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THE MACRO-ECONOMIC IMPACT OF BREXIT: USING THE CBR MACRO-ECONOMIC MODEL OF THE UK ECONOMY (UKMOD)

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ABSTRACT. This working paper uses the new Centre for Business Research (CBR) macro-economic model of the UK economy to investigate possible futures following the referendum decision to leave the EU. The model was originally developed in response to the failure of academic and commercial economic forecasters to foresee or understand the economic crisis of 2008–9. The paper briefly explains and describes some of its key features. Since Brexit is a unique event with no precedent it is not possible to do a normal forecast in which a few assumptions are made about a limited range of exogenous variables. The best that can be done is to construct scenarios and two are presented here. The difficult part is to decide what scale of adjustment is needed to reflect the likely realities of Brexit. Gravity model analysis by HM Treasury of the potential impact of various outcomes for trade outside the EU is examined and found wanting. The gravity model approach is replicated and shows that the impact of EU membership on the level of exports to the EU is much smaller for the UK than for other EU members. The implication is that the impact of EU membership on UK trade is much less than suggested by the Treasury. In addition, the actual experience of UK export performance is examined for a long

period including both pre- and post-accession years. This augments the gravity model results in suggesting a more limited impact of EU membership. While we include a scenario based on Treasury assumptions, a more realistic, although in our view still pessimistic, scenario assumes a much lower level of the trade loss than that of the Treasury. The results are presented through comparing these scenarios with a pre-referendum forecast. In the milder Brexit scenario, there is a minor loss of GDP by 2025 (around 1%) but no loss of per capita GDP, and also less unemployment but more inflation. In the more severe, Treasury-based scenario the loss of GDP is nearer 4% (2.5% for per capita GDP), inflation is higher and the advantage in unemployment less.

JEL codes: E12; E17; E27; E37; E47; E66; F17

Keywords: Brexit; HM Treasury; macro-economic policy; fiscal and monetary policy; macro-economic forecasts; macro-economic models

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1. Introduction

The result of the referendum on membership of the European Union in June 2016 generated a large shock to the UK economy. Even after triggering the formal Article 50 mechanism in March 2017 to begin the process of leaving, the final arrangements for trade and migration are not yet known. The UK government intends to achieve an exit from the EU which returns control of migration to the UK, involving leaving the single market, and removing the UK from the jurisdiction of the European Court of Justice. The aim is to secure a free trade agreement with the remainder of the EU, but if this is not feasible then the UK will leave without a formal trade agreement and rely on World Trade Organisation (WTO) rules to govern its trade with both the EU and with the rest of the world.

The UK was already a semi-detached member of the EU, outside both the Euro single currency area and the Schengen area of passport-free movement of people, and as a result the likely impact of leaving the EU will be less of a shock than might otherwise have been the case. Even so, leaving will involve one of the largest changes in the institutional arrangements for the UK economy since joining the EU in 1973. It is not of course the only large shock over this period. The accession of the Eastern European A10 states between 2004 and 2013 represented a large shock, albeit one not immediately recognized, in setting up the large-scale immigration flows in the UK which became one of the two strongest factors behind the "leave" vote in the referendum.

In this paper we use the Centre for Business Research (CBR) macro-economic model of the UK economy to estimate the potential impact of what has come to be known as "Brexit." From the outset we need to say that no normal forecast is possible. The CBR model is an econometric model which uses a large set of equations to forecast future trends, each equation based on data covering the last few decades of UK economic behaviour.[1] Because this period has been almost wholly one in which the UK has been a member of the EU, the equations contain little or no direct information about how the UK would fare outside the EU. Put simply, leaving the EU is a unique event; no country has ever done this. The best we can do is to construct a series of scenarios based on assumptions about future trading arrangements, migration controls and about the short-term uncertainties which could affect business investment in the run-up to the likely leaving date of 2019.

Our estimates of the impact of Brexit will depend partly on the nature of the CBR model and we will say a little about this. Mostly the estimates will reflect the assumptions entered into the model. Much was written and said during the referendum campaign about such assumptions, much of it highly controversial. Most detailed were the two major reports from H.M. Treasury, one on the long-term impact and the other on the more immediate consequences of a vote to leave.[2] Although the analysis in these Treasury reports was inevitably colored by the Government's stated opposition to leaving the EU, the two reports, together involving 280 pages of analysis, offered a comprehensive literature review and were based on best practice in that literature. We thus review the Treasury's methodology leading to their conclusion that a complete break with the EU Single Market would lead to a loss in GDP of 7.2% by 2030. Since the Treasury analysis strangely says little directly about the UK's trade record within the EU we also examine this in detail to see whether this supports the more indirect methods used by the Treasury in assessing the impact of EU membership on the volume of trade.

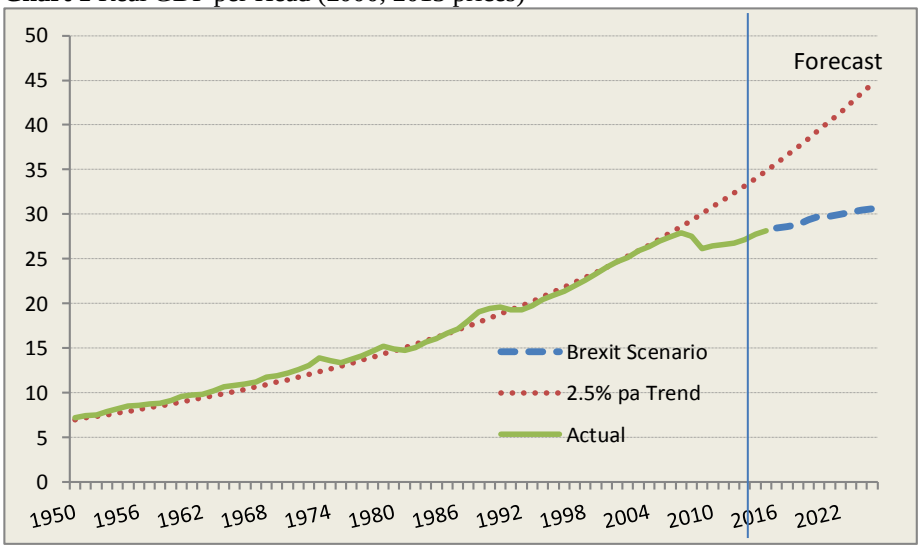
2. The CBR Macro-Economic Model

The main burden of this paper involves assessing what assumptions should be entered into our CBR macro-economic model and then using these assumptions to generate forecasts for two scenarios over the period 2017–25. These issues are dealt with below, but first we describe some of the relevant context of the UK economy and the way in which the CBR model approaches key issues.

Something has gone badly wrong with economic growth in the UK where a relatively consistent growth trend of close to 2.5% per annum has comprehensively broken down (Chart 1). Similarly dramatic breaks of trend can be observed for the USA and the EU although in the latter case the slowdown

began rather earlier in 2000 coinciding with the introduction of the Euro. These breaks of trend are related to the so-called "productivity puzzle" for which economists have no agreed explanation. The puzzle is to explain why the growth of output per hour worked has slowed since 2000, and especially since the financial crisis of 2008. Alongside the failure of existing forecasting models to predict the 2008 economic crisis this break of trend provides another reason for developing a new model which can predict and help to account for these bewildering trends. Our general view is that the slowdown in growth is due to credit conditions in a post-crisis world with a badly impaired banking system. Perverse government austerity programs in major economies have exacerbated the situation but the main cause is financial.

Chart 1 Real GDP per Head (£000, 2013 prices)



Note: The forecast to the right of the vertical line is our baseline Brexit scenario described below.

2.1. Consumption, borrowing and credit super-cycles

One key feature of the model is the important role of credit in generating business cycles. The consumption function shown in Table 1 has conventional features in that consumption depends on disposable income and wealth. Importantly, these loans are taken out to purchase houses (excluding re-mortgaging) but around 75% of the loans are for the purchase of existing rather than new dwellings and these are thus loans which end up largely as bank deposits of those selling houses (often inherited property). The evidence of the equation above is that a proportion of these deposits are used to finance consumption.

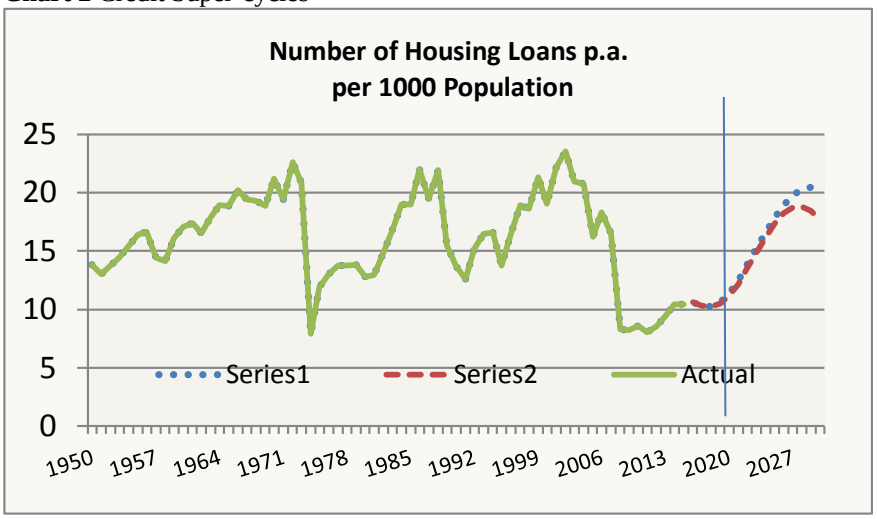
Table 1 Consumption Function

Dependent Variable: D(CV)		
Method: Least Squares		
Sample: 1975 2015		
Variable	Coefficient	t-Statistic
Constant	17653	1.7
CV(-1)	-0.39	-8.6
YD(-1) /CP(-1)	0.31	7.5
FASN(-1)/(CP(-1))	0.011	2.9
DEBT_ST(-1)/CP(-1)	-0.18	-3.0
NEW_HOUSING_LOANS(-1)/CP(-1)	0.33	9.3
D(YD/CP)	0.29	5.3
D(FTSE/CP)	1191	5.4
DLOG(HPI)	64129	5.0
R-squared	0.96	
F-statistic	43.8	Durbin-Watson 2.2

Note: CV is consumption in constant prices, YD is disposable income, CP is the consumption deflator, FASN is financial assets, DEBT_ST is short term household debt; FTSE is the stock exchange all-share index and HPI is the house price index. All variables in current prices unless otherwise stated.

This in turn is important because of the volatility of mortgage credit. The number of housing loans has fluctuated in large 20-year cycles, termed financial cycles by Claudio Borio of the Bank for International Settlements, to distinguish this long-period financial cycle from the usual business cycle of 3–5 years. We will use the term super-cycles to emphasize the long-duration of this phenomenon. The extended period with a very low volume of loans since 2008 is unprecedented in the post-war economic history of the UK and is largely responsible for the sluggish growth of GDP over this period. This is the way in which a badly impaired banking system prevents a normal recovery from a deep recession. Our estimate is that the potential demand for loans is currently at historically high levels due to very low mortgage interest rates, but the number of loans is low due to banks' restrictions on the supply of loans including requirements for sizable deposits. With house prices remaining very high in the UK, the requirement for substantial deposits places a large barrier in the way of new buyers.

Chart 2 Credit Super-cycles



Source of data: Council of mortgage lenders. Data is estimated for the period before 1974.

The importance for this in assessing the impact of Brexit lies in the context it sets for economic growth. Credit is currently on the upswing of the latest super-cycle leading to reasonably rapid rates of household spending. This upswing, helped by government schemes to stimulate house purchase for first-time buyers, allowed the previous Chancellor of the Exchequer, George Osborne, to pursue a policy of mild public sector austerity without doing much harm to the growth of aggregate GDP. A continuing upswing for the next five years would provide a favorable context for the disruptive process of leaving the EU. Beyond the middle years of the next decade we had expected before the referendum that the credit cycle would turn down, as demand for loans became the main constraint on loan volumes with demand depressed by high debt levels and falling real wages. Chart 2 shows that the cycle is now expected to continue its sluggish recovery, towards fully meeting demand for housing loans which is potentially large when interest rates are as low as they have been in recent years.

3. Assumptions on Brexit

The difficulty in generating any forecast for the future of the UK economy is in knowing what to assume about both future trade arrangements and the short-term impact of uncertainty about these arrangements. As we have stated, the best that is possible is to generate scenarios based on assumptions about these things. This is not to say that there is little on which to base assumptions. A plethora of reports were produced during the referendum campaign to

assess what the impact might be of a vote to leave the EU and, several months on from the referendum, some consequences have also begun to emerge.

3.1. Short-term impact of Brexit

These reports published during the referendum campaign generally produced separate estimates for both the short-term impact of uncertainty and the long-term impact of changed trading arrangements. A summary of short-term impacts from non-government sources is shown in Table 2. The government's own estimates are shown in Table 3. The estimates vary depending on what is assumed about the nature of the likely eventual relationship sought with the EU. In general the largest estimates of losses of GDP stem from an expectation that the UK will leave the single market and customs union and will fall back on WTO rules. Something of a consensus emerges from these studies with an expectation that uncertainty will reduce GDP (relative to a pre-referendum baseline) by around 1% after one year, 2–4% after 2 years, 3–4% after three years and 4–6% after 5 years. The Treasury's estimates are at the high end of this spectrum of views with a view that GDP would be reduced by between 3.5% and 6%.

The Treasury summarized its own view in the following words, "The analysis shows that the economy would fall into recession with *four quarters of negative growth*. After two years, *GDP would be around 3.6% lower*…. the fall in the value of the pound would be around 12%, and *unemployment would increase by around 500,000*, with all regions experiencing a rise in the number of people out of work. The exchange-rate-driven increase in the price of imports would lead to a material increase in prices, with the CPI *inflation rate higher by 2.3 percentage points after a year*"[3] (our emphasis added).

Table 2 HMT Summary of Studies of Short-term Impact of Brexit on GDP

	Effect on level of GDP (%)
PwC/CBI[54]	-3.1 to -5.5 (over 5 years)
Citi[55]	-4.0 (over 3 years)
Credit Suisse[56]	-1.0 to -2.0 (over 2 years)
Deutsche Bank[57]	-3.0 (over 3 years)
HSBC[58]	-1.0 to -1.5 (over 1 year)
JP Morgan[59]	-1.0 (over 1 year)
Morgan Stanley[60]	-1.5 to -2.5 (over 2 years)
Nomura[61]	-4.0 (over 1 year)
Société Générale[62]	-4.0 to -8.0 (over 5 years)

Source: H.M. Government (2016). H.M. Treasury Analysis: The Long-term Economic Impact of EU Membership and the Alternatives, April 2016. Cmnd. 9250. Box 3.D

Table 3 HM Treasury Estimates of the Short-term Impact of Brexit

Immediate impact of a vote to leave the EU on the UK (% difference from base level unless specified otherwise)

	Shock scenario[a]	Severe shock scenario[a]
GDP	-3.6%	-6.0%
CPI inflation rate (percentage points)	+2.3	+2.7
Unemployment rate (percentage points)	+1.6	+2.4
Unemployment (level)	+520,000	+820,000
Average real wages	-2.8%	-4.0%
House prices	-10%	-18%
Sterling exchange rate index	-12%	-15%
Public sector net borrowing (£ billion)[b]	+£24 billion	+£39 billion

[a] Peak impact over two years. Unemployment level rounded to the nearest 10,000. [b] Fiscal year 2017-18.

Source: H.M. Government (2016). H. M. Treasury Analysis: The Immediate Economic Impact of Leaving the EU. May 2017 Cmnd. 9292, p. 8.

The mechanism underlying the Treasury assessment is that firms and households would begin adjusting to the expected new relationship with the EU, and business investment would be damaged by uncertainty. Financial markets would react immediately with a 10–14% fall in the sterling exchange rate. Consumer spending would be reduced because higher inflation occasioned by a lower exchange rate would lead to lower real wages. Exports would be higher and imports lower but the overall impact would be sharply negative. Some econometric work was done to assess the relationship between measures of uncertainty and key macro-economic variables. However the actual judgment on uncertainty impacts is arbitrary with the assumption of a 1 to 1.5 standard deviation rise in uncertainty. A similar assumption is used to obtain the financial markets effect resulting in a 1–2 percentage point rise in market interest rates and equity risk premia.

Writing almost a year after the referendum result, only one of the Treasury's expectations has been clearly realized. This is the fall in the value of sterling. A 12% fall in the effective exchange rate matches the HMT "severe shock" scenario. There was however little movement on interest rates, even after the US Presidential election result in November 2016 when anticipated higher infrastructure spending and higher expected inflation quickly drove bond yields upwards. The UK Treasury expectation that equity risk premia would rise, leading to lower equity prices, has thus proved wrong. The sterling depreciation instead led to higher UK equity prices as corporate earnings from abroad became worth more in sterling. Preliminary data also suggest little or no fall in consumption, house prices or house building. GDP in the third and fourth quarters of 2016 was well above Treasury expectations, although slow

growth in the first quarter of 2017 may indicate the start of a period of slower growth.

Our own expectation has been that there would be little direct impact of Brexit on consumer spending or investment in housing. Since, as we argue below, the long-term impact of Brexit is expected to be well below Treasury estimates, even if the UK ends up with no free trade agreement or other privileged access to the EU Single Market, our expectation of any transitional losses to investment would be relatively small. Uncertainty effects on company investment are harder to assess. It seems reasonable to expect that at least some domestic firms will delay investment until they are clearer about future trade arrangements; foreign direct investment will be reduced partly for the same reasons and also because some firms wish to locate within the EU. The initial evidence to date has been mixed. Several strategically important firms have announced major investments. Others, particularly in financial services are said to be at least exploring the possibility of relocating some activities into the continuing EU. These announcements have no doubt influenced the OBR in the March 2017 forecasts released in conjunction with the Chancellor's Spring Budget. Their forecast of GDP growth of 2.0% in 2017 is a long way from the Treasury's four quarters of negative growth.[4]

We have made two arbitrary assumptions on short-term impacts to drive our Brexit scenarios. We propose two scenarios. A severe scenario broadly matches Treasury expectations even though we view these as unrealistic. A mild scenario assumes a significant but milder reduction in business investment. In the mild scenario net new business investment is arbitrarily reduced in 2017 by close to 3% below the pre-referendum baseline, after which uncertainty reduces and some recovery of investment occurs. In the severe scenario the reduction in business investment is closer to 30%. The sterling effective exchange rate is assumed to depreciate immediately by 10%, although some of the depreciation into 2017 was already projected in our pre-referendum baseline forecast. The impact on consumer spending, household investment and exports and imports are all indirect consequences of the above assumptions without any more direct impacts.

3.2. Long-term impact of Brexit

It is widely accepted that the long-term impact of Brexit depends on the trade arrangements agreed for the UK after leaving the EU. Several forecasters have made separate estimates for the UK joining the European Economic Area (EEA), negotiating a new free-trade agreement with the EU, or most drastically having no agreement and falling back on World Trade Organisation (WTO) rules. In this paper we focus on the last of these three as the putative worst-case scenario. It should be noted that the average tariff the UK would face under WTO rules for exports of most manufactures to EU countries is

only 4%, the main exceptions being cars and some agricultural products. If there were a significant loss of trade when the UK leaves, it would probably arise if there are documentation issues when goods cross borders. The UK would begin by being already compliant with EU regulations on items such as pharmaceuticals and food, having been a member state for over forty years.

Other scenarios should not be as bad for the UK. The Institute for Fiscal studies (IFS) usefully summarized the range of estimates for fourteen years after the referendum (Table 4). Several major forecasters (Treasury, OECD, NIESR and the LSE's Centre For Economic Policy (CEP) broadly agree that leaving the single market and falling back on WTO rules would lead to GDP being more than 7% lower by 2030 than it would otherwise have been. PwC, Oxford Economics and Open Europe have lower impacts for the scenarios they consider, but the main reason seems to be that they exclude the productivity effects included in the Treasury, OECD, NIESR and CES studies. The one clear outlier is that of the Economists for Brexit led by the free-market economists Patrick Minford and Gerard Lyons. The main reason for the positive impact of Brexit in their study appears to be their assumption that all exports and imports behave like oil and other commodities. Commodities can always be sold in world markets at prevailing world prices; the only constraint on how much quantity can be sold in any market is the cost of the goods produced, so that at world prices, the exports are profitable. In this view, being shut out of any particular market makes little difference. This seems to us an assumption which, although true for some exports and more imports, is not representative of most exports.

Table 4 IFS Summary of Assessments of 2030 Economic Impact of Brexit

Organisation	Scenario	Estimate (% GDP)	Range	Impacts modelled
CEP (2016a)	Dynamic EEA/FTA	–7.9	(–6.3 to –9.5)	Budget, trade, productivity
	Static EEA	–1.3	N/A	Trade only
	Static WTO	–2.6	N/A	Trade only
HM Treasury	EEA	–3.8	(–3.4 to –4.3)	Budget, trade, FDI, productivity
	FTA	–6.2	(–4.6 to –7.8)	
	WTO	–7.5	(–5.4 to –9.5)	
OECD	WTO/ FTA	–5.1	(–2.7 to –7.7)	Budget, trade, FDI, productivity, migration, regulation
NIESR	EEA	–1.8	(–1.5 to –2.1)	Budget, trade, FDI
	FTA	–2.1	(–1.9 to –2.3)	
	WTO	–3.2	(–2.7 to –3.7)	
	WTO+	–7.8	N/A	Adds productivity
PwC/CBI	FTA	–1.2	N/A	Budget, trade, FDI, regulation
	WTO	–3.5		
Oxford Economics	FTA[a]	–2.0	(–0.1 to –3.9)	Budget, trade, FDI, migration, regulation
Open Europe	FTA	–0.8 to +0.6	(–2.2 to 1.6)	Budget, trade, migration, regulation
Economists for Brexit	WTO	+4.0	N/A	Budget, trade[b]

[a] FTA with moderate policy scenario used as central estimate; range includes 'liberal customs union' (–0.1) to 'populist MFN scenario' (–3.9).
[b] Regulation impacts assessed separately.
Note: Estimates are for impact on GDP in 2030.
Source: Estimates from organisations above. Authors' assessment of impacts modelled.

Source: Institute of Fiscal Studies (2016). Brexit and the UK's Public Finances. Table 3.1, p. 18.

3.3. How does the Treasury estimate its long-term impact?

In this paper we focus on the Treasury's assessment of the long-term impact of Brexit as a representative example. The Treasury examines three possible cases (EEA, FTA and WTO rules) and we take only the last of these as an example of a worst-case scenario. The Treasury report[5] made estimates of three macro-economic variables and then inserted these estimates into the NIESR's NiGEM model to calculate overall impacts on GDP and GDP per head. The three variables are:

- Trade (exports and imports)
- Foreign Direct Investment (FDI)
- Productivity (GDP per head).

3.4. The Treasury's estimates for WTO rules

The Treasury's estimates are summarized in the Box below. These estimates are for a case in which the UK leaves the EU without joining the European Economic Area or concluding a new free-trade agreement. The estimated loss of trade with the EU in this option is very large at 43%, and is based on coefficients from econometric work which the Treasury regards as being in line with academic studies. The same work leads the Treasury to conclude that these losses would not be offset by any gains in trade with non-EU countries.

Box Summary of Treasury Estimates of 2030 Impacts of Brexit with WTO Rules

Trade

• 76% gain in trade with EU due to membership of EU assumed to be fully reversible, giving a loss of trade with EU of 43% (=76/176)

• No trade diversion i.e. no loss of trade with 3rd parties due to membership

• Giving **a total loss of trade (to EU and non-EU destinations) of 24%**

FDI

• **Loss of 22% of FDI** (measured in money)

Productivity

• Productivity (per capita GDP) impact due to loss of trade at 25% of trade loss.

• Extra small productivity loss of 4% of FDI loss

• **Overall loss of GDP is 7.5% after 15 years** (Table 3.D)

Migration

• No impact of any reduction in migration

Source: HM Treasury (2016a) Appendix A.

The gains from membership of the EU, relative to no FTA are assumed to be largely reversible; hence it is imperative to understand how these gains are estimated.[6] The EU6 share of UK goods exports at Accession in 1973 was 25% and a 76% increase in trade due to EU membership, without any change in non-EU trade would take that share up to 35% (=1.76*25/125). By the next wave of accessions to the EU in 1986 the actual UK share had risen to 37.7%, roughly in line with the Treasury calculation. However the EU6 share peaked at the end of the 1980s at just over 40% and has subsequently fallen back to 30% by 2015. Hence, by 2015 the overall increase in UK goods exports to the EU6 was only half of the Treasury estimate. How, then did the Treasury arrive at the high estimate of 76%?

4. The Gravity Model Approach

The most common approach to estimating the impact of free trade areas, customs unions or monetary unions, over the last decade, has been "gravity" modeling. The Treasury report describes this as "best practice" and uses this approach to derive its own estimate of the UK gain in trade in goods and services from membership of the EU. The approach is analogous to gravity in Newtonian physics where the attraction between planetary bodies is directly proportional to their masses and inversely proportional to the distance between them. In trade analysis the volume of trade in any period between a pair of countries is assumed to be proportional to the product of the size of their economies, and inversely proportional to some measure of the distance between them. Other factors such as common language or currency can also be taken into account. In the Treasury version below, the product of the populations of the trade partners is also taken into account to give some weight to productivity (GDP per head) as well as GDP per se.[7]

$$\ln(T_{ijt}) = \alpha_{ij} + \gamma_t + \alpha_1 \ln(Y_{it} * Y_{jt}) + \alpha_2 \ln(POP_{it} * POP_{jt}) + \varepsilon_{ijt}$$
$$= \alpha_{ij} + \gamma_t + \alpha X_{ijt} + \varepsilon_{ijt}$$

Where:

- T_{ijt} denotes trade flows between country i and country j at time t
- Y_{it} and Y_{jt} are the GDP of countries i and j at time t
- POP_{it} *and* POP_{jt} are the population of countries i and j at time t
- γ_t is a set of time dummies
- α_{ij} is the country-pair fixed effect

In practice the influence of all time-invariant factors, including distance, are usually wrapped up in the fixed effects for each pair of countries, α_{ij}. The impact of membership is simply measured via dummy variables indicating which countries are members of the EU or associated free trade areas:

$$\ln(T_{ijt}) = \alpha_{ij} + \alpha X_{ijt} + \beta_1 EU2_{ijt} + \beta_2 EU1_{ijt} + \beta_3 EEA_{ijt} + \beta_4 FTA_{ijt} + \varepsilon_{ijt}$$

Where:

- *EU1 is a dummy variable which equals 1 if only one country is a member of the euro area at time t and zero otherwise*
- *EU2 is a dummy variable which equals 1 if both the origin and destination countries are members of the euro area at time t and zero otherwise*
- *EEA is a dummy variable which equals 1 if both the origin country is a member of the European Free Trade Area*
- *FTA is a dummy variable which equals 1 if both the origin country is a member of a FTA with the EU.*

The Treasury report gives limited information about the nature of their analysis but it appears to involve trade for over 118 countries over the period 1948–2013. With (118 x 117 =) 13,806 country pairs over 28 years this gives over 380,000 individual observations.

The coefficients on the EU dummy variables are an average over the period of EU members' deviations from the level of trade predicted by the general world relationship between trade and GDP etc. The issue of trade diversion, i.e. loss of third party trade from countries which are EU members, is determined from the dummy EU1 where only of a country pair is an EU member. With 118 countries in all, the number of such country pairs will be very large and the impact is estimated as an average over all of these countries, many of which will be small developing nations.

The Treasury is thus relying on averages across a range of EU member states at different dates, rather than on the direct experience of the UK itself. Indeed, the Treasury analysis provides virtually no information directly about UK trade with the EU. We will return to this issue below, but will first complete a description of the Treasury approach to estimating the overall impact of Brexit.[8]

4.1. Service sector trade

A similar approach is used to estimate the impact of EU membership on trade in services. Once again the data includes a large range of countries over the period 1981–2009. Once again the method finds a positive impact of EU membership, albeit smaller than for goods, and no evidence of trade diversion.

4.2. The impact on FDI

The Treasury again uses a gravity model to assess the extent to which EU membership increases the flow of foreign direct investment between country pairs. The data in this case covers 40 countries over the period 2000–14. Although the Treasury does not say so, the data is in the form of financial flows. It thus includes financing flows and mergers and acquisitions alongside physical investment projects such as new green-field sites or extensions to existing sites. The Treasury does admit that the data is troublesome due to profit shifting for tax reasons. In fact the data can be very difficult, with annual FDI inflows into Luxemburg in recent years averaging 320% of GDP and flows into Ireland and the Netherlands averaging 25% of GDP. Our own estimates for the UK are that under a quarter of FDI flows measured in money terms relate to new physical investment projects.[9] The issue then is: even if EU membership increases FDI flows in money it is difficult to assess what impact this will have on an individual economy. The impact of new physical investment is likely to be very different from acquisitions or profit-shifting.

The estimation period used in this analysis, i.e. 2000–14, means that the results are dominated by countries which joined the EU in these years. These were of course largely Eastern-European post-Soviet bloc countries with very low labor costs. The impact of EU membership was generally very large, as restrictions on inward investment from the EU were removed and EU-based companies were able to take advantage of the low cost of labor. The analysis estimates that EU membership increased FDI flows by 22% with no diversion from other countries, but it is difficult to know what this implies for physical FDI flows into the UK and hence for UK economic development.

4.3. The impact on productivity

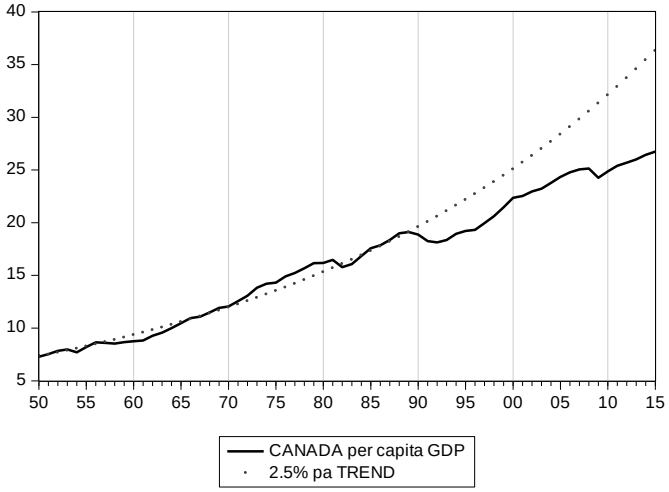
The Treasury Report summarizes a few academic reports linking expansion in trade and FDI to increases in economy-wide or firm productivity. Some of the trade studies are based on a gravity model methodology. Once again the relationships emerging from these studies are based on the experience of up to 200 countries. Most of these countries are necessarily small emerging economies. In some cases, trade increases as economies emerge from behind high tariff walls allowing multi-national companies to operate. In these circumstances it is unsurprising that aggregate productivity rises, but it is not obvious that these results can be applied to a well-developed open economy like the UK leaving a single market and customs union with generally low tariffs.

An average elasticity of 0.25 is drawn by the Treasury from this literature for the relationship between trade and productivity changes. Even if this were applicable, any impact depends on the size of the trade losses based on gravity model studies which, in our view, are unreliable. Two established practitioners of this approach recently published a *mea culpa* in which they discovered that their earlier results were extremely sensitive to equation specification. They concluded that it is "currently beyond our ability to estimate the effect of currency unions on trade with much confidence."[10] This paper referred to trade and currency unions but it seems likely that the conclusions apply to similar studies of trade and customs unions.

The Treasury also cites a number of firm-level studies. It is well known that foreign-owned firms generally have higher productivity than domestic companies – much of this is because the former are more likely to be exposed to greater competition and to be involved in international trade and foreign direct investment. The most comprehensive of these studies in the view of the Treasury is the study by Melitz and Trefler (2012), showing that productivity in Canadian manufacturing grew by 14% from 1988–96 following Canada's joining the US–Canada FTA in 1989 and the full NAFTA in 1993. What the Treasury did not say was that part of the effect was due to an 18% loss of jobs in low productivity plants in Canada. Nor did they apparently

know that the impact on the Canadian economy as a whole was entirely the opposite. Per capita GDP fell sharply in 1990 and has never regained the 2.5% per annum growth trend established over the previous four decades and more (Chart 3). What seems to have happened is that opening Canada to greater competition raised productivity in a range of surviving manufacturing firms but displaced a significant amount of labor in low productivity sectors. Importantly, this labor was never re-employed at pre-NAFTA levels of productivity. This may be a general process since most countries joining the EU at various dates between 1970 and 1996 had a similar experience. This includes the UK joining in 1973.

Chart 3 Per capita GDP in Canada



The Treasury also conducts a production function analysis to estimate a link between FDI and "technology." They find a small elasticity of 0.04. However, given our misgivings about the earlier link between FDI and trade openness it is not obvious that this is very informative.

4.4. Summary of treasury views on the impact of Brexit

The Treasury estimate of a 43% loss of trade with the EU in the event of reverting to WTO rules translates into a 24% loss in total trade. They also estimate that no diversion in trade with non-EU countries occurs to offset these losses. Both of these conclusions appear implausible, especially since EU external tariffs average only 4% although additional costs of customs documentation will add to this. Non-tariff barriers can be high but these are unlikely to be relevant to UK exporters since most of these will already be compliant with most EU regulation, at least in the short term. Issues like "passporting"[11] for financial services may also add to the cost of trade,

although it is not yet clear whether EU equivalence rules will make this less of an issue. Another issue is whether the introduction of customs checks and associated documentation will disrupt firms with complex supply chains to and from EU firms and which rely on "just in time" production methods. While this could increase the costs of trade, it is worth noting that the European Commission has announced plans to introduce an electronic customs process, which should speed up the movement of goods.

Most importantly, our view is that the gravity model technique is controversial and as applied by the Treasury is flawed. The Treasury conclusion that EU membership doubles the amount of goods trade appears not to apply to the UK. In estimating the impact of EU membership on UK trade the Treasury analysis relies on the coefficients of a dummy variable for EU membership. In principle this is reasonable, but the value of the coefficient obviously depends on the underlying equation. In the Treasury analysis this equation is estimated over a very large number of countries most of which are involved in minimal levels of trade with the UK. The estimate is also an average across EU members and is estimated over the long period spanning almost three decades. In Appendix B to this paper we estimate a gravity model for goods trade. This analysis generates a smaller coefficient for EU membership than does the Treasury analysis and a much smaller impact for the UK alone.

The Treasury approach also assumes that the EU coefficient captures the beneficial impact of the Single Market on trade between EU members, but in our view this cannot be the entire impact. A major additional factor is the growth of demand for imports within the EU compared with elsewhere. The fact that the EU, and especially Eurozone, economies have grown so slowly over recent decades has meant that exports to EU countries have grown less rapidly than exports to other destinations.[12] This will affect all exporters but especially those which undertake most trade with EU countries, and hence mainly the EU countries themselves. Since gravity models estimate the amount of extra trade occurring between EU members, *after allowing for the size of the economies,* the measure does not take account of any slower growth in the sizes of EU economies relative to non-EU economies. Even if there are persistent benefits from EU membership due to an absence of tariffs and border controls, and to uniform regulations, there will be offsetting disadvantages from slow growth. Our estimate in Appendix B of the impact of EU membership on UK exports is relatively stable over time, but as we show in the next section, actual UK exports to the EU have grown over the last decade much more slowly than UK exports to non-EU destinations.

The Treasury has used an impact for membership of the Single Market which is an average over all member states. The evidence of our analysis indicates that the UK experience is very different from the other member

states. It turns out that UK exports to EU partners are much lower than predicted by our equation with the single exception of exports to Ireland. This may also be the case in the Treasury analysis but their report makes no comment on this, even though an earlier Treasury paper showed clearly that the impact of EU membership on goods trade was much smaller than the average impact across all EU members.[13]

Since the loss of trade turns out to be much lower in our analysis than in that of the Treasury, their assumption that a loss of trade will reduce productivity becomes less important. In any case it is not obvious that a productivity link of this magnitude based on evidence dominated by emerging economies is appropriate for the Brexit situation. Nor is the evidence cited on FDI impressive, although there is likely to be some loss of physical FDI.

Another issue ignored in the Treasury analysis is the importance of exchange rates. The 12% depreciation of sterling that occurred immediately after the Referendum will do much to offset EU tariffs on EU exports. Our estimate is, for instance, that a 15% depreciation of sterling relative to the euro is sufficient to offset the impact of a 10% EU external tariff on motor vehicles, including the higher costs of intermediate imports to this sector. For most engineering firms, tariffs of close to 2% are small in relation to a sterling depreciation of this magnitude.

Our preferred gravity model equation agrees with the Treasury in indicating that there is no evidence that membership of the EU has led to reduced exports to non-EU markets. However, this does not mean in our view that leaving the EU cannot result in increased exports to non-EU markets. We do not go as far as the "Economists for Brexit" in assuming that all exports lost in EU markets can be sold in non-EU markets,[14] but it defies logic to move to the opposite extreme and accept the Treasury estimate that no trade will be diverted. Some UK exports (e.g. milk powder) are commodities that can be sold on world markets as the Economists for Brexit suggest. For other exports it may take longer, in some cases much longer, to build additional export sales.

In summary, we regard much of the Treasury evidence on the likely impact of Brexit on trade, FDI and productivity to be flawed and not directly relevant to the likely impact on UK trade from leaving the EU. Our attempt to replicate the gravity model analysis, reported in Appendix B, generated very different conclusions to those of the Treasury. It was a serious weakness of the Treasury report that almost no evidence of the record of UK trade with the EU was included in the analysis. Before outlining this analysis we examine the direct evidence on UK trade.[15]

5. Direct Evidence on UK Exports to the EU

Another approach to analyzing the impact of the UK joining the EU, so as to understand what might happen when the UK leaves, is to examine time series data. This approach compares the pre-accession trends in economic behavior with post-accession behavior. Two variables are of key interest. The first is trade, and we will examine the EU share of UK exports of goods and services. Instead of looking at the EU membership at any particular date, we examine a constant set of the current 28 members throughout a period from 1950–2015. Second is productivity. If membership of the EU is beneficial for productivity, this should show up in the UK's productivity record. The difficulty comes in allowing for factors other than EU membership, especially since the UK's accession date of 1973 was in many ways a turning point in post-war economic history, especially in Western Europe.

5.1. Data sources

For data on trade we have used the IMF's Direction of Trade (DOT) series of annual goods exports by country from 1948.[16] This provides data for our 1950–2015 period for all of those current member states that have been independent states throughout the period. Data is thus missing prior to 1990 for the Baltic States, formerly part of the Soviet Union and Slovenia and Croatia which were part of the former Yugoslavia. Even without these five states, the data covers 98% of the exports of the current EU. However for completeness we have estimated UK exports to these five states for the period prior to 1990.[17]

ONS data on total UK exports of goods and services is available back to 1950. The IMF DOT data provides data for exports to the EU28 but only for goods. For services, ONS provides data only from 1999. For earlier years we have assumed that the EU28 share of UK services exports expanded at the same rate as the share for goods. The sum of exports of goods and services at current prices is deflated by the same UK export price deflator whether these exports are to the EU or to other countries.

Productivity is measured as per capita GDP. Data for GDP and population has been obtained for the EU28 countries from the Conference Board database. GDP is measured in $1990 at purchasing power parity. Data is converted into sterling using the average dollar-sterling exchange rate for each year. Missing data for the Baltic and former Yugoslav States prior to 1990 is estimated in the same way as for trade.

5.2. Trends in UK exports to the EU28

We examine exports to all current EU member states from 1950 to 2015 irrespective of whether the states were EU members at any particular date, or

even whether they were independent states. This avoids the problem of an EU membership which changes over time. If membership of the EU promotes trade then we might expect to see growing exports to the EU28 not only after the UK joined in 1973, but also as other countries joined in subsequent years and as countries left the Soviet orbit after the fall of the Iron Curtain in 1989.

Total exports to the EU28 countries grew surprisingly rapidly through most of the post-war period (Chart 4). The 6% per annum pre-accession growth trend was sustained right up until the end of the 20th century, despite the sharp slowdown in the growth of the European economies.[18] UK exports to the rest of the world grew more slowly than exports to the EU28 in the pre-accession period at just over 3% per annum or around half the rate of exports to the EU28 (Chart 5). This reflected the more rapid growth of the European economies recovering from the enormous damage of World War II and catching up with the USA representing the best practice frontier for technological efficiency. The growth of UK exports to non-EU28 countries clearly slowed down after UK accession in contradiction to the Treasury finding that no trade diversion took place.[19] From the millennium, UK exports to non-EU countries have grown rapidly, and much more rapidly than to the EU. It is a little-known fact that Commonwealth markets have grown faster than EU markets since the UK's historic switch from the former to the latter in 1973.[20]

Chart 4 UK Exports to the EU28 States (£2013 prices)

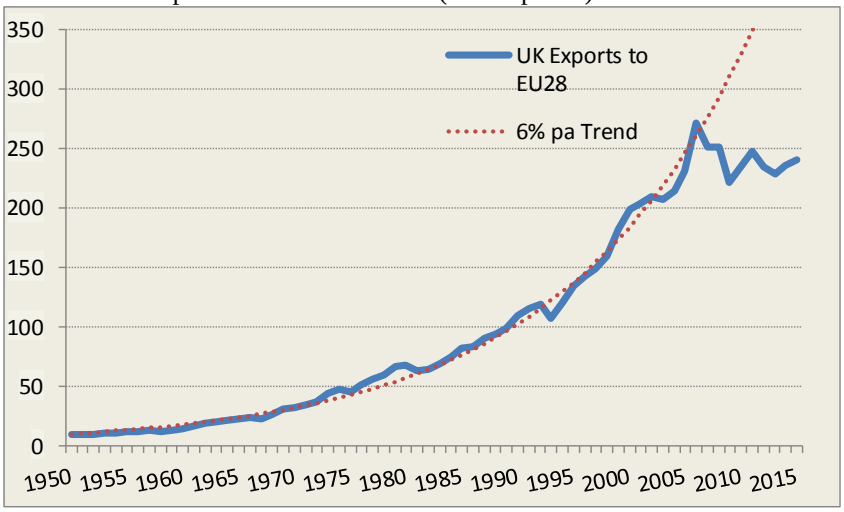


Chart 5 UK Exports to the EU28 and Non-EU States (£2013 prices)

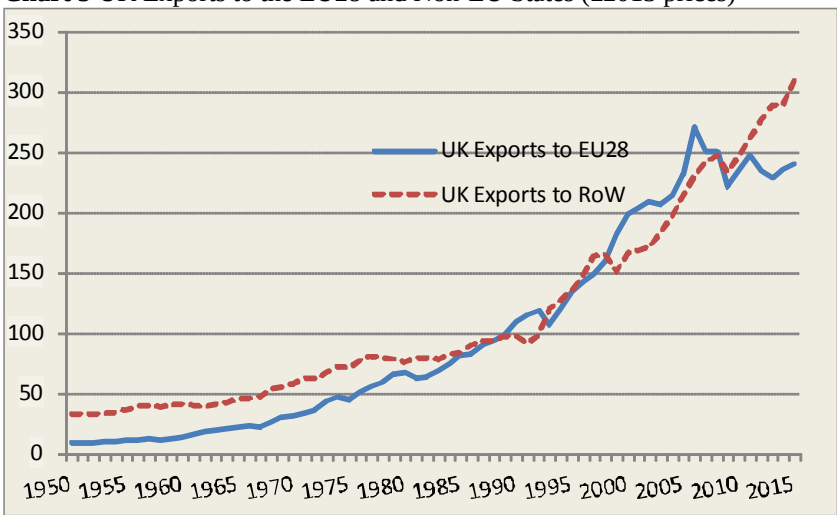
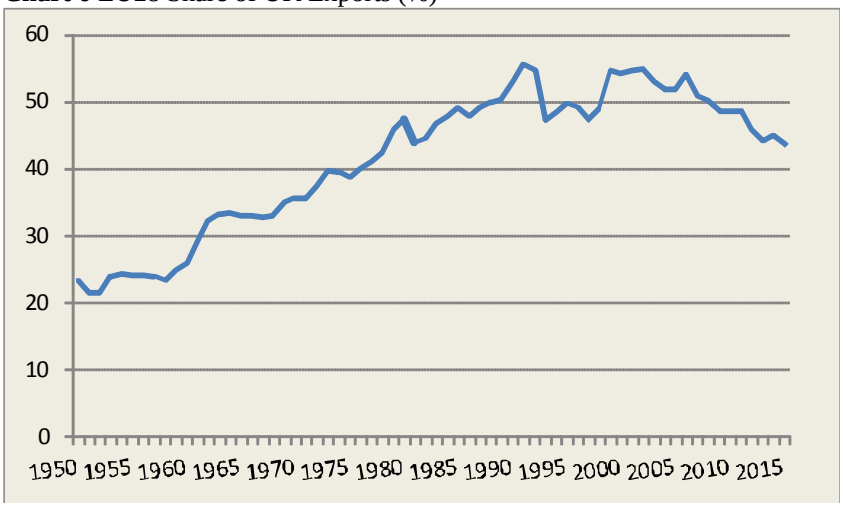


Chart 6 EU28 Share of UK Exports (%)

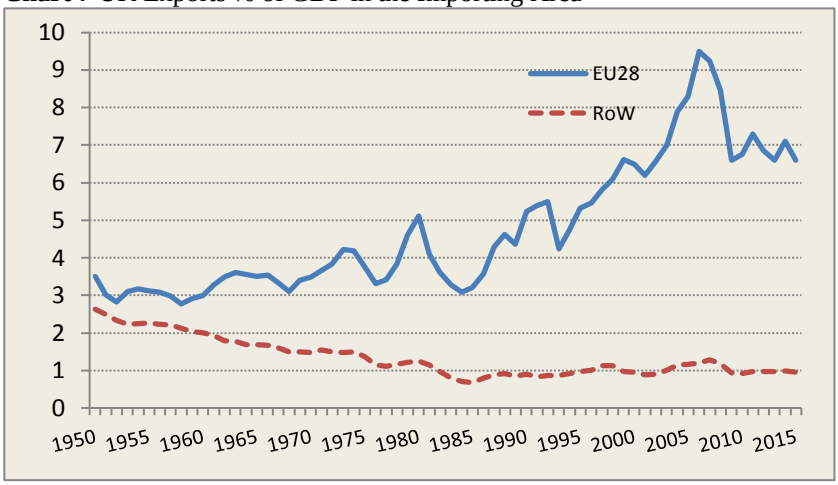


These trends mean that the EU28 share of UK exports rose steadily over the post-WWII period with no obvious acceleration in the trend after accession to the EU in 1973. After peaking at the end of the 1980s the EU share first flattened and since the formation of the Eurozone has fallen sharply. The share is now 43% and is only a little above the 40% share at accession.

It is not possible to discern the precise role of EU membership from the above trends. Part of the changes in trend is due to changes in economic growth in markets for imports. The fact that European growth rates fell sharply just as the UK joined the then EEC makes it difficult to interpret raw

data on trade. More informative is a measure of import penetration, i.e. the volume of exports divided by the GDP of the import market.

Chart 7 UK Exports % of GDP in the Importing Area

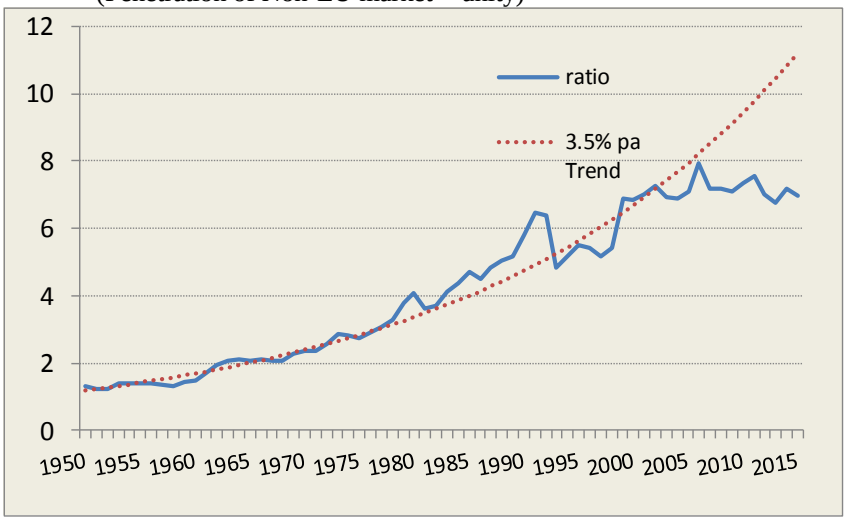


The penetration of EU and non-EU markets by UK exports is shown in Chart 7. UK penetration of EU28 markets was on a slowly growing trend from the late 1950s, but the trend accelerated markedly from the early 1990s coincident with the formation of the EU single market in 1992 and the fall of the Iron Curtain in 1989.

The path of UK penetration of non-EU markets was quite different. Penetration fell steadily until the late 1970s and then stabilized with UK exports equivalent to around 1% of Non-EU GDP. We can take the penetration of non-EU markets as a benchmark of what might have happened in Europe without UK accession to the EU. UK export penetration of EU28 markets is shown *relative to* penetration of non-EU markets in Chart 8. Penetration of EU28 was already growing faster than penetration of non-EU markets prior to 1973. This probably reflected reductions in global tariffs under the various GATT rounds, allowing the natural geography of trade to re-assert itself.

After UK accession, UK penetration of EU28 markets was generally above this rising trend with a peak of 30% above trend in the recession years of 1991–2. However the average for the 15 years after EU tariffs were fully removed in 1978 was only 10% above trend. Since 1999, the trend has been flat with no further widening of the gap in import penetration between EU and non-EU markets. By this time UK export penetration of EU markets was seven times higher than for non-EU markets, but in 2015 it was 40% below the extended pre-accession trend.

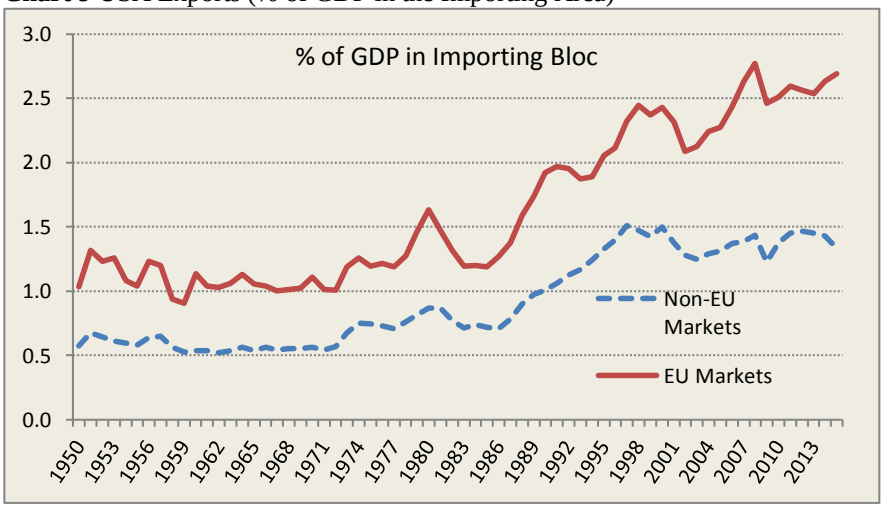
Chart 8 UK Exports: Penetration of EU28 market
(Penetration of Non-EU market = unity)



The influence of the UK membership of the EU single Market is difficult to discern among these shifting trends. On the one hand UK penetration of EU markets is seven times higher than for non-EU markets, but most large EU markets are less than 1000 miles from London. Non-EU markets are generally 5 to 10 times further away. If UK exports to the EU fell by 43% as suggested by the Treasury's gravity model analysis, then import penetration would fall to 4% of EU GDP, or 4 times higher than penetration of non-EU markets. This would take the UK back to close to the pre-accession level.

The key question is whether it is reasonable to assume that UK exports to the EU could fall by as much as this, especially when average tariffs are so low. One further piece of evidence that can shed some light on this conundrum is the trend of US penetration of EU markets. US penetration of EU28 markets rose sharply after 1973 despite the USA not being a member of the EU (Chart 9). Indeed the level of penetration of EU markets by US exports rose by 250–300% above the pre-1973 level. The increase was much the same as for the UK. US penetration of non-EU markets also rose after 1973 and by similar amounts. The greatest rise for non-EU markets appears to coincide with the USA signing FTAs with Canada and Mexico under the US Canada FTA in 1989 and NAFTA in 1993.

Chart 9 USA Exports (% of GDP in the Importing Area)



UK penetration of EU markets remains 4–5 times higher than US penetration of the same markets. Some of this advantage may be due to the single market, but distances are much shorter for the UK and it seems unlikely that all of the advantage is due to membership of the Single Market.

5.3. Summary of trade assumptions

It seems that much of the large increase in UK trade with the EU has been a continuation of previous trends and that large increases have also occurred for exports into the EU from non-member states such as the USA. The share of the EU as a market for UK exports has been falling fast in the present century and will soon be below the level of 1973. Another factor is the sterling-euro real exchange rate which is now about a third lower than was the (Deutschmark) rate in 1973 (Chart 10). With low tariffs and a low exchange rate it seems implausible that Brexit would result in the large decline in markets calculated by the Treasury.

In the model scenario described below, we will model the Treasury assumption on trade losses due to Brexit. However, our main Brexit scenario will use a much smaller reduction in exports. Based on our own gravity model work described in Appendix B, we have assumed a potential loss of 20% of EU markets, i.e. under half of that calculated by the Treasury. In practice the loss will be much smaller due to depreciation in sterling and eventually due to trade replacement in non-EU markets. We assume that these market losses are offset by gains in non-EU markets over a 20-year period.

Chart 10 Real Exchange Rate: Sterling v Euro/Deutschmark

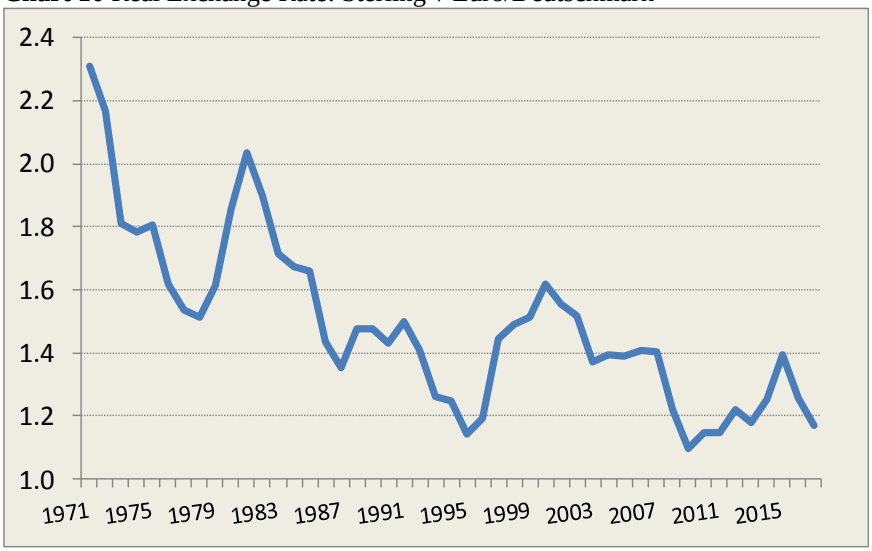
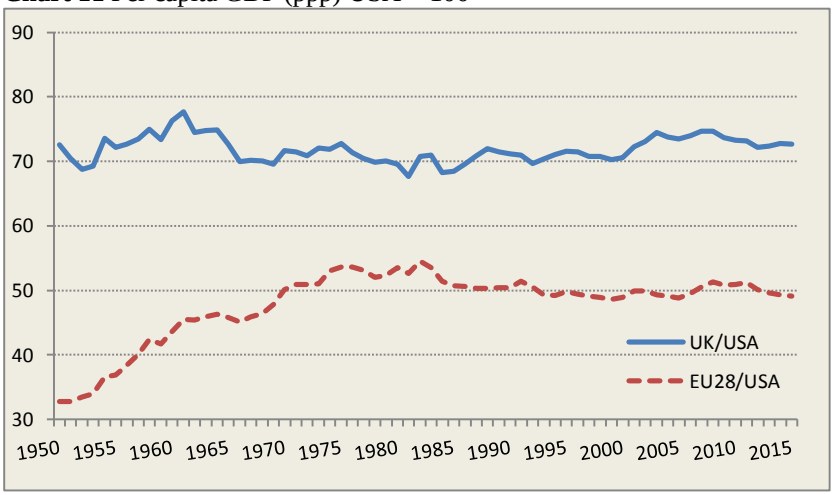


Chart 11 Per capita GDP (ppp) USA = 100



We make no assumptions in the model about Brexit-induced reductions in productivity since we find no significant link between the two in UK data, although the model equations will generate indirect changes in productivity. We should note that if the trade losses are lower than assumed by the Treasury then the associated productivity losses would also be lower. Our expectation is that there will be no marked productivity effect at all. Chart 11 shows that per capita GDP has remained close to 72% of the US level throughout the post-war period. It is not obvious that membership of the EU since 1973 has

made any sustained difference. Even starker is the evidence that per capita GDP in the EU28 has remained at close to 50% of the US level since the early 1970s. Per capita GDP in the original EU6 states reached 78% of the US level in the 1980s but has since fallen to 75% while levels in the new A10 members have risen from initially very low levels since their accession. The evidence appears to be that the accession of new members has led to a redistribution of GDP from older members, but has not raised productivity in the union as a whole.

6. Assumptions for the Scenarios

The assumptions used in the Brexit scenarios are shown in the Box below. The key assumptions have already been outlined. Business investment is assumed to be reduced due to uncertainty by 9.5% in 2017 in the baseline Brexit scenario and by over 30% in the severe Brexit scenario. These declines diminish from 2019 once the UK leaves the UK, even though all of the long-term arrangements may not be fully settled.

The scenarios here are a worst case, assuming no free-trade agreement and instead that UK trade with the EU occurs within WTO rules. Demand for UK exports within the remaining EU is assumed to fall by 20% in the baseline Brexit scenario and by 45% in the severe Brexit scenario based on Treasury estimates. Offsetting growth in export sales to non-EU economies is assumed to be slow with full replacement of markets occurring only after 20 years. These assumptions are viewed as pessimistic rather than realistic, and are presented as worst-case scenarios.

It is assumed (again pessimistically and for illustrative purposes) that the UK imposes tariffs equal to those it faces for exports into the EU, leading to a fall in import volumes. These falls are similar to the reductions in exports in spite of the fact that many UK imports are food and commodities. In practice a degree of diversion of imports may occur. For instance new world wines displace French, Italian, Spanish and other EU wines.

We have assumed substantial losses in net FDI flows into the UK. These are flows of physical investment with direct effects on employment, rather than the financial flows in the Treasury analysis. The numbers are essentially arbitrary but are based on the belief that a significant proportion of FDI enters the UK as a base for accessing an EU-wide market, and will be less attracted to a UK location once the UK leaves the EU.

The sterling effective exchange rate has been adjusted so that the average value in 2017 is 12% below the pre-referendum level. No further adjustment is made and the exchange rate after 2017 is determined by the exchange rate equation in the model.

Fiscal policy for 2017–18 is taken directly from government plans announced in the 2017 Budget. In these plans spending rises faster than in pre-referendum plans by close to 1% per annum. We increase this extra spending by closer to 1% in 2019–20, and continue faster growth by 2% from 2021. Government current and capital spending on goods and services is consequently 8% higher by 2025 than in the pre-referendum forecast. Monetary policy is accommodating of higher inflation and the bank rate is assumed to be kept 0.5 percentage points lower in 2017, and 1 point lower in 2018–19, than in the pre-referendum forecast with the gap eliminated by 2021.

Finally, controls on migration from the EU are assumed to be imposed in mid-2019, leading to net migration falling to around 150,000 from 2025.

Assumption	Assumptions	Reduction
Capital investment by businesses	• 9.5% initial reduction in business investment • Tapered from 2018 • Bounce-back in investment from 2019 • *Severe scenario=30% fall*	-9.5% 2017 5.0% 2018 2.5% 2019 *-30% 2017–19*
Exports	• 20% loss in EU markets from 2019 • Exports helped by lower £ • Replaced by non-EU markets over 20 years • *Severe trade Loss Scenario – 45%*	Exports rise initially due to lower exchange rate but 7% lower by 2025 *Exports reduced by 13% from 2019*
Imports	• Assumes UK tariffs imposed on imports from EU equal to EU tariff on UK exports • Impact on imports reduced to 0 by 2040	Imports lower by: 5% in 2025 5% in 2030 *Severe scenario loss:* *11% in 2025 & 2030*
FDI	• Permanent losses in annual FDI, assumed due to restricted access to EU • *Losses greater in severe scenario*	-11% in 2019 -15% in 2025 *-12% in 2019* *-21% in 2025*
Effective Exchange Rate	• Effective rate initially 12% lower in than the pre-referendum level	7% lower in 2025 4% lower in 2030 *16% lower in 2025 in severe scenario*
Fiscal and Monetary Policy	• Spending rises at 2% from 2019 in both scenarios • with accommodating monetary policy (Bank rate 1% by 2019)	Spending 6% p.a. higher by 2025 Bank rate allows CPI to rise to 4% by 2018
Migration	• Zero **net** migration from EU after 2019	Net migration falls to 17,000 pa by 2025

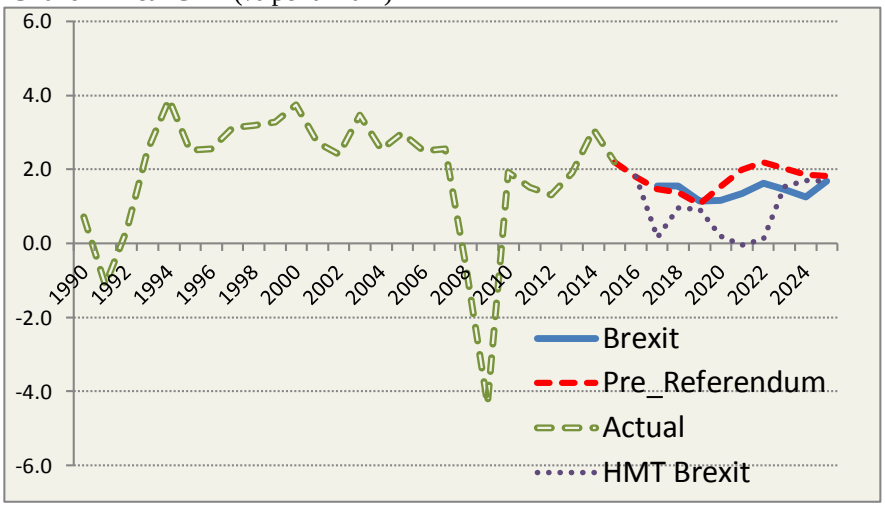
6.1. Scenario results

As outlined above we generate two scenarios. Our baseline Brexit scenario uses the main assumptions in the Box above. The other more severe "HMT Brexit" scenario uses the Treasury's calculated impact on trade and short-term uncertainty impacts which are much higher than those in the baseline Brexit scenario. These assumptions were entered into the CBR UKMOD model with no further adjustments. The following sections calculate an estimated impact of Brexit as the difference between the Brexit scenarios and our pre-referendum forecasts run in June 2016 and with none of the adjustments listed in the Box. We emphasize again that we regard these scenarios as pessimistic but illustrative of what could happen. In practice, we expect a free-trade agreement to emerge between the UK and EU. Since this a continuation of the status quo it should be easier to negotiate than a completely new FTA such as the Canada-EU agreement. Political differences may however mean that this takes a long time to emerge, although it seems likely that transitional arrangements based on free-trade will be put in place.

6.2. Real GDP

The short-term impact of uncertainty alone would reduce the growth of GDP in 2017 to 1.2% but the lower exchange rate, lower interest rate and higher government spending raise this to 1.5%, similar to the pre-referendum forecast (Chart 12). The difference in 2018 is slightly greater.

Chart 12 Real GDP (% per annum)



The more severe HMT Brexit scenario generates slower growth of only 0.1% in 2017 and 1.0% in 2018. One aspect of these scenarios is that uncertainty leads to a postponement rather than cancellation of investment. Once uncer-

tainty diminishes, normal capital-output ratios are restored. For the Brexit forecast, this causes some bounce-back in GDP to partly offset the negative impact of reduced exports to the EU from 2019. The bounce-back in the HMT Brexit scenario is more obvious due to the greater degree of uncertainty assumed in this scenario for 2017 and 2018.

The assumed loss of trade from 2019 leads to a more severe downturn with GDP growth at 1.3% for 2021 in the baseline Brexit scenario, and -0.1% in the severe HMT scenario. We have assumed that government expenditure on goods and services accelerates to 2% per annum from 2022. This provides some offsetting stimulus; growth picks up but only to around 1.4% per annum, by 2023. A few years later the credit super-cycle begins to turn down making growth harder to achieve without a major policy stimulus.

The overall impact in the baseline Brexit scenario is that GDP is a little higher up to 2020 as the lower exchange and interest rates offset the negative impact of uncertainty. After 2020 the loss of trade results in GDP falling below the pre-referendum trend, ending up in 2025 some 1.2% below the pre-referendum forecast. Part of this reduction in GDP comes from lower migration. As a result, there is less of a fall in per capita GDP which ends up 1.5% lower in 2025 but becomes higher than in the pre-referendum forecast by 2030. The HMT Brexit scenario has a greater loss, at 8% of GDP in 2025. This is close to the Treasury's 7% for 2030. Once again, the fall in per capita GDP by 2025 is less in this scenario at 6%. Unlike the NiGEM model our CBR model predicts a negative impact of migration on productivity measured as per capita GDP. This is to be expected when the majority of recent immigrants from the EU come to work initially in minimum wage jobs.

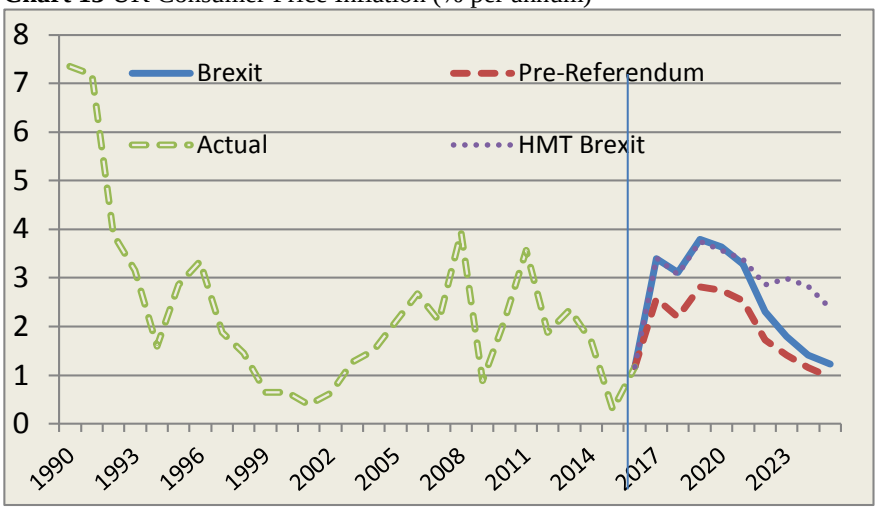
Beyond 2025, the model predicts a pick-up in GDP and per capita GDP as trade begins to slowly recover. By 2030 both GDP and per capita GDP are above the pre-referendum forecast. Again, a lower exchange rate and faster growth in government spending play a role in this recovery. This recovery is broadly sustainable in that the current account on the balance of payments is more favorable by 2030 than in the pre-referendum forecast. The government deficit remains low at close to 3% of GDP. Government debt is substantially higher than in the pre-referendum forecast but does decline from 89% in 2017 to 79% in 2030.

6.3. Consumer Price Inflation

The one indisputable result of the Brexit Referendum has been a large fall in sterling relative to most other currencies, although in our view this brings forward a depreciation that would eventually have occurred albeit more slowly. The long-term result of this depreciation is expected to be a welcome reduction in the large balance of payments deficit to a manageable level. The

more immediate impact is to increase the price of imported goods and services leading to a general rise in consumer price inflation.

Chart 13 UK Consumer Price Inflation (% per annum)



We had expected inflation to pick up to over 2% in 2017 even in the pre-referendum forecasts although much depended on the relative paths of UK and US interest rates in influencing the sterling exchange rate. The 12% depreciation since the referendum raises inflation by a further 1% (Chart 13). A further depreciation resulting from trade losses on leaving the EU in 2019 is projected to maintain consumer price inflation over 3% for three successive years from 2019. Inflation could be reduced by higher interest rates, but we assume that the Bank of England "looks through" this bout of high inflation just as it did after the 20% depreciation in 2008. The bank rate is assumed to rise only slowly, eventually reaching a plateau at 1% by 2019. Inflation begins to fall although it does not reach the 2% until 2022.[21]

We have assumed even lower interest rates in the severe Brexit scenario to offset the harsher assumptions about investment uncertainty and trade. In this case the bank rate is assumed not to rise above 0.5% before 2019.

6.4. Real wages

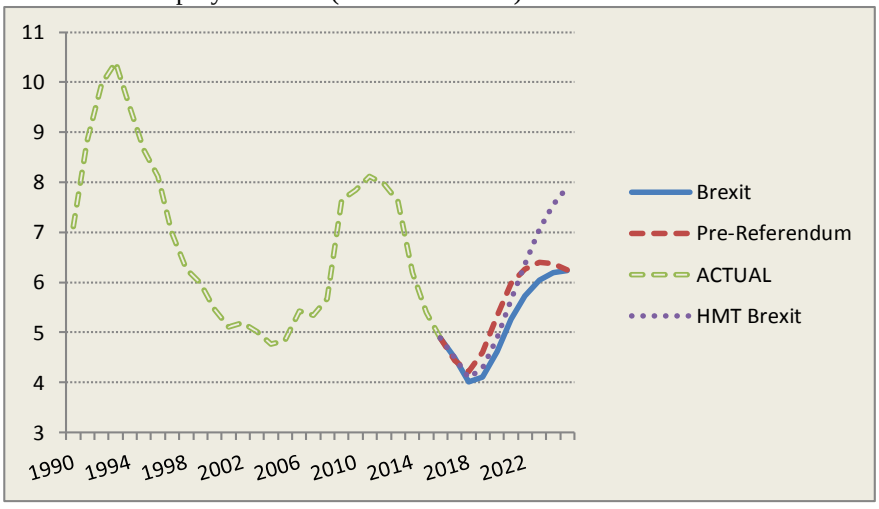
High inflation resulting from the sterling depreciation can undermine the real value of wages, leading in turn to lower consumption and hence lower GDP. Much depends on whether wages rise in response to higher inflation. Average earnings have risen by less than 2% per annum in most years since the economic crisis of 2008 and there is a widespread view among economists that there is a relatively stable 2% per annum wage norm among employers. Average weekly wages did break this ceiling in 2013 and 2015 but not by much.

Our equations for earnings suggest that earnings will rise by more than 2% as employment rates reach a peak in 2017 and especially as migration reduces from 2019. The UK labor market has become very dependent on foreign-born labor with the increase in foreign-born workers being equivalent to over 80% of additional employment since 2004. Immigration restrictions will provide the biggest shock to wage bargaining for over a decade. Even so, we expect real wages to decline gently until 2020 and to decline only a little more than would have been the case in the absence of Brexit. Nominal wages will fail to keep pace with rising consumer prices but only by a little. Real wages in 2025 are expected to be only 4% above the level in 2005 shortly after the accession of the EU10 member states to the EU. It is only later that we expect lower migration to be associated with steady rises in real wages.

6.5. Unemployment

The unemployment rate is projected to keep falling into 2017 but to begin rising from 2018. Our pre-referendum forecast had unemployment rising back to almost 7% of the labor force by 2025 due to continuing public sector austerity and higher interest rates. The lower interest rates of the baseline Brexit scenario stimulate more employment growth (Chart 14). Unemployment rises but more slowly than previously expected. Lower interest rates prevent a downturn in the credit cycle and have a positive impact on company cashflows. The harsher conditions of the severe Brexit scenario have an intermediate impact on unemployment, but even lower interest rates cannot prevent unemployment rates from rising above 7%.

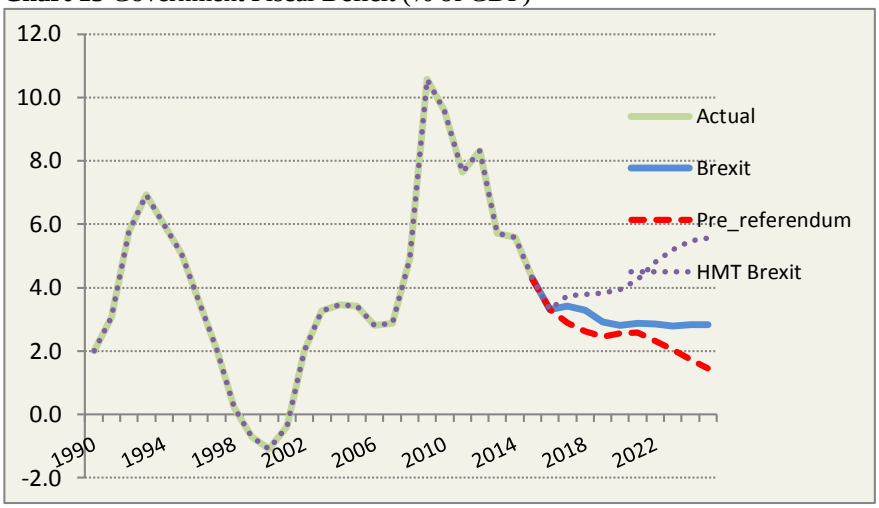
Chart 14 Unemployment rate (% of labor force)



6.6. Public sector finances

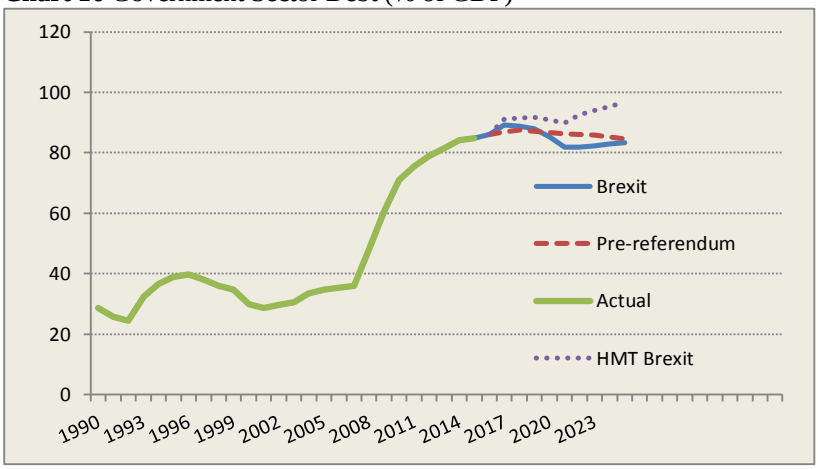
Public expenditure on goods and services increases 0.5–1% per annum faster than in our pre-referendum forecast. With GDP growth generally slower, public sector revenues are initially lower but improve into the next decade as economic growth picks up and with savings on contributions to the EU. The values we use for public spending assume that the EU savings are spent on other things and these are built into the spending assumptions above. The same spending assumptions are used in both Brexit scenarios, but tax revenues are lower in the severe scenario due to lower growth in GDP.

Chart 15 Government Fiscal Deficit (% of GDP)



In our pre-referendum forecast we had not expected the government's fiscal deficit to hit the Chancellor's target of budget balance by 2019–20, but instead to flatline at around 2.5% of GDP for a few years before continuing a downward trajectory (Chart 15). The Brexit scenarios, not surprisingly, have initially higher deficits. The deficit in the baseline Brexit scenario remains below 3% of GDP which is low enough keep aggregate debt on a downward path from 2017 helped by higher price inflation (Chart 16). In the severe scenario the deficit does rise above 4% after 2021, allowing the debt ratio to rise above its 2016 level by 2025.

Chart 16 Government Sector Debt (% of GDP)

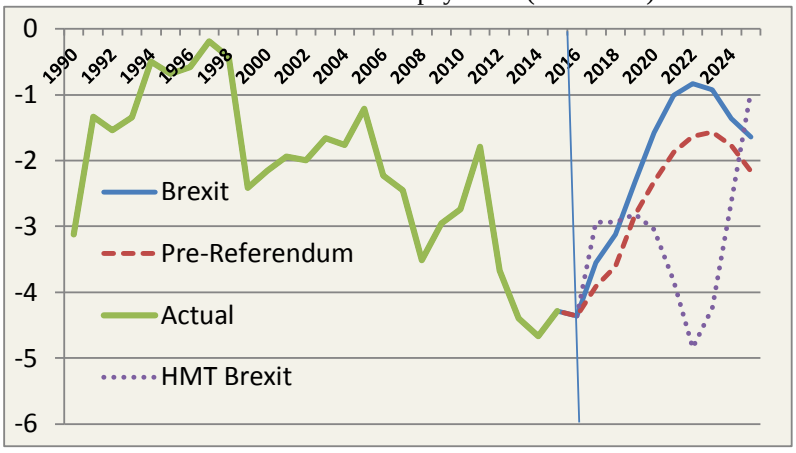


6.7. Balance of payments

The UK has managed to finance unprecedentedly large current account deficits for many years. Indeed, deficits have been the norm almost every year since 1980. The capital inflows supporting this deficit are likely to be lower in the uncertain conditions of the run-up and immediate aftermath of Brexit. This is probably the main reason for the large depreciation of sterling following the referendum.

A slow improvement in the current account had been expected in the pre-referendum forecasts, but the improvement is faster in the Brexit forecasts due to the lower level of the sterling exchange rate (Chart 17). Part of this improvement is due to the trade balance, but importantly we also project an improvement in the net earnings on UK foreign investment.

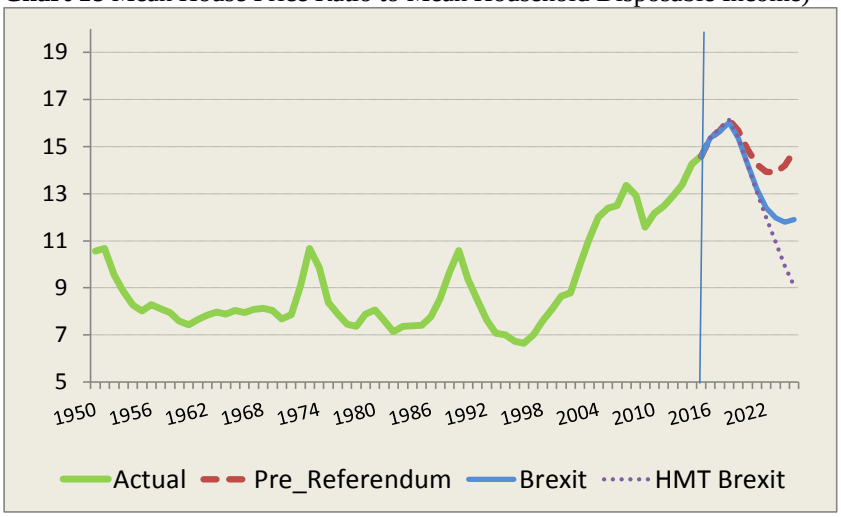
Chart 17 Current Account Balance of payments (% of GDP)



6.8. Unbalanced housing markets

Housing markets play an important role in economic cycles in the UK. The market has been unbalanced for many years, and the ratio of house prices to household disposable incomes is close to double the pre-crisis average. We had expected this ratio to become even more extreme, but in the Brexit scenarios lower demand for housing due to reduced migration causes the ratio to decline from 2019 (Chart 18). The number of dwellings needed to house migrants with net migration running at 330,000 per annum has been close to the 150,000 dwellings actually built each year. The provision of housing for migrants through the buy-to-let market has pushed up prices and crowded out other potential buyers. With lower net migration after 2019 this pressure is expected to recede.

Chart 18 Mean House Price Ratio to Mean Household Disposable Income)



7. Conclusions

A model based largely on equations reflecting past relationships between macro-economic variables has little to go on in attempting to project a long-term future outside the EU. Nor is there much on which to base a judgment about how much of investment and consumption might be delayed or cancelled due to inevitable uncertainty about the future. Our two scenarios about possible futures leading up to and following Brexit are based on a series of assumptions not only about what form trade arrangements might take, but importantly, what impact these changes will have on the wider economy. We do not feel that it is possible to rely strongly on the gravity model approach in estimating the impact of EU membership on trade. The method can generate

different results in different formulations and the Treasury's use of this approach is inappropriate. The Treasury relies on average impacts across all EU members and on equations estimated across over a hundred countries most of them involved in little trade with the UK. The impact on UK exports to the EU is much smaller. Our attempt to replicate the Treasury analysis with a gravity model using data with a Poisson estimator to deal with the higher variability among small countries demonstrates that the UK's dependence on the EU is much weaker than the average. The Treasury failed to recognise this and its conclusion must be regarded as flawed.

We enter this lower trade estimate into our macro-economic model as a baseline Brexit scenario. Our other scenario examines the impact of the Treasury's assumptions even though we feel that these have little basis in reality. The baseline Brexit scenario builds in things we already know including the depreciation of sterling and the government's expenditure plans for the next five years. In this baseline scenario the loss of GDP peaks at 2.5% in 2025, before beginning to recover. Postponed investment, loss of EU trade and lower migration all play a role, but an accommodating monetary policy and a depreciated currency help to manage the shock, as they should. In per capita terms, there is never any loss of more than 1.5%, and in the longer term a substantial gain as lower cumulative migration exerts an influence. Even under these somewhat pessimistic assumptions about (temporary) uncertainty and trade losses, the path of GDP is projected to be only a little lower than it might have been in the absence of a Leave vote. Inflation is higher but unemployment lower as migration is restrained.

The economic outlook is grey rather than black, but this would, in our view, have been the case with or without Brexit. The deeper reality is the continuation of slow growth in output and productivity that have marked the UK and other western economies since the banking crisis. Slow growth of bank credit in a context of already high debt levels, exacerbated by public sector austerity prevent aggregate demand growing at much more than a snail's pace.

Acknowledgements
We are grateful for comments made on a version of this paper at a seminar series at St. Catharine's College in Cambridge, November 2016.

NOTES

1. Appendix A compares the CBR macro-economic model with other official models and contains further detail on the properties of the CBR macro-economic model. A manual describing the model is available at: Working Paper 472. www.cbr.cam.ac.uk/publications/working-papers.

2. HM Treasury (2016a) and HM Treasury (2016b).

3. HM Treasury (2016b), p. 8.

4. Office for Budget Responsibility. Economic and Fiscal Outlook. March 2017.

5. HM Treasury (2016a) op. cit.

6. In their milder scenarios the Treasury assumes that only half of the gains to trade from EU membership are reversed since non-tariff barriers in the form of regulatory differences will initially be limited. In the Treasury's severe scenario it is assumed that gains are fully reversed.

7. There is something odd about a gravity model applied to trade in that the amount of trade between two countries is not constrained by the size of the smaller economy. Hence the size of the term ln(Yi*Yj) can be the same for trade between say Luxemburg and the USA as between two medium sized countries even though in the former case the size of the Luxemburg economy imposes an upper limit on the level of trade.

8. For comparison with the Treasury estimate we produce an alternative estimate which is discussed in Appendix B.

9. We have used data from FDI Intelligence, an FT subsidiary, on employment in FDI projects to estimate the money value of physical projects. The Treasury does undertake some sensitivity analysis but in our view this will not solve the problem.

10. Glick and Rose (2015). In a revised version of this paper published in March 2016, Glick and Rose repeat the point that different econometric methodologies deliver different results. In particular, different samples of countries deliver widely variant results. However, in this paper they adopt a preferred form of equation which generates a positive impact for membership of the EMU. See Rose and Glick (2016).

11. Passporting is the right for financial services firms registered in the European Economic Area (EEA) to conduct business in any EEA country without requiring further authorization in each country.

12. Over the last decade the volume of UK exports to the EU has grown by only 4% due to stagnation in many Eurozone markets, while exports to non-EU markets have grown by 42%. The Treasury forecast of a future loss of 43% of the EU market equates with a fall in the EU share from the current level (also of 43%), down to 32% by 2030. This level was last seen (for the same 27 countries) in the early 1960s. If the falling share of EU markets for UK exports experienced over the last decade were to continue, the EU share would in any case fall to around 30% even if the UK stayed fully within the UK. Oxford Economics have undertaken a more precise calculation and estimates a fall to 32%. See Slater (2016).

13. HM Treasury (2005).

14. This implies that all exports are standard commodities for which there is a world price at which all exporters can sell their goods.

15. For further information on our estimation of gravity models, see Gudgin et al. (2017a) and (2017b).

16. A convenient source for accessing this database is at www.stats.ukdata-service.ac.uk

17. For the Baltic States, we assume that exports grew at the same rate as in Poland, and for Croatia and Slovenia at the same rate as the former Yugoslavia.

18. GDP at purchasing power parity in the EU28 countries grew at an annual average rate of 4.7% in the period 1950–79 but only at 2.4% over the subsequent 1980-1999 period, falling to 1.1% after the Eurozone was established in 1999.

19. Growth in UK exports to Non-EU28 countries was 3.3% per annum prior to 1976 but only 1.5% per annum in the following 13 years. New Zealand was the most obvious market affected by UK accession to the EU. NZ exports to the UK fell sharply and UK exports to NZ fell by three-quarters between 1974 and 1984 and have remained low ever since.

20. Source: The Commonwealth Association. The World Economics website (http://www.worldeconomics.com/papers/Commonwealth_Growth_Monitor_0e53b963-bce5-4ba1-9cab-333cedaab048.paper) shows that since 1971 the Eurozone has declined from 22% to 12% of world GDP while the Commonwealth has grown from 10% to 16%.

21. Our assumption of accommodating monetary policy plays a small role in generating the GDP scenario. If monetary policy is tightened, with Bank rate rising to 2% by 2019, the impact on GDP is about 0.25% lower than our main projection, with inflation about 0.4% lower.

22. In a Keynesian demand-based system a reduction in government spending would normally result in slower growth in GDP. In the OBR model medium-term GDP is determined independently of demand and the link between austerity and slower growth is broken.

23. These are ECM equations estimated as single regressions, rather than as a system.

24. See Godley and Lavoie (2007).

25. See footnote 10.

26. A convenient source is available at: www.ukdataservice.ac.uk. Data on GDP and population by country is available at Conference Board Total Economy Database, http://www.conference-oard.org/data/economydatabase/

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Appendix A

The CBR Model of the UK Macro-economy

The CBR model has been developed and refined over the last five years. It was originally developed in response to the failure of academic and commercial economic forecasters to foresee or understand the economic crisis of 2008–9 or to recognize the dangers in the preceding accumulation of debt by the household and financial sectors. The "business as usual" response of much of the forecasting industry leaves much to be desired and the nature of the main public sector models in the UK is, in our view, unfit for several aspects of policy analysis.

The OBR model, which took over from the Treasury model in 2010, when the Office for Budget Responsibility was set up as an independent body to place official economic forecasting at arm's length from Government, has particular problems. In an attempt to make a predominantly demand-side system into a supply-side model, the OBR model gives precedence to its projections of productive capacity. This capacity is projected purely by assumption. The key assumption relates to labor productivity which is exogenous and usually presumed to grow at close to 2% per annum despite the fact that there has been virtually no increase in UK productivity since 2007. In the OBR's world, next year will always be better. The other, less important assumption is on the growth of labor supply, and the OBR adopts official ONS projections with their arbitrary assumptions about future migration flows. To make the demand system consistent with supply the OBR assume that actual output will move to achieve full-capacity operation within 3 or 4 years. At times like the present where the economy is already operating at close to full capacity, the forecast for GDP is almost exactly just the track of productive capacity. In the latest OBR Economic and Fiscal Outlook, released in March 2017, the forecast for growth in real GDP is 2.1% per annum from 2019. In such a system there can be no Keynesian multiplier and as a result OBR forecasts have been consistently over-optimistic about tax revenues and hence the Government's ability to achieve fiscal balance.[22]

The forecasting model of the Bank of England (in line with other Central Banks) is a new Keynesian general equilibrium system, with rigorous but unrealistic micro-economic foundations. This has a poor forecasting record leading to unfortunate embarrassments for the Governor of the Bank of England. These include the debacle in 2013 when Mark Carney attempted to introduce a "forward guidance" regime to guide financial markets as to the probable future path for interest rates. The Bank's unemployment forecasts which underpinned the regime proved hopelessly pessimistic and the regime had to be quietly side-lined.

A general equilibrium model is also used by the HM Revenue and Customs (HMRC) side of the Treasury. Our dealings with HMRC over the transfer of responsibility for corporation tax to Northern Ireland showed that use of this model defied common sense to an extant verging on the bizarre. The model predicted that changes in corporation tax would lead to rapid adjustments in the capital stock of businesses with no medium or long-term impact on FDI flows. In reality low corporation tax rates continue to attract investment year after year as the experience of the Republic of Ireland has demonstrated for more than half a century. The decisions of successive Chancellors of the Exchequer to reduce UK corporation tax rates from 30% down to 17% since 2007 suggest that the advice of their own modelers has been comprehensively ignored.

The CBR Macro-Economic Model (UKMOD)

The CBR model is described in CBR Working Paper 472 at www.cbr.cam.ac.uk/publications/working-papers. In brief the model consists of series of econometric equations[23] and identities describing how important macro-economic indicators are related to one another in both the long-term and short-term. All equations consist of statistically significant relationships estimated from UK data over recent decades. A Keynesian view of the economic world influences the relationships selected for inclusion in these equations, but ultimately it is the data that determines what precisely is included in each equation and with what weights. There is no overt attempt to insert profit-maximizing or other optimizing behavior into the model except in as far as it is implicit in the equations for such things as company investment or private-sector employment. Nor is the model precise about the formation of expectations. Since it is assumed that most expectations are based on the recent history of the economy these become subsumed within econometric equations.

Importantly, there is no explicit NAIRU (non-accelerating inflation rate of unemployment). Instead the estimated equations prevent employment rates rising above historic peaks via higher inflation and rising interest rates. We estimate equations for various key aggregate price terms based on past behavior. In practice these show that price inflation reflects changes in wage and import costs. Wage inflation in return reflects price inflation and the employment rate. Interest rates also influence inflation with a two year lag (mainly via their influence on the sterling exchange rate) but there is no strong tendency in the data in recent decades for inflation to accelerate when unemployment is below some critical rate as assumed in many forecasting models. Forecasts and simulations generated with UKMOD indicate that rises in wage inflation associated with low unemployment (or high employment rates) can be contained with relatively small increases in short-term interest rates.

The forecasts generated by the model are conditional on a number of exogenous variables chiefly reflecting government fiscal policy and economic conditions outside the UK. Key exogenous variables are:

- World trade (weighted by UK markets)
- Government fiscal policy plans (tax rates and *nominal* spending plans)
- Short-term interest rate (used as a policy variable to target consumer price inflation)
- Interest rates in the USA
- Global price of oil and other raw materials.

The model is based on the post-Keynesian approach of Wynne Godley described in "Monetary Economics" by Godley and Lavoie:[24]

- 4 sector approach: households, companies, government and foreign (importantly Godley-Lavoie also has a separate monetary/banking sector which is not yet developed in this model)
- Stock-flow consistent with a tendency for ratios of assets to incomes not to diverge too far from long-term averages
- Consumer spending depends on borrowing as well as income, assets and liabilities
- Mark-up pricing (i.e. consumer prices rise with wage and other costs of production)
- Wages determined as attempts to gain a traditional share of value-added but constrained by changes in the employment rate.

In its present form the model does not have a banking sector, although lending to households *is* modeled. Household borrowing is semi-exogenous determined by an equation reflecting past experience in the demand for housing loans but with a partial adjustment mechanism to move from the current situation in which bank lending is constrained by impaired balance sheets back towards a relatively unconstrained position.

Appendix B

An Alternative Gravity Model

In the academic literature, there has been an explosion of papers in the past two decades on empirical estimates of trade relationships, using the workhorse of the gravity model. The basic hypothesis is that trade between any country pair is proportional to the products of the GDPs of the two countries and is inversely related to some measure of distance between the country pair – hence the analogy with the Newtonian theory of gravitation. This approach underpinned the Treasury's estimates of the impact of Brexit. The method used residuals from a basic gravity equation to measure the impact of EU membership on trade flows. The gravity model approach is used by the Treasury to establish a crucial elasticity for the impact of EU membership on the size of trade between EU member countries in the years when both country pairs have been members. The other elasticity, for country pairs where one country is an EU member, but the other is not, is interpreted as indicating whether there is a trade diversion effect for the country which joins the EU. Given the Treasury's methodology of using the size and significance of these two factors in

estimating the overall loss to UK trade for leaving the EU, the econometric procedure bears a great deal of weight in the Treasury's overall assessment.

The Treasury equation was not described in detail but appeared to be based on data from around 114 countries and 65 years, providing about 390,000 observations in all. A feature of this large country sample used by the Treasury is that the vast majority of the sample consists of non-OECD countries. Much of the cross-section variation is likely to reflect the large differences in GDP per capita and trade between emerging economies and mature industrial economies. This is important since the measure of the EU impact depends on the underlying gravity equation. An average relationship between trade, GDP and distance obtained from such a large range of countries, most of which do little trade with the UK or the EU, may not be the best basis for estimating the impact of EU membership on trade flows. Rose and Glick (2016) show that in the context of membership of the European Monetary Union (EMU) the number of countries included in the sample makes a large difference to the results obtained from a gravity model.[25]

To investigate further the properties of the gravity modeling adopted by HM Treasury, we have used a similarly large dataset but with a Poisson quasi-likelihood estimator to take account of the heteroscedasticity induced by the presence of a large number of small countries and also the presence of zero data entries for trade. In this case, the fixed effects for individual countries are replaced by a range of dummy variables for distance, contiguity of borders, and common languages, membership of free-trade areas and separately for membership of the EU. The distance variable is also expressed relative to the mean distance for each country. The final equation, omitting non-significant variables is as follows:

$$\ln(X_{ij}) = \alpha_0 + \gamma_t + \alpha_1 \ln(Y_{it}Y_{jt}) + \alpha_2 \ln\left(\frac{Y_{it}}{POP_{it}}\right) + \alpha_3 \ln\left(\frac{Y_{jt}}{POP_{jt}}\right) + \ln\left(\frac{DIST_{ij}}{R_i R_j}\right) + CONTIG_{ij} + \beta_1 EU2_{ijt} + \beta_2 EU1_{ijt} + \beta_3 CHINESE_{ijt} +$$

where:

- X_{ijt} Exports of goods between pairs of countries in current $
- Y_{it} GDP of the exporting country in 1990 $ at PPP.
- Y_{jt} GDP of the importing country in 1990 $ at PPP.
- POP_{it} Population of the exporting country
- POP_{jt} Population of the importing country
- $DIST_{ij}$ Distance between the two countries in each trade-pair
- R_i Mean distance between the exporting country and all trade partners
- Rj Mean distance between the importing country and all of its trade partners
- EU2 Dummy variable for both countries in a trade-pair being members of the EU
- EU1 Dummy variable for exporting country in a trade-pair being an EU member
- UK_EU Dummy variable for UK exports to an EU member count
- CONTIG Dummy for a common border between both countries in a trade-pair
- FTA Dummy for both members of a trade-pair being members of same FTA
- NOR_EU Dummy for Norway' exports to EU
- SWZ_EU Dummy for Swiss exports to EU
- CHINESE Chinese is where both countries speak Chinese
- GERMAN German is where both countries speak German
- $\mathbf{a_0}$ Constant

Data is readily available for exports from country *i* to country *j* from the IMF Direction of Trade statistics for a large number of countries and for long time

periods. Similarly, data on GDP and population by country is easily available.[26] The resulting equation, estimated over the full period 1950-2015, is given below:

Equation B1 all countries without fixed effects

Dependent Variable: TRADE
Method: Generalized Linear Model (Newton-Raphson / Marquardt steps)
Date: 04/23/17 Time: 20:41
Sample: 1950 2015
Included observations: 722366
Family: Poisson Quasi-likelihood
Link: Log
Dispersion fixed at 1
Convergence achieved after 7 iterations
Coefficient covariance computed using the Huber-White method with observed Hessian

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-12.96323	0.131690	-98.43779	0.0000
LOG(Yit)	0.851496	0.005066	168.0877	0.0000
LOG(Yjt)	0.862108	0.005124	168.2519	0.0000
LOG(Yit/POPit)	0.449555	0.010018	44.87443	0.0000
LOG(Yjt/POPjt)	0.447144	0.007786	57.43147	0.0000
LOG(DIST/ (Rit * Rjt)	-0.819123	0.008534	-95.98123	0.0000
CONTIG	0.109109	0.018964	5.753385	0.0000
UK_EU	-0.530022	0.028728	-18.44986	0.0000
EU2	0.756215	0.014136	53.49502	0.0000
FTA_BOTH	0.217137	0.039998	5.428669	0.0000
NOR_EU	0.505767	0.043613	11.59667	0.0000
SWZ_EU	0.317785	0.031014	10.24659	0.0000
CHINESE	2.580000	0.060013	42.99053	0.0000
GERMAN	0.496659	0.031686	15.67432	0.0000
Mean dependent var	3.55E+08	S.D. dependent var		4.06E+09
Sum squared resid	2.66E+24	Quasi-log likelihood		5.60E+15
Restr. quasi-logl	4.79E+15	Quasi-LR statistic		1.61E+15
Prob(Quasi-LR stat)	0.000000	Pearson SSR		3.47E+14
Pearson statistic	4.80E+08	Dispersion		1.000000

The equation has a coefficient of 0.76 for trade between two members of the EU (EU2). This measures the average impact of EU membership on intra-EU trade, and is very close to the coefficient of 0.78 obtained by the Treasury with their least-squares equation. There is also a coefficient of -0.53 on the dummy variable UK_EU , denoting UK exports to the EU. To obtain the impact of EU membership on UK exports we add these two coefficients together. In this case 0.76 – 0.52 gives 0.24. This in turn indicates that EU membership raises UK exports by (exp(0.24)) or 27%. To investigate the stability over time of the estimates we re-estimate the equations for successively shorter time periods. The results are shown in Table B1.

Table B1 Gravity Model Equation Coefficients
(Poisson quasi-Maximum likelihood, All Countries)

	1950-2015	1960-2015	1970-2015	1980-2015	1990-2015	2000-2015	2010-2015	1950-2000
Constant	-12.963	-12.928	-12.771	-12.546	-12.421	-12.195	-11.640	-13.503
Ln(Yit)	0.851	0.850	0.845	0.837	0.831	0.830	0.835	0.858
Ln(Yjt)	0.862	0.861	0.857	0.849	0.844	0.843	0.827	0.876
Ln(Yit/POPit)	0.450	0.448	0.440	0.435	0.428	0.402	0.418	0.517
Ln(Yjt/POPjt)	0.447	0.446	0.439	0.439	0.441	0.429	0.407	0.443
Ln(Distij/(Ri*Rj)	-0.819	-0.821	-0.824	-0.828	-0.835	-0.830	-0.793	-0.811
CONTIG	0.109	0.112	0.124	0.158	0.202	0.222	0.240	
UK_EU	**-0.530**	**-0.529**	**-0.529**	**-0.505**	**-0.493**	**-0.527**	**-0.576**	**-0.375**
EU2	**0.756**	**0.751**	**0.741**	**0.712**	**0.691**	**0.722**	**0.779**	**0.677**
FTA	0.217	0.212	0.197	0.149	*0.091*	*0.100*	*0.184*	0.362
Nor EU	0.506	0.502	0.496	0.472	0.457	0.523	0.608	0.379
Swz_EU	0.318	0.312	0.312	0.300	0.293	0.333	0.502	0.247
Chinese	2.580	2.573	2.546	2.488	2.402	2.299	2.168	3.581
German	0.497	0.498	0.500	0.494	0.478	0.493	0.457	0.493
Observations	722336	627221	531552	435802	332536	213617	81520	521674

The coefficient on the EU2 dummy variable, again measuring the average impact of EU membership on intra-EU trade, falls a little from 0.76 until the 2000–2015 and later periods when it rises. This is likely to be due to a large impact of EU membership on the trade of Eastern European and other countries, which joined the EU after 2003. The UK_EU term denoting the average residual for EU exports to the EU, is also relatively stable in the different periods. Adding the EU2 and UK_EU terms gives an average coefficient for the impact of EU membership on UK exports of goods to the EU which remains between 0.2 and 0.25 in each period.

Our conclusion is that the impact of EU membership on UK exports to the EU is much smaller than the impact reported by the Treasury. The latter was reported as though it applied to the UK, even though it was estimated as an average across all EU member states. Our preferred gravity equation is the one reported above with a Poisson estimator, but the difference in impacts between an EU average and the UK alone is also observed with the Treasury's least squares approach. The Treasury neglected to point out that this was the case, even though they observed this difference in an earlier (2005) paper.