A Stochastic Frontier Analysis of Trade Efficiency for the New EU Member States: Implications of Brexit

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ABSTRACT

Examining the trade performance for the new European Union (EU) member states is an important issue in the context of the enlargement process – and in a new era of membership contraction with the likely exit of the United Kingdom from the EU. Typically, the degree of trade integration is assessed by comparing actual trade volumes with potential trade volumes projected from the gravity model parameters estimated for a reference group of countries that best represent normal trade relations. This approach, however, does not compare trade levels against a maximum level of trade defined by a stochastic frontier. In this paper, a stochastic frontier specification of the gravity model is used to identify the efficiency of trade integration relative to maximum trade levels. The findings, based on a panel dataset of bilateral exports from 18 Western European countries to the 13 new member states over the 1995-2022 period, indicate a high degree of trade integration close to two-thirds of frontier estimates. Using forecast data for 2017-2022, trade efficiency should remain broadly stable and even increase for the larger countries in the likely post-Brexit phase.

JEL Classification: F14, F15, C23

Keywords: Gravity model, Stochastic frontier analysis, New member states, Brexit

1. INTRODUCTION

Examining the trade performance for the new European Union (EU) member states is an important issue in the context of the enlargement process and greater economic integration with neighbouring countries – perhaps even more important with the likely contraction of EU membership to 27 countries as a consequence of the June 2016 referendum to withdraw the United Kingdom from the EU.

Strong bilateral trade links were formed in advance of formal EU entry. Indeed, soon after the Council for Mutual Economic Assistance (CMEA)[2] was disbanded in the early 1990s – rendered obsolete by democracy, current account convertibility and trade liberalisation, an increasing degree of trade integration culminated in the Western European countries becoming the main trading partners for the ex-communist countries.[3]

Figure 1 shows a plot of trade volumes (exports plus imports) for the new EU member countries summed across 18 Western European countries over the 1995-2016 period. Amounting to US$150 billion in 1995, the Western European countries were already important trading partners for the group of 13 new member states, not long after many countries cut economic ties with the former Soviet Union. Rising to US$845 billion in 2016, double-digit trade growth rates dominate the period with some exceptions.[4] Poland leads the field of 13 new member states with trade volumes surging from US$37 billion to over US$260 billion over the period, implying double-digit annual growth rates of ten per cent. Together with the Czech Republic and Hungary, the big-trio account for two-thirds of total trade volumes with the new member states, rising to 85 per cent when Romania and Slovakia are added in. Next in line is Slovenia followed by Bulgaria while

the Baltic states (Estonia, Latvia and Lithuania), Croatia and the two Mediterranean islands (Cyprus and Malta) lag behind in the bilateral trade volume rankings.

[Insert Figure 1 here]

The breakdown of the CMEA system raised the issue of where and to what extent trade among its member countries might be re-directed. The trade-diverting effects of the CMEA system – resulting in the post-war economic isolation of its members from the rest of the world – would, however, jeopardise the credibility of trade measures based on simple extrapolations from historical data. Typically, the degree of trade integration is assessed by comparing actual trade volumes with potential trade volumes projected from the gravity model parameters estimated for a reference group of countries that best represent normal trade relations. Focusing on the central and eastern European (CEE) countries, several studies have sought to estimate the volume and direction of trade flows using the gravity model (Hamilton and Winters 1992; Wang and Winters 1992; Baldwin 1994; Gros and Gonciarz 1996; Nilsson 2000; Papazoglou *et al* 2006). In finding potential-to-actual trade ratios far in excess of unity, these early studies concluded in favour of a large expansion of future CEE–EU trade. These studies, however, do not compare trade performance against a maximum level of trade defined by a stochastic frontier.

Two distinguishing features characterise this paper. First, trade performance is assessed using a stochastic frontier specification of the gravity model. In essence, a trade frontier representing the maximum level of bilateral trade is constructed for a panel of exports from 18 Western European countries to the 13 new EU member countries over the 1995-2022 period. Using the frontier specification of the gravity model, efficiency

scores for each bilateral pair of countries are generated. If two countries achieve an efficient level of trade, they will operate on the trade frontier and will realise their maximum trade potential, otherwise deviations of observed trade levels from the trade frontier indicate inefficient levels of trade, implying scope for further trade expansion.

Only a few studies have previously estimated the gravity model as a frontier specification. Among the first to estimate a stochastic frontier gravity model, Drysdale *et al* (2000) evaluate the efficiency of China's bilateral trade with 57 countries over the 1991-1995 period. Given the existing 'behind the border' and 'beyond the border' constraints to exports, Kalirajan and Singh (2008) undertake a comparative analysis of export performance between China and India. The role of free trade agreements in determining India's trade efficiency is the focus of attention for Kumar and Prabhakar (2017). For the ago-based economy Pakistan, Atif *et al* (2017) estimate a stochastic frontier gravity model to examine untapped agricultural export potential with 63 countries over the 1995-2014 period.

Expanding the analysis beyond a single country (or a comparison of two countries), Kang and Fratianni (2006) use stochastic frontier estimation to rank the trade efficiency of 177 countries, ten geographic regions and 11 regional trade agreements (RTAs). Focusing on a regional group of countries, Ravishankar and Stack (2014) have assessed trade performance between the Western European countries and ten new EU member states over the 1994-2007 period while Bhattacharya and Das (2014) analyse the potential for improving trade complementarities among the members of the South Asian Association for Regional Cooperation (SAARC).

Second, the sample period includes actual data (1995-2016) covering the transformation phase from communism to EU entry and forecast data (2017-2022) to account for the expected exit of the United Kingdom from the EU in March 2019.

Using the stochastic frontier specification of the gravity model, the parameter coefficients obtained accord with theoretical priors. In short, trade increases with income, dissimilarity of income per capita, an adjacent land border, a common language, a shared colonial history and regional integration, but decreases with the geographic characteristics of greater distance and being landlocked.

The efficiency scores suggest a high degree of trade integration, with all new member states achieving, on average, close to two-thirds of frontier estimates over the 1995-2022 period. Efficiency scores, on average, are highest for the Netherlands, Belgium-Luxembourg and Spain and are lowest for Norway and the United Kingdom, where potential for trade expansion is greatest.

Bilateral scores are shown to depend on a variety of factors, including a country's trading regime and RTA membership as well as other characteristics related to history (a common colonial past, a shared language and a mutual heritage, implying similar tastes and preferences), geography (physical distance, landlocked features, shared boundaries) and economic variables (income). A comparison of the efficiency scores across various sub-periods (before and after the financial crisis and before and after Brexit) indicate high efficiency scores were achieved early on, consistent with the rapid opening up and accompanying reorientation of trade towards Western Europe. Using forecast data for 2017-2022, trade efficiency should remain broadly stable and even increase for the larger

countries in the post-Brexit phase, absent any unforeseen shocks that would derail a broadly optimistic outlook of projected income growth.

This paper is structured as follows. Section 2 sets out the gravity model specification, distinguishing between the conventional gravity equation and the stochastic frontier gravity equation. The data definitions and sources are provided in Section 3. The results in Section 4 are split between the gravity model parameter estimates and the efficiency scores on trade performance. Section 5 concludes.

2. MODEL SPECIFICATION AND ESTIMATION METHOD

2.1 The Gravity Model

The gravity model specification of trade determinants has the following form:

$$TRADE_{ij}^{t} = f(GDP_{i}^{t}, GDP_{j}^{t}, DIST_{ij}, GDPPC_{i}^{t}, GDPPC_{j}^{t}, Z_{ij}, X_{ij}^{t})\varepsilon_{ij}^{t} \quad (1)$$

where $TRADE_{ij}^{t}$ are the bilateral trade flows between countries i and j over a given time period t; GDP_{i}^{t} and GDP_{j}^{t} denote the economic size of both countries; $DIST_{ij}$ is the geographic distance between their capital cities; and $GDPPC_{i}^{t}$ and $GDPPC_{j}^{t}$ are the per capita income levels for the respective countries capturing factor endowments in country i on the supply-side and consumption patterns in country j on the demand-side. Equation (1) also includes a vector of time-invariant explanatory variables, Z_{ij}; a vector of time-varying variables, X_{ij}^{t}; and the usual random error term, ε_{ij}^{t}.

To capture the main determining factors of trade between the Western European countries and the new EU member states, the full model specification is as follows:

$$\ln EXP_{ij}^{t} = \beta_0 + \beta_1 \ln GDP_i^t + \beta_2 \ln GDP_j^t + \beta_3 \ln DIST_{ij} + \beta_4 DGDPPC_{ij}^t + \beta_5 ADJ_{ij} + \beta_6 LANG_{ij} + \beta_7 COL_{ij} + \beta_8 LOCK_j + \beta_9 EU_{ij}^t + \varepsilon_{ij}^t \quad (2)$$

where EXP_{ij}^{t} are the bilateral export flows from 18 Western European countries to 13 new member countries over the period 1995 to 2022. GDP and distance are as before and GDP per capita is restated in relative terms as the absolute difference in GDP per capita income levels, $DGDPPC_{ij}^{t} = \left|\ln GDPPC_i^t - \ln GDPPC_j^t\right|$, as a measure of relative factor endowments. These variables are estimated in their natural logarithmic (ln) form.

In its basic form, the standard gravity equation posits that bilateral trade increases with national income and declines with the distance between them.[5] Larger countries tend to trade more, consistent with the conduct of much of intra-industry trade between the advanced countries (Helpman and Krugman 1985), hence the GDP coefficients for both countries, GDP_i^t and GDP_j^t should be positively signed. The distance coefficient, $DIST_{ij}$, should be negatively signed because the cost of transporting goods increases with physical distance.

In the augmented version of the gravity model, the separate roles for per capita income identified by Bergstrand (1989) are merged by Gruber and Vernon (1970) into the per capita income differential as an indirect way of testing the Linder (1961) hypothesis. The Linder hypothesis is concerned with income similarities. In brief, the demand-based theory suggests that country j will develop industries similar to country

i if the aggregated preferences for goods in the importing country are similar to the consumption patterns in the exporting country. A negative coefficient for the per capita income differential, $DGDPPC_{ij}^{t}$, suggesting trade is positively related to consumers with similar per capita incomes and therefore having similar consumption patterns, indicates support for the Linder hypothesis. On the other hand, a positive coefficient suggests trade is driven more by differing per capita incomes consistent with the Heckscher–Ohlin model (Heckscher 1919; Ohlin 1933) of relative factor abundance.

The vector of time-invariant bilateral factors, Z_{ij}, comprises three binary-coded dummy variables denoting adjacent borders, ADJ_{ij}, as an indicator for geographic proximity; a common official language, $LANG_{ij}$, as an indicator for cultural proximity; and historical colonial ties, COL_{ij}, as an indicator for institutional proximity, all of which should boost trade. A dummy variable denoting the geographic characteristic of being landlocked, $LOCK_{j}$, is also included in the model. Landlocked countries located in the heart of Europe can be disadvantaged in trade terms because the overland costs of transporting goods tends to be higher than shipping costs.

The vector of time-varying explanatory variables, X_{ij}^{t}, refers to the EU dummy, EU_{ij}^{t}, which takes the value of one when both countries are EU members, and otherwise zero, by way of capturing European intra-regional integration. The expected positive effect of EU membership on trade stems mainly from the deposed trade barriers initiated under the programme to complete the single market. Values of unity are assigned when the 15 established EU countries became the EU-25 with the embrace of many ex-communist countries in 2004, later becoming the EU-27 when Bulgaria and Romania

gained membership in 2007, and finally becoming the EU-28 in 2013 when Croatia joined the club. The trend of expansion is set to reverse with the expected exit of the United Kingdom in March 2019, which marks an unprecedented withdrawal of a large country from the world's largest trading block.

Binary-coded dummy variables are frequently used to assess the trade effect of regional integration within a gravity model framework. For example, Aitken (1973) examined the trade effects of the dummy variables denoting the European Economic Community (EEC) and the European Free Trade Association (EFTA) over the period 1951-1967 to assess the importance of regional integration within a gravity model framework. In a similar vein, Bayoumi and Eichengreen (1998) estimate the trade effects of the EEC and EFTA using a gravity model for the industrialised countries over the period 1956-1992.

2.2 The Gravity Model estimated using Stochastic Frontier Analysis

To assess trade performance, the gravity model is estimated using the stochastic frontier approach to gauge actual performance between the Western European countries and the new member states against a benchmark frontier function. The gravity model is thus modified as follows:

$$\begin{aligned}\ln EXP_{ij}^{t} = {} & \theta_0 + \theta_1 \ln GDP_i^t + \theta_2 \ln GDP_j^t + \theta_3 \ln DIST_{ij} + \theta_4 DGDPPC_{ij}^t \\ & + \theta_5 ADJ_{ij} + \theta_6 LANG_{ij} + \theta_7 COL_{ij} + \theta_8 LOCK_j + \theta_9 EU_{ij}^t + v_{ij}^t - u_{ij}^t\end{aligned} \tag{3}$$

where the error term, ε_{ij}^{t}, in equation (2) is now comprised of two parts, viz., a two-sided error element, v_{ij}^{t}, representing statistical noise due to measurement error and a non-negative inefficiency element, u_{ij}^{t}, representing a measure of trade performance. The former follows a normal distribution, $v_{ij}^{t} \sim iid\ N(0,\sigma_{v}^{2})$, as is typical of the conventional gravity specification, while the latter follows a half-normal distribution, $u_{ij}^{t} \sim N^{+}(0,\sigma_{u}^{2})$, and captures deviations from maximum trade that are specific to each bilateral relation. The terms v_{ij}^{t} and u_{ij}^{t} are distributed independently of each other and the regressors. Following Aigner *et al* (1977), equation (3) is operationalised as a pooled frontier such that the parameter values are obtained by maximum likelihood estimation (MLE). Country-pair specific efficiencies are obtained as $E[\exp(-u_{ij}^{t}|\varepsilon_{ij}^{t})]$ and range between zero and unity (Battese and Coelli 1988). The latter implies that actual and potential trade levels coincide while the former indicates scope to raise actual trade nearer maximum levels.

Evidence of negative skewness in the least squares residuals supports estimation by SFA. This is because the composed error term is specified as $\varepsilon_{ij}^{t} = v_{ij}^{t} - u_{ij}^{t}$ with v_{ij}^{t} symmetrically distributed and u_{ij}^{t} following a non-negative, one sided distribution. If u_{ij}^{t} takes a value of zero, the composed error term reverts to the usual symmetric error term i.e. $\varepsilon_{ij}^{t} = v_{ij}^{t}$. Schmidt and Lin (1984) use a test statistic, $(\sqrt{b_1} = m_3 / m_2^{3/2})$, based on the second (m_2) and third moments (m_3) of the least square residuals. Statistical significance is assessed under the null hypothesis of no skewness using tables provided by D'Agostino *et al* (1990).

Coelli (1995) proposes an alternative test statistic that is asymptotically distributed as a standard normal variable. The test statistic is obtained as $[b^{1/2} = m_3 /(6m_2^3 / N)^{1/2}]$, where N is the number of observations. A finding of statistical significance rejects the null of no skewness in the least squares residuals.

Finally, a generalised likelihood ratio (LR) test between the unrestricted SFA model and its restricted OLS counterpart, $[LR = -2(\ln L_R - \ln L_U) \sim \chi^2(J)]$, can also be used to test for the absence of inefficiency effects. The critical value for the test statistic is asymptotically distributed as a mixture of chi-squared (χ^2) distributions (Coelli 1995), and is obtained from Kodde and Palme (1986).

3. DATA

The panel data set consists of bilateral export flows from 18 Western European countries[6] to 13 new member states[7] over the 1995-2022 period.[8] The sample period includes actual data (1995-2016) covering the transformation phase from communism to EU entry and forecast data (2017-2022) to account for the expected exit of the United Kingdom from the EU in March 2019.

The data sources for the 1995-2016 period are as follows. Bilateral exports (free on board), in US dollars, are sourced from the *Direction of Trade Statistics* (DOTS), International Monetary Fund (IMF 2017a). Data on GDP and GDP per capita, in current US dollars, are from the *World Development Indicators* (WDI), World Bank. The geographic distance between two capital cities, in kilometres, the dummy variables

denoting an adjacent border,[9] a common language[10] and a common colonial history[11] as well as the geographic characteristic of being landlocked[12] are all obtained from CEPII.

For the years 2017-2022, data projections for trade growth, GDP and per capita GDP are taken from the *World Economic Outlook Database* (WEO), IMF (2017b). Note that bilateral exports are calculated on the assumption that import growth projections for the 13 countries of interest apply equally across all Western European trading partners.

4. EMPIRICAL RESULTS

4.1 Gravity Model Estimates

Table 1 presents the results for the stochastic frontier specification of the gravity model of exports from 18 Western European countries to 13 new member states estimated by maximum likelihood over the 1995-2022 period. Column (1) shows the results for the baseline model (equation 3). Column (2) augments the baseline model with time specific effects to control for common shocks affecting all countries in the sample.[13] Column (3) additionally includes country specific effects capturing varying country characteristics among the new member states.[14] The statistical significance of the skewness test (Schmidt and Lin 1984) and the M3T test based on the second and third moments (Coelli 1995) confirm the presence of negative skewness in the least squares residuals, thereby indicating the suitability of applying SFA estimation of the gravity model. These results are consistent with the significance of the LR test between the unrestricted SFA model and its least squares counterpart.

[Insert Table 1 here]

Regarding the core gravity parameter estimates, the positive and significant coefficient estimates for GDP suggest larger countries trade more. The trade-impeding effect of trade-related costs, however, reduces the volume of trade, as indicated by the distance coefficients. In support of the Heckscher–Ohlin model, the per capita income difference coefficients suggest factor endowments are sufficiently different between the two groups of countries, although the relatively small magnitude suggests the gap is quite narrow.

An adjacent land border, a common language and a shared colonial history significantly increase bilateral trade flows. The geographic characteristic of being landlocked lowers trade mainly because the lack of access to the sea tends to increase transport costs.[15] Finally, the positive and significant coefficient estimates for the EU dummy confirms the trade-enhancing effect of regional integration. In short, the parameter coefficients obtained using the preferred stochastic frontier specification of trade determinants (column 3, Table 1) accord with theoretical priors.

4.2 Trade efficiency scores

Taking the trade efficiency scores for each bilateral pair of countries associated with the preferred stochastic frontier specification (column 3, Table 1) and averaging over the years 1995 to 2022, the results are shown in Table 2. High efficiency scores suggest trade between two countries is close to maximum levels whereas low efficiency scores indicate deviations of actual trade from frontier estimates, implying scope for improved trade performance.

[Insert Table 2 here]

***Average efficiency scores*:** Averaging the efficiency scores across the Western European countries (final column of Table 2) indicates reasonably high trade performance with all 13 new member states achieving close to two-thirds of maximum levels. At the top end, Poland achieves the highest score of 61 while, at the other end, Cyprus attains an efficiency score of 57. Averaging the efficiency scores across the new member states (final row of Table 2), suggests the values are highest for the Netherlands and Belgium-Luxembourg (75 and 72 respectively), closely followed by Spain (69) and are lowest for Norway and the United Kingdom (45 and 47 respectively), hence indicating a degree of variability in the export performance among the group of Western European countries.

***Highest bilateral efficiency scores*:** Not surprisingly, bilateral trade between the Netherlands and Belgium-Luxembourg is consistently high across all new member states, reflecting an open trading regime since becoming founding members of the EU. High efficiency scores are also obtained for Spain, driven mainly by exports of chemicals, pharmaceuticals and food.

***Mixed bilateral efficiency scores*:** For other countries, bilateral trade performance can vary. In particular, mixed results accrue for bilateral trade with Austria (a small landlocked country), Greece (characterised by an ongoing economic crisis), the United Kingdom (a prospective non-EU member) as well as Iceland and Norway (EFTA members). Take, for example, Iceland. Proximity helps explain high efficiency scores with Lithuania, Latvia and Poland (86, 71 and 70 respectively) whereas low scores with

Romania, Slovenia and Bulgaria (21, 26 and 31) partly reflect distance between the Nordic and Southern countries and partly reflect generally less integration with EFTA members when compared with EU members. Norway follows a broadly similar pattern.

For Greece, efficiency scores are highest with Bulgaria (which shares a common border) and Cyprus (which shares a common heritage) and other nearby countries (Malta and Slovenia), but are lowest with more distant countries (Estonia and Lithuania) as well as Hungary. For Austria, efficiency scores are highest with two newer member countries (Bulgaria and Romania) and its southern bordering country (Slovenia). A shared land boundary, however, does not guarantee high efficiency scores. Indeed, trade efficiency is lowest between Austria and its eastern neighbour (Slovakia) and is relatively modest with its other bordering countries (the Czech Republic and Hungary). Similarly for historical colonial linkages; Austria shares colonial ties with Slovenia as well as Croatia and the Czech Republic. Bilateral efficiency scores for the United Kingdom are somewhat less variable, ranging between the highest value vis-à-vis Cyprus (60), which shares a common language and a colonial past, and the lowest values vis-à-vis Croatia, Slovenia and Lithuania (38 and 39). Also sharing a colonial history with the United Kingdom, a mid-range value (48) is obtained for trade efficiency with Malta.

***Intermediate bilateral efficiency scores*:** For the remaining countries, bilateral efficiency scores tend to veer around mid-range values, albeit somewhat higher for Germany, Italy and Portugal, likely reflecting already well-established trade linkages with the new member states long before EU entry.

***Evolution of efficiency scores*:** It is also interesting to consider the evolution of trade efficiency. Specifically, to determine if there are any discernible differences in the efficiency scores over time, the sample period is split into four sub-periods. Rows (1) and (2) in Table 3 show the bilateral efficiency scores averaged across the sub-periods representing before and after the financial crisis (1995-2007 and 2008-2014) and rows (3) and (4) represent before and after the expected exit of the United Kingdom from the EU (2015-2018 and 2019-2022).

[Insert Table 3 here]

High efficiency scores are obtained for the pre-financial crisis phase (row 1, Table 3), not surprising as rapid trade expansion and a re-orientation of trade between many ex-communist countries and the Western European countries took place soon after ties with the former Soviet Union were cut in the early 1990s. During this phase, efficiency scores are highest for many of the smaller countries (Cyprus, Estonia and Latvia) and the newer member countries (Croatia, Bulgaria and Romania).

During the post-financial crisis phase (row 2, Table 3), the smaller countries have tended to register a fall in trade efficiency in line with sharply declining economic growth and tumbling trade volumes. On the other hand, the larger countries have tended to maintain similar efficiency scores (Romania) or even increase them (the Czech Republic, Hungary, Poland and Slovakia). Clearly, changes in the core gravity variables (GDP and GDP per capita) have consequences on the trade efficiency scores. Take, for example, the Baltic countries, which registered negative GDP growth rates in 2009 of the order of 14 per cent (WDI 2017). In contrast, Poland – the only new member state unscathed by the financial crisis – remains in positive territory throughout the post-financial crisis phase.

The outlook for trade efficiency (rows 3 and 4, Table 3) should remain broadly stable and may even increase for the larger countries in the post-Brexit phase in tandem with positive projections of income growth. In other words, assuming the income growth forecasts are correct, the expected exit of the United Kingdom from the EU should not severely hamper trade efficiency with the new member states.

In short, bilateral trade efficiency scores depend on a variety of factors, including a country's trading regime and membership of a regional trade agreement (RTA) as well as other characteristics related to history (a common colonial past, a shared language and a mutual heritage, implying similar tastes and preferences) and geography (physical distance, landlocked features, shared boundaries). Perhaps more important, trade efficiency depends on positive income growth; the evolution of the efficiency scores highlighted the flipside, that is, the linkage between declining growth in the post-financial crisis and lower efficiency scores.

5. CONCLUSIONS

The opening up process of the ex-communist countries began with trade integration. Long before the twenty-fifth anniversary of the fall of the Berlin Wall, the Western European countries had already become their main trading partners. In anticipation of a reorientation of trade towards Western Europe, early studies sought to quantify the volume of trade likely to prevail in a bilateral direction assuming full economic liberalisation. Typically, the degree of bilateral trade integration is assessed by comparing actual trade volumes with potential trade volumes using the gravity model parameters that fit a model of a normal country's trade patterns. This approach, however, does not

allow a comparison of trade levels against a maximum level of trade defined by a stochastic frontier.

Using a stochastic frontier approach to estimating the gravity equation for a panel of exports from 18 Western European countries to the 13 new EU member countries over the 1995-2022 period, the efficiency of bilateral trade integration is identified relative to maximum levels. The sample period includes actual data (1995-2016) covering the transformation phase from communism to EU entry and forecast data (2017-2022) to account for the expected exit of the United Kingdom from the EU in March 2019.

The efficiency scores, averaged across all 18 Western European countries, suggest a high degree of trade integration, with all new member states achieving close to two-thirds of frontier estimates over the 1995-2022 period. Averaging the efficiency scores across the new member states, efficiency scores are highest for the Netherlands, Belgium-Luxembourg and Spain and are lowest for Norway and the United Kingdom, where potential for trade expansion is greatest.

Bilateral scores are shown to depend on a variety of factors, including a country's trading regime and membership of a regional trade agreement (RTA) as well as other characteristics related to history (a common colonial past, a shared language and a mutual heritage, implying similar tastes and preferences), geography (physical distance, landlocked features, shared boundaries) and economic variables (income). A comparison of the efficiency scores across various sub-periods (before and after the financial crisis and before and after Brexit) indicate high efficiency scores were achieved early on, consistent with the rapid opening up and accompanying reorientation of trade towards Western Europe. Clearly, the early liberalisation of trade and the dismantling of barriers

under the bilateral free trade agreements (FTAs) have boosted trade efficiency. Using forecast data for 2017-2022, trade efficiency should remain broadly stable and may even increase for the larger countries in the post-Brexit phase.

Of course, the outlook for the stability of trade efficiency depends in part on positive economic growth projections, which can change as the full consequences of Brexit become apparent. In the meantime, the effect of the exchange rate has already begun to bite: the sharp fall in the value of the pound sterling after the 2016 referendum on EU membership, while lowering the price of exports abroad, raises the price of imports from the EU and beyond. Furthermore, the prospect of introducing tariffs on trade, declarations in terms of the origin of goods as well as border checks together with their concomitant costs, contractual obligations and time in transit heighten the possibility of reduced trade efficiency.[16] One consequence is that some of the new member states may diversify trade away from the United Kingdom towards the remaining EU member countries.[17] In time, the full scale of what Brexit entails will become clearer; analysing its economic consequences will likely be an important basis for future research.

ENDNOTES

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[2] The CMEA system, also known as COMECON, was formed in 1949 to co-ordinate economic development and industrial production between the Soviet Union and its member countries.

[3] Once the ex-communist countries began to trade competitively in convertible currencies, their trading regimes soon shared the main features of their European counterparts: state monopolies were abolished allowing private activity in the foreign trade sector to flourish; licensing and quotas were largely removed; and tariffs and exchange rates became the primary instruments of trade policy (Gros and Gonciarz 1996).

[4] In the aftermath of the financial crisis, trade growth plummeted by nearly a quarter in 2009, fell sharply in 2012 and 2015 (seven and nine per cent respectively) and slowed to a trickle in 1999 as the internet bubble burst.

[5] Anderson (1979) was the first to derive the gravity equation using the properties of the expenditure system and the Armington (1969) assumption that goods are differentiated by country of origin.

[6] The 18 Western European countries include the 15 established EU member countries (Austria, Belgium-Luxembourg, Denmark, Finland, France, Germany, Greece, Ireland,

Italy, the Netherlands, Portugal, Spain, Sweden and the United Kingdom) with Belgium and Luxembourg treated as a single country and the three EFTA member countries (Iceland, Norway and Switzerland).

[7] The 13 new member states comprise ten countries that joined the EU in 2004 (Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia), followed by two countries in 2007 (Bulgaria and Romania) and, more recently, Croatia in 2013.

[8] The start period avoids pre-transition data, which do not adequately capture changing trade structures as the transition process got underway (Nilsson 2000).

[9] A land border is shared between Austria and the Czech Republic, Hungary, Slovakia and Slovenia; Germany and the Czech Republic and Poland; Greece and Bulgaria; and Italy and Slovenia.

[10] The same official language is spoken in Greece and Cyprus (Greek); and Ireland, the United Kingdom and Malta (English).

[11] Colonial linkages are shared between Austria and Croatia, the Czech Republic and Slovenia; Germany and Poland; Greece and Cyprus; Sweden and Estonia; and the United Kingdom and Cyprus and Malta.

[12] Three new member states are landlocked: the Czech Republic, Hungary and Slovakia.

[13] Common shocks include the global downturn at the turn of the century when the dot-com bubble burst; the global financial crisis and the ensuing debt crisis; and the more recent general slowdown in 2015 linked to China's decelerating growth and falling commodity prices.

[14] Bussière *et al* (2005) have previously highlighted unobservable transition-related characteristics, for example, the development of financial institutions, the building of transport facilities and the amount of time it takes for businesses to establish new contacts and to acquire new skills.

[15] In addition to the geographic obstacle of no open access to the sea, landlocked countries also accumulate an array of economic and institutional obstacles (Raballand 2003).

[16] Current indications are that the UK will leave the EU's single market and customs union as the price of imposing restrictions on EU migrants. Without an agreed transition arrangement upon exit, trade tariffs will apply under World Trade Organisation (WTO) rules between the UK and the EU and with all other countries that have negotiated a free trade agreement with the EU, implying newly introduced tariffs on trade with more than 50 countries that currently enjoy tariff-free trade.

[17] In terms of the big trio's exports volumes (IMF 2017), the United Kingdom is Poland's second most important trading partner (accounting for US$144 billion in export volumes over the 1995-2016 period); the Czech Republic's fifth most important trading partner (US$96.6 billion); and Hungary's sixth most important trading partner (US$63.7 billion).

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Table 1 A stochastic frontier specification of EU and EFTA exports determinants to the new member states (1995-2022)[a]

Regressors	(1)	(2)	(3)
$Country_i$ GDP	0.99***	0.99***	0.97***
	(0.01)	(0.01)	(0.01)
$Country_j$ GDP	0.67***	0.74***	1.23***
	(0.01)	(0.01)	(0.07)
Distance	–1.16***	–1.14***	–1.38***
	(0.02)	(0.02)	(0.02)
GDP per capita difference	0.11***	0.08***	0.16***
	(0.02)	(0.02)	(0.02)
Adjacency	0.21***	0.17***	-0.35×10^{-2}
	(0.07)	(0.06)	(0.06)
Language	1.09***	1.08***	0.66***
	(0.10)	(0.10)	(0.09)
Colony	0.43***	0.44***	0.34***
	(0.07)	(0.06)	(0.06)
Landlocked	–0.11***	–0.20***	–0.89***
	(0.03)	(0.03)	(0.06)
EU	0.26***	0.63***	0.53***
	(0.03)	(0.03)	(0.03)
Constant	–14.76***	–16.59***	–26.12***
	(0.41)	(0.42)	(1.72)
No. of obs	6164	6164	6164
Skewness test[b]	–0.60***	–0.59***	–0.63***
M3T test[c]	–3.12***	–3.02***	–3.27***
LR test[d]	190.39***	163.00***	169.15***
Time	–	Yes	Yes
NMS country fixed effects	–	–	Yes

[a] Standard errors are in parentheses.
[b] Test of skewness in the least squares residuals (Schmidt and Lin 1984).
[c] M3T test of skewness in the least squares residuals (Coelli 1995).
[d] A likelihood ratio (LR) test between the unrestricted SFA model and its restricted OLS counterpart.
*** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level.

Table 2 Efficiency score estimates from the stochastic frontier specification of the gravity model (1995-2022)[a,b]

	AUT	BEL-LUX	DNK	FIN	FRA	DEU	GRC	IRL	ISL	ITA	NLD	NOR	PRT	ESP	SWE	CHE	GBR	Avg
BGR	0.67	0.73	0.50	0.52	0.52	0.67	0.78	0.57	0.31	0.58	0.75	0.26	0.64	0.71	0.48	0.61	0.48	0.58
HRV	0.61	0.68	0.61	0.55	0.44	0.70	0.60	0.54	0.47	0.70	0.75	0.49	0.50	0.68	0.62	0.49	0.38	0.58
CYP	0.43	0.70	0.53	0.40	0.51	0.56	0.75	0.57	0.50	0.58	0.75	0.60	0.63	0.65	0.40	0.49	0.60	0.57
CZE	0.51	0.71	0.47	0.59	0.52	0.59	0.53	0.66	0.44	0.66	0.77	0.51	0.71	0.73	0.62	0.57	0.50	0.59
EST	0.61	0.73	0.65	0.41	0.45	0.60	0.32	0.52	0.60	0.65	0.78	0.54	0.62	0.64	0.54	0.63	0.49	0.58
HUN	0.54	0.74	0.54	0.62	0.58	0.73	0.34	0.65	0.63	0.58	0.78	0.27	0.71	0.68	0.58	0.57	0.49	0.59
LVA	0.56	0.72	0.63	0.63	0.43	0.55	0.41	0.56	0.71	0.64	0.74	0.52	0.58	0.62	0.47	0.66	0.48	0.58
LTU	0.41	0.74	0.61	0.58	0.42	0.51	0.39	0.35	0.86	0.60	0.72	0.66	0.53	0.71	0.57	0.46	0.39	0.56
MLT	0.37	0.64	0.63	0.56	0.61	0.58	0.69	0.46	0.60	0.65	0.74	0.49	0.52	0.62	0.56	0.42	0.48	0.57
POL	0.53	0.74	0.51	0.59	0.56	0.51	0.43	0.67	0.70	0.68	0.76	0.62	0.67	0.72	0.58	0.57	0.49	0.61
ROM	0.70	0.72	0.44	0.41	0.65	0.72	0.58	0.65	0.21	0.71	0.75	0.34	0.71	0.70	0.43	0.58	0.48	0.58
SVK	0.32	0.74	0.52	0.62	0.66	0.74	0.46	0.55	0.60	0.66	0.77	0.30	0.75	0.74	0.60	0.60	0.45	0.59
SVN	0.71	0.71	0.47	0.67	0.56	0.72	0.69	0.58	0.26	0.71	0.74	0.27	0.53	0.72	0.60	0.53	0.38	0.58
Avg	0.54	0.72	0.55	0.55	0.53	0.63	0.54	0.56	0.53	0.65	0.75	0.45	0.62	0.69	0.54	0.55	0.47	–

[a] Efficiency scores are derived from the parameter estimates of the preferred specification, (column 3, Table 1).

[b] The 13 new member states comprise Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.

Table 3 Evolution of efficiency score estimates (1995-2022)[a]

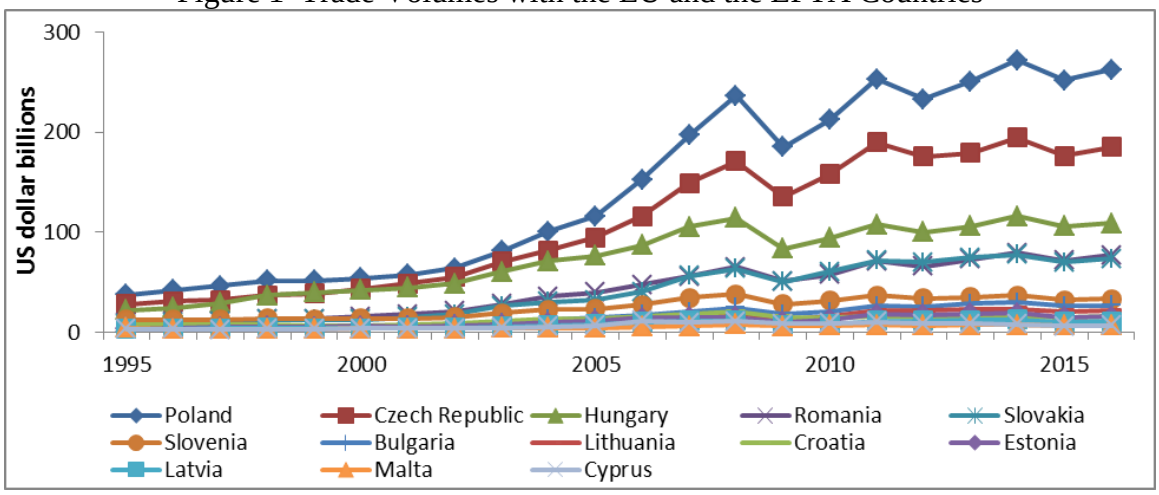
		AUT	BEL-LUX	DNK	FIN	FRA	DEU	GRC	IRL	ISL	ITA	NLD	NOR	PRT	ESP	SWE	CHE	GBR	Avg
BGR	(1)	0.72	0.71	0.62	0.66	0.60	0.69	0.80	0.61	0.36	0.60	0.72	0.21	0.58	0.58	0.63	0.61	0.47	0.60
	(2)	0.68	0.70	0.48	0.47	0.49	0.65	0.77	0.59	0.26	0.55	0.72	0.21	0.60	0.72	0.45	0.60	0.39	0.55
	(3)	0.64	0.76	0.46	0.49	0.49	0.67	0.78	0.56	0.33	0.58	0.78	0.31	0.68	0.78	0.43	0.61	0.44	0.58
	(4)	0.63	0.76	0.44	0.48	0.49	0.67	0.77	0.52	0.31	0.59	0.78	0.31	0.68	0.77	0.42	0.62	0.60	0.58
HRV	(1)	0.66	0.68	0.66	0.65	0.52	0.71	0.50	0.67	0.54	0.72	0.72	0.62	0.35	0.64	0.74	0.45	0.41	0.60
	(2)	0.64	0.64	0.64	0.62	0.45	0.70	0.61	0.54	0.67	0.70	0.76	0.45	0.52	0.65	0.65	0.48	0.39	0.59
	(3)	0.58	0.68	0.55	0.45	0.39	0.68	0.64	0.47	0.34	0.68	0.76	0.43	0.56	0.71	0.53	0.50	0.29	0.54
	(4)	0.59	0.70	0.57	0.48	0.42	0.70	0.66	0.48	0.35	0.70	0.77	0.48	0.58	0.72	0.55	0.54	0.45	0.57
CYP	(1)	0.45	0.70	0.66	0.54	0.62	0.60	0.68	0.70	0.52	0.64	0.71	0.52	0.59	0.68	0.63	0.55	0.67	0.62
	(2)	0.55	0.72	0.56	0.54	0.54	0.57	0.74	0.58	0.40	0.60	0.79	0.48	0.63	0.67	0.45	0.49	0.62	0.58
	(3)	0.38	0.71	0.48	0.28	0.44	0.54	0.80	0.52	0.56	0.55	0.77	0.69	0.65	0.65	0.27	0.45	0.50	0.54
	(4)	0.34	0.69	0.43	0.26	0.42	0.52	0.78	0.47	0.50	0.54	0.75	0.70	0.64	0.62	0.25	0.45	0.61	0.53
CZE	(1)	0.55	0.69	0.46	0.72	0.55	0.57	0.46	0.75	0.21	0.64	0.69	0.61	0.57	0.70	0.68	0.56	0.51	0.58
	(2)	0.52	0.71	0.50	0.57	0.49	0.58	0.46	0.71	0.41	0.62	0.78	0.64	0.76	0.71	0.62	0.60	0.45	0.60
	(3)	0.50	0.73	0.48	0.54	0.52	0.60	0.61	0.61	0.57	0.68	0.81	0.39	0.77	0.75	0.61	0.57	0.45	0.60
	(4)	0.48	0.72	0.46	0.52	0.51	0.59	0.59	0.57	0.55	0.68	0.80	0.39	0.76	0.74	0.59	0.55	0.59	0.59
EST	(1)	0.64	0.72	0.73	0.60	0.50	0.61	0.32	0.67	0.67	0.66	0.75	0.55	0.56	0.60	0.64	0.50	0.50	0.60
	(2)	0.59	0.73	0.63	0.38	0.46	0.63	0.27	0.49	0.77	0.65	0.76	0.59	0.65	0.58	0.56	0.64	0.49	0.58
	(3)	0.61	0.74	0.63	0.35	0.43	0.59	0.35	0.46	0.49	0.65	0.80	0.52	0.64	0.70	0.49	0.68	0.41	0.56
	(4)	0.61	0.74	0.62	0.33	0.42	0.58	0.35	0.46	0.46	0.65	0.80	0.49	0.63	0.68	0.49	0.68	0.55	0.56
HUN	(1)	0.60	0.73	0.48	0.74	0.56	0.71	0.30	0.69	0.21	0.57	0.72	0.21	0.68	0.64	0.66	0.55	0.46	0.56
	(2)	0.51	0.72	0.54	0.60	0.57	0.71	0.28	0.65	0.61	0.53	0.77	0.24	0.67	0.66	0.57	0.59	0.43	0.57
	(3)	0.51	0.74	0.57	0.55	0.59	0.74	0.37	0.63	0.85	0.59	0.80	0.31	0.74	0.71	0.54	0.57	0.45	0.60

	(4)	0.53	0.76	0.59	0.58	0.60	0.76	0.40	0.63	0.84	0.62	0.81	0.32	0.75	0.73	0.54	0.59	0.62	0.63
LVA	(1)	0.60	0.71	0.71	0.72	0.48	0.60	0.40	0.57	0.74	0.64	0.73	0.63	0.53	0.56	0.62	0.61	0.50	0.61
	(2)	0.57	0.67	0.60	0.59	0.43	0.53	0.33	0.54	0.75	0.62	0.72	0.52	0.57	0.60	0.45	0.70	0.45	0.57
	(3)	0.55	0.75	0.61	0.62	0.42	0.55	0.47	0.58	0.69	0.65	0.75	0.48	0.62	0.68	0.42	0.66	0.41	0.58
	(4)	0.53	0.74	0.60	0.60	0.41	0.53	0.43	0.55	0.67	0.64	0.75	0.45	0.61	0.66	0.39	0.67	0.55	0.58
LTU	(1)	0.44	0.68	0.71	0.68	0.46	0.55	0.30	0.45	0.87	0.59	0.66	0.51	0.48	0.62	0.59	0.49	0.43	0.56
	(2)	0.41	0.76	0.59	0.53	0.42	0.49	0.29	0.36	0.90	0.60	0.71	0.61	0.51	0.63	0.54	0.48	0.35	0.54
	(3)	0.40	0.77	0.58	0.55	0.40	0.51	0.48	0.31	0.85	0.60	0.75	0.75	0.57	0.80	0.58	0.44	0.33	0.57
	(4)	0.39	0.77	0.57	0.54	0.41	0.51	0.46	0.29	0.84	0.60	0.75	0.76	0.57	0.80	0.56	0.44	0.47	0.57
MLT	(1)	0.44	0.68	0.67	0.43	0.76	0.62	0.63	0.57	0.50	0.66	0.72	0.73	0.51	0.63	0.50	0.51	0.54	0.59
	(2)	0.41	0.65	0.68	0.48	0.65	0.56	0.67	0.47	0.72	0.67	0.77	0.61	0.59	0.58	0.61	0.52	0.51	0.60
	(3)	0.33	0.62	0.61	0.67	0.54	0.58	0.74	0.42	0.59	0.64	0.76	0.33	0.52	0.65	0.60	0.34	0.38	0.55
	(4)	0.30	0.59	0.58	0.68	0.51	0.54	0.71	0.39	0.57	0.62	0.74	0.31	0.47	0.62	0.54	0.31	0.50	0.53
POL	(1)	0.50	0.70	0.51	0.65	0.56	0.44	0.35	0.65	0.58	0.66	0.70	0.51	0.54	0.66	0.59	0.54	0.45	0.56
	(2)	0.53	0.74	0.49	0.60	0.54	0.51	0.37	0.66	0.80	0.67	0.76	0.65	0.68	0.70	0.58	0.59	0.45	0.61
	(3)	0.54	0.77	0.52	0.55	0.57	0.53	0.50	0.69	0.71	0.69	0.79	0.66	0.74	0.76	0.58	0.57	0.45	0.62
	(4)	0.54	0.77	0.52	0.55	0.58	0.54	0.51	0.69	0.71	0.71	0.79	0.66	0.74	0.75	0.58	0.59	0.61	0.64
ROM	(1)	0.74	0.72	0.47	0.45	0.67	0.72	0.63	0.65	0.22	0.76	0.72	0.32	0.51	0.57	0.60	0.58	0.54	0.58
	(2)	0.70	0.69	0.49	0.44	0.64	0.70	0.53	0.73	0.25	0.69	0.74	0.44	0.75	0.68	0.40	0.63	0.42	0.58
	(3)	0.69	0.74	0.40	0.38	0.65	0.73	0.58	0.62	0.20	0.69	0.77	0.31	0.78	0.77	0.37	0.55	0.40	0.57
	(4)	0.68	0.74	0.39	0.36	0.64	0.73	0.58	0.59	0.19	0.70	0.77	0.28	0.79	0.77	0.36	0.56	0.55	0.57
SVK	(1)	0.22	0.70	0.49	0.70	0.56	0.71	0.35	0.63	0.31	0.62	0.69	0.34	0.58	0.70	0.63	0.54	0.40	0.54
	(2)	0.30	0.74	0.58	0.63	0.68	0.74	0.42	0.57	0.67	0.65	0.79	0.29	0.72	0.71	0.60	0.61	0.43	0.60
	(3)	0.38	0.77	0.52	0.59	0.70	0.75	0.55	0.50	0.71	0.69	0.79	0.29	0.84	0.77	0.59	0.61	0.41	0.62
	(4)	0.37	0.77	0.50	0.57	0.70	0.75	0.54	0.49	0.70	0.70	0.79	0.29	0.84	0.77	0.58	0.62	0.57	0.62

SVN	(1)	0.71	0.67	0.52	0.68	0.70	0.71	0.51	0.59	0.25	0.70	0.70	0.39	0.42	0.73	0.70	0.49	0.40	0.58
	(2)	0.71	0.70	0.46	0.68	0.56	0.72	0.70	0.48	0.35	0.71	0.73	0.35	0.55	0.70	0.56	0.53	0.33	0.58
	(3)	0.71	0.72	0.46	0.67	0.48	0.73	0.78	0.61	0.22	0.71	0.77	0.20	0.56	0.73	0.57	0.55	0.32	0.58
	(4)	0.72	0.73	0.46	0.67	0.49	0.73	0.79	0.64	0.22	0.72	0.77	0.14	0.57	0.73	0.57	0.56	0.47	0.59

[a] Efficiency scores are derived from the parameter estimates of the preferred specification, (column 3, Table 1) and averaged over four sub-periods. For each new member state, rows (1) and (2) represent before and after the financial crisis (1995-2007 and 2008-2014) and rows (3) and (4) represent before and after the expected exit of the United Kingdom from the EU (2015-2018 and 2019-2022). Note that the efficiency scores for the period 2017-2022 are based on data projections.

Figure 1 Trade Volumes with the EU and the EFTA Countries



Source: *Direction of Trade Statistics*, International Monetary Fund.