenario we apply the appropriate shocks in line with the ONS High migration and Principle population projections as discussed in Section 4. This effectively mirrors the migration assumption as in the WTO scenario.

Shock	Bilateral Trade Agreement
Reduction in Scotland and UK export market share in the EU	-29%
Increase in tariffs on Scotland and UK trade with the EU	-
Productivity	-3.5%
Reduction in inward FDI flows and Private Sector Investment (PSI) to the UK and Scotland	-17.5% (-2.6% PSI)
Population (impact of lower Net Migration)	-2% UK -2.8% Scot
EU budget savings, % of GDP	+0.3%

4.1.3 EEA Membership

The final scenario under consideration is where both the UK and Scotland retain EEA membership. The assumptions for trade, tariffs, FDI and productivity are spelt out below:

Trade

Similar to the previous scenarios the size of the reduction in trade with EU member countries is again based from the gravity model estimates. We again follow NIESR's example by drawing on the evidence presented in in (Baier, Bergstrand, Egger, & McLaughlin, 2008), whose estimates imply that leaving the EU in a Bilateral Trade scenario would be associated with a decline in EU goods trade of between 25% and 38%. The reduction in services trade with the EU is based on (Ceglowski, 2006), whose estimates imply that leaving a free trade area in an EEA scenario would lead to a reduction in services trade of between 19% - 28%. Again following NIESR's we take a weighted average of these two estimates resulting in a decline in total UK trade in goods and services with the EU of between 23% - 35%. We take the more conservative estimate of 23% for the bilateral trade agreement scenario. This is in contrast to the 50% WTO assumption and the 29% Bilateral Trade assumption.

We assume that this assumption applies equally to both Scotland and the UK. As discussed in Section 4, we apply a trade shock, beginning in 2019 Q1 (assuming this is the end of the two year negotiation period) by shocking the value of $\epsilon_{eu(Scot)}$ and $\epsilon_{eu(UK)}$, both initially set to equal 1, so that they both fall gradually in a linear fashion to equal 0.77 by 2021. This implies a reduction in the size of EU import markets for the EU by 23%, from which point it remains at this new level to the end of the scenario period.

Tariff

No Shock

FDI

As mentioned previously, the analysis by (H.M.Treasury, 2016) offer a range of estimates for the likely fall in FDI flows for different scenarios leaving the EU would entail. Applying a similar analysis as NIESR in (Ebell, Hurst, & Warren, 2016) this would result in a net fall in private sector investment (PSI) of roughly 1.5%, relative to a fall of 3.5% in the WTO scenario.

In a similar manner to before the 1.5% PSI shock is applied as a small negative shift to the intercept of the capital accumulation equation 11) in each period for the entire simulation. This is done to achieve the desired fall in PSI of 1.5% by 2030. This shock is applied to begin in 2019 Q1 and lasts for the remainder of the scenario. We again assume that this shock is equally applied to Scotland and the rUK.

EU Budget Repatriation

We assume that membership of the EEA would involve contributions towards the EU budget. Hence for the EEA scenario no repatriation of budget contributions is applied.

Productivity

Again as stated before, the (H.M.Treasury, 2016) and (OECD, 2016) analysis pull from the literature as a basis for implementing direct shocks to productivity within NiGEM for a range of scenarios. Again while the (H.M.Treasury, 2016) do not give the size of the productivity shock directly, they report that its analysis is based on an elasticity of productivity to trade of between 0.2 to 0.3 - e.g. a 1% decline in trade would lead to between a 0.2% to 0.3% fall in productivity. NIESR find estimates of a fall in total UK trade of between 10% to 17% for the EEA scenario this equates to roughly a fall in TFP of around -2.4%. Again we assume this is the same for both the UK and for Scotland.

Shock	EEA
Reduction in Scotland and UK export market share in the EU	-23%
Increase in tariffs on Scotland and UK trade with the EU	-
Productivity	-2.4%
Reduction in inward FDI flows and Private Sector Investment (PSI) to the UK and Scotland	-10% (-1.5% PSI)
Population (impact of lower Net Migration)	0%
EU budget savings, % of GDP	0%

Migration

We assume that membership of the EEA would involve some form of continued free movement of labour. Hence we do not apply a migration shock as was the case for the WTO and FTA scenarios.

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