Spatial interaction and security: A review and case study of the Syrian refugee crisis[1]

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ABSTRACT

Sir Alan Wilson's ideas and approaches have been highly influential in a number of fields within urban and regional modelling, including migration, transport and economics. Latterly, a substantial volume of research has explored the application of similar ideas to new problems, and at larger scales, many of which relate to major global challenges with significant policy implications. In this paper, we first review some of Alan's contributions in this area, focussing on his work on crime and security and its relationship with other dynamic phenomena. Following this, we present the results of some original empirical work concerning forced migration associated with the current Syrian refugee crisis. This work is directly inspired by Alan's work, and shares his ambition of contributing to a pressing policy challenge. In our model, which applies a spatial interaction framework, we examine the flows of migrants forced to leave Syria and the characteristics which influence their choice of destination country. In line with the intuitions of the broader literature, we find that shorter distances, economic prosperity, and cultural similarity (e.g., shared language and historical ties) attract forced migrants. Furthermore, we find that migrants are more likely to favour countries in which the probability of being granted asylum is higher; a finding with potential implications for policy. Contrary to expectation, we find little influence for levels of security in potential host nations (e.g. absence of crime and terrorism). This paper represents a preliminary modelling effort in this area which will be extended in future work incorporating dynamic models.

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INTRODUCTION

In this paper, we discuss some of Sir Alan Wilson's contributions to the study of crime and security, which is the field in which we have most closely collaborated. We then present the findings of an original empirical study concerned with the Syrian refugee crisis, which is inspired by – and builds directly upon – his earlier work and illustrates the diversity of subject areas to which his approaches continue to be applied. We start by reviewing some of the work in which Alan has been directly involved, discuss how this inspired our work on Syrian refugees, and then present our findings.

Between 2010 and 2015, three of the current authors (Braithwaite, Davies and Johnson) had the pleasure of working on a large interdisciplinary EPSRC-funded project for which Alan was the Principle Investigator. This project – Explaining, Modelling, and Forecasting Global Dynamics (ENFOLDing) – sought to develop and apply mathematical tools to understand the global dynamics and inter-dependencies of four systems: trade, migration, security (including crime), and overseas development aid. One of the central themes of this project was the desire to apply the modelling approaches pioneered by Alan – which had been successful in urban and regional modelling – at both a larger scale and in novel domains. Crime and security were one such domain and, in what follows, we discuss some of the research in this area conducted as part of that project, as well as some of the work concerned with migration which directly influenced the original research that we present in this paper. We direct the reader interested in more details of the wider research conducted within ENFOLDing to two edited collections that describe the project. The first (Wilson, 2016a) adopts a more mathematical orientation, while the second (Wilson, 2016b) is primarily concerned with policy implications.

Crime and Security

Just like many other phenomena, incidents of crime - and threats to security more generally - exhibit clear spatial patterns (e.g., Johnson, 2010; Weisburd, 2015; LaFree et al., 2012). In the ENFOLDing project, we explored the spatial patterns of a number of crime and security phenomena, at a range of geographic scales, with a focus on those which invited analogy with the other systems under

consideration. Some analyses used novel data, while others used novel mathematics, and indeed many used both.

The first example we will discuss concerned the sudden onset riots, which occurred in London over the five-day period between August 6th and 10th 2011. Unprecedented in scale for the UK in recent times, these were estimated to have caused more than £250 million damage (Met Police, 2012) and led to over 3,000 arrests. Unlike pre-planned protests, the riots could have happened anywhere, which presented challenges to their policing. With a few exceptions (e.g., Abudu-Stark et al., 1974), previous empirical research on riots had tended to examine patterns at the city scale (e.g., Midlarsky, 1980; Myers, 2010), which provides only limited understanding of the precise spatial patterns, how they evolve, and how law enforcement might police them. To provide more insight, we conducted a series of studies at much smaller spatial scales to examine whether the spatial pattern of the riots was random, as would be expected by some perspectives (Le Bon, 1960), or whether there were distinct spatial patterns. Our findings provided clear support for the latter, with there being statistical evidence of spatial clustering at a range of spatial scales including census areas and 400 metre grid squares (Baudains et al., 2013c; Baudains et al., 2013a). Evidence of spatial contagion was also found, whereby rioting appeared to spread to nearby locations (Baudains et al., 2013a; Baudains et al., 2013b).

Having established that patterns were not random, the next stage of the research sought to examine the spatial behaviour of offenders; that is, why they chose to riot in the locations that they did. We tested hypotheses identifying the utility of certain locations as a function of their properties, which is a familiar problem in urban and regional modelling. Two approaches were taken to do this, one using a statistical random utility framework (McFadden, 1974) to examine the target choices of offenders, relative to their home location, and a second employing a more mathematical framework. These studies (Baudains et al., 2013a; Baudains & Johnson, 2018) showed that, all else equal, offenders tended to engage in the riots in areas that were closer to their home location, in areas with higher

levels of deprivation, in areas with more retail facilities, and in areas that had experienced rioting in the previous 24 hours.

These findings supported suggestions made elsewhere that the London riots had been largely acquisitive in nature, with looting a dominant driver. This invited a natural analogy with retail modelling: if rioters sought similar rewards to shoppers, then models which had been successful in that context might be adapted in order to understand the large-scale behaviours of rioters. Alan's previous work in the retail context represented a canonical example of spatial interaction modelling (Wilson, 1970), one goal of which is to estimate flows of some quantity (e.g., money or people) between a system of locations. In particular, given stocks at origins, and the utility characteristics of destinations, an entropy-maximising approach can be used to calculate the most likely inter-location flows. Subsequent work (Wilson, 2008) showed how this approach could be combined with other models in order to represent evolving flows in dynamical systems.

The riot scenario could be framed in these terms: the populations of residential areas constituted the 'stocks' of potential rioters, and the utility of potential targets could be modelled in terms of their retail volume and travel distance. This was combined with a model of riot involvement based on the 'SIR' epidemiological paradigm (Anderson and May, 1992) to produce a dynamic model of riot activity across the city, with a simple model of police activity also included (Davies et al, 2013). The model was capable of reproducing many of the empirical features of the London activity, such as distance decay and agglomeration at certain locations, and therefore constitutes a dynamic, macro-level equivalent of the previous target-choice research. In particular, the nature of the model meant that alternative scenarios – such as changes in police behaviour or resourcing – could be run in order to explore the potential effect of policy interventions.

A second example explored in the ENFOLDing project was maritime piracy. At the time, little was known about spatial patterns of maritime piracy, but the problem was escalating, particularly around the Gulf of Aden, and estimates suggested that this problem was costing the global economy around

$7 billion per year (Ploch, 2010). Our initial research thus aimed at describing patterns using a statistical framework, and in Marchione and Johnson (2013) we demonstrated that incidents of Maritime Piracy were not only spatially clustered, but also clustered in space *and* time, more than would be expected assuming that the timing and location of events were independent. In Marchione, Johnson and Wilson (2014) we built an agent-based model of maritime piracy, using the Gulf of Aden as a case study. In that paper, we used empirical data on shipping activity to model the flow of potential victims (modelling the activity of different types of vessels from different origins, with different risks associated with each) through the Gulf of Aden, and developed rules – based on the available literature – to guide their behaviour and that of pirate (offenders) and naval vessels (capable guardians). Methods were developed to enable us to calibrate (with one sample of data) and compare the model outcomes to (a different sample of) empirical data. While imperfect, due to missing data on naval strength and operating tactics (which were simply not available), the final model provided a good fit to the empirical data and provided insight into the phenomena and a framework for testing naval strategies. Exemplifying the diversity of approaches applied within the project, Marchione & Wilson (2016) also developed an alternative approach, using a spatial interaction framework rather than an agent-based formulation. In this case, the quantity modelled represented a notion of "threat"; an example of an abstract flow that was developed further in later work relating to military conflict (Baudains et al, 2016).

Migration

A different strand of the ENFOLDing project focused on migration flows. While this workstream of the project did not examine the direct implications of migration on security, systems of migration can clearly influence crime and security risk. There is little evidence to suggest that migration leads to crime in neighbourhoods (e.g., Nunziata, 2014), but migrants — particularly those without formal documentation — may themselves be vulnerable, creating opportunities for their victimisation, including trafficking, extortion, and exploitation (e.g., Newell et al., 2016). Likewise, as will be

discussed later in this paper, outbreaks of unrest, including wars, can lead to the displacement of populations who are forced to flee their homes. Understanding to where they flee and why is important for policy makers.

In the ENFOLDing project, an important question concerned the modelling of interregional migration flows within Europe. While some data exist on such flows, much of it was missing for a number of countries and years of interest. To address this, Dennett and Wilson (2013) developed a multi-level spatial interaction model to estimate the missing flows, using the distance between origins and destinations as the key parameter of the model. While the data necessary to establish the "ground truth" for the entire system was not available, data for some countries (including the UK) were. Comparison of the SI model results with the UK data demonstrated a good overall fit for most countries, with R-squared values of 50% or more. Further analyses suggested that the exclusion of inner London, which offers (for example) substantial job opportunities, improved the model fit further, indicating the role of omitted variables in migrant decision making. A final point to make here about the model presented in Dennett & Wilson was that they show how it could be used to produce predictions for the flows from the UK to all other countries – a modelling goal that we sought to address in the work we will discuss next.

As discussed above, three of the current authors were successful in acquiring funding from the US Department of Defense's Minerva Research Initiative to develop, amongst other things, spatial interaction models to help understand refugee flows from conflict zones, focusing on the case of Syria, in particular. These models were informed by and drew inspiration from the ENFOLDing project and hence Alan's contributions to understanding flows and the importance of so doing for policy and research. In what follows we describe this aspect of the work in more detail, presenting some initial findings.

BACKGROUND TO FORCED MIGRATION

Spatial interaction models of forced migration do not fundamentally differ from equivalent models of other flows, including several of the examples already discussed, and indeed regular migration. They both attempt to mathematically describe and explain flows between sets of origins and destinations, taking into account the stocks and characteristics of both. For a model of the displacement caused by the Syrian Civil War beginning in 2011 (and still ongoing in 2019), these flows will – as with other models of migration – be comprised of people, and in particular the millions of Syrians displaced around the world by the conflict. Where this scenario is distinct from others, though, is in the variables expected to explain the flows, due to the particular (and extraordinary) conditions under which forced migration decisions are taken. Drawing from the wider literature (and the available data), we propose 15 factors which might influence Syrian refugee destination choices, and which we will include in our model.

Firstly, and particularly in the case of forced migration, the decision to flee may be sudden, meaning that those affected may have little opportunity to plan and/or will have limited resources available for their trip. Under such constraints, refugees are likely to prefer, or only be capable of, making shorter trips. Furthermore, because the primary motivation for fleeing in such scenarios is likely to be safety (Moore and Shellman 2007; Missirian and Schlenker 2017), refugees are likely to simply prefer taking refuge in the nearest safe haven, which will often be a bordering country. As well as distance, which is common to all spatial interaction approaches, we therefore include an explicit indicator of contiguity. Further to this point, refugees would also be expected to prefer locations where there are fewer perceived security threats. While such dangers can manifest, and be measured in a variety of ways, some of the most significant issues relevant to the current paper are rates of conflict, terrorism, and crime.

Although forced refugee movements occur under highly constrained circumstances, the literature also emphasizes that it will also generally entail a degree of choice. That is, while refugees may flee to the most easily accessible safe area in the first instance, subsequent journeys to future destinations may

resemble those observed during other forms of migration, such as those motivated by employment or family reunification (Collyer et al. 2012, Davenport et al. 2003, Zimmermann 2009). As such, factors associated with voluntary migration – such as labour market conditions (including average wages and unemployment rates), the size of an ethnically similar diaspora (or colonial ties), and shared language or cultural similarity – are also relevant to refugee destination choices (e.g., Thieleman 2003, Bocker and Havinga 1997) and as such are modelled in what follows.

We also expect that civil liberties and political rights will play an important role in destination choice (Fitzgerald et al. 2014, Neumeyer 2005, Moore and Shellman 2006). Political rights include, for example, the right to form political parties or groups, have fair elections and party competition. Civil liberties include the right to free speech, freedom of the media and the prevalence of the rule of law. Such liberties and rights are important to refugees who were commonly persecuted in their home countries and wish to avoid a similar fate in their new host countries.

Finally, we expect that the likelihood of being granted refugee status will be an important determinant of destination choice. Many states have publicly declared a willingness to observe international law with respect to *non-refoulement* of those who seek asylum (Moore and Shellman 2006). As such, refugees may expect not to be turned away immediately when seeking asylum in these countries. However, refugees are likely to seek destinations where there is a higher probability of attaining formal asylum status in the longer-term, which affords them greater rights and a lower risk of deportation.

In what follows, we test the influence of each of these factors (also summarised in Table 1) briefly discussed here have on refugee flows from Syria. In the sections that follow, we describe the methods adopted, including the data analysed and the specific form of the spatial interaction model used, and then present our findings.

METHODS

Data

For this analysis of the effects of the Syrian Civil War on migration, data on the flows of official refugees[2] from Syria are taken for the years 2011 to 2016 from data provided by the United Nations High Commissioner for Refugees [UNHCR]. It is worth noting that these data exclude those who are internally displaced within Syria, of whom there are at least 6 million people. While such displacement is an important component of the forced migration phenomenon, the inconsistency of data between this and the international component – the sources, and methods used, differ[3] – represents a barrier to their modelling in an integrated way, and so here we consider only the international case. Furthermore, due to limitations in the temporal resolution of the data regarding country characteristics (see below), our models relate to the cumulative total of refugees (2011-2016) rather than the yearly totals. Lastly, as the data for 2017 and 2018 are either unavailable (the latter) or small counts are anonymised (the former), only data up to 2016 are used.

Refugee flows could be modelled at a range of spatial scales from towns, to countries, to regions. In this paper, we focus on flows at the country level[4], which is the spatial unit of analysis for which data

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[2] In accordance with the UNHCR and the 1951 and 1967 United Nation Conventions and the 1969 Organisation of African Unity Convention, refugees are defined as:

- "[persons] who, owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his nationality and is unable or, owing to such fear, is unwilling to avail himself of the protection of that country, or who, not having a nationality and being outside the country of his former habitual residence as a result of such events is unable or, owing to such fear, is unwilling to return to it"; or
- "[persons] who, owing to external aggression, occupation, foreign domination or events seriously disturbing public order in either part or the whole of his country of origin or nationality, is compelled to leave his place of habitual residence in order to seek refuge in another place outside his country of origin or nationality".

[3] Such differences may substantially affect the estimates of flows and may include the criteria used to classify or define refugees, the sampling method applied, or the data used, the time period over which data are collected, and so on.

[4] We employ the most inclusive definition of 'country', as offered by the International Organization for Standardization's 3166-1 standard, which is an internationally-recognised standard for designating countries. Unlike many other designations, this scheme identifies countries where there are populations occupying

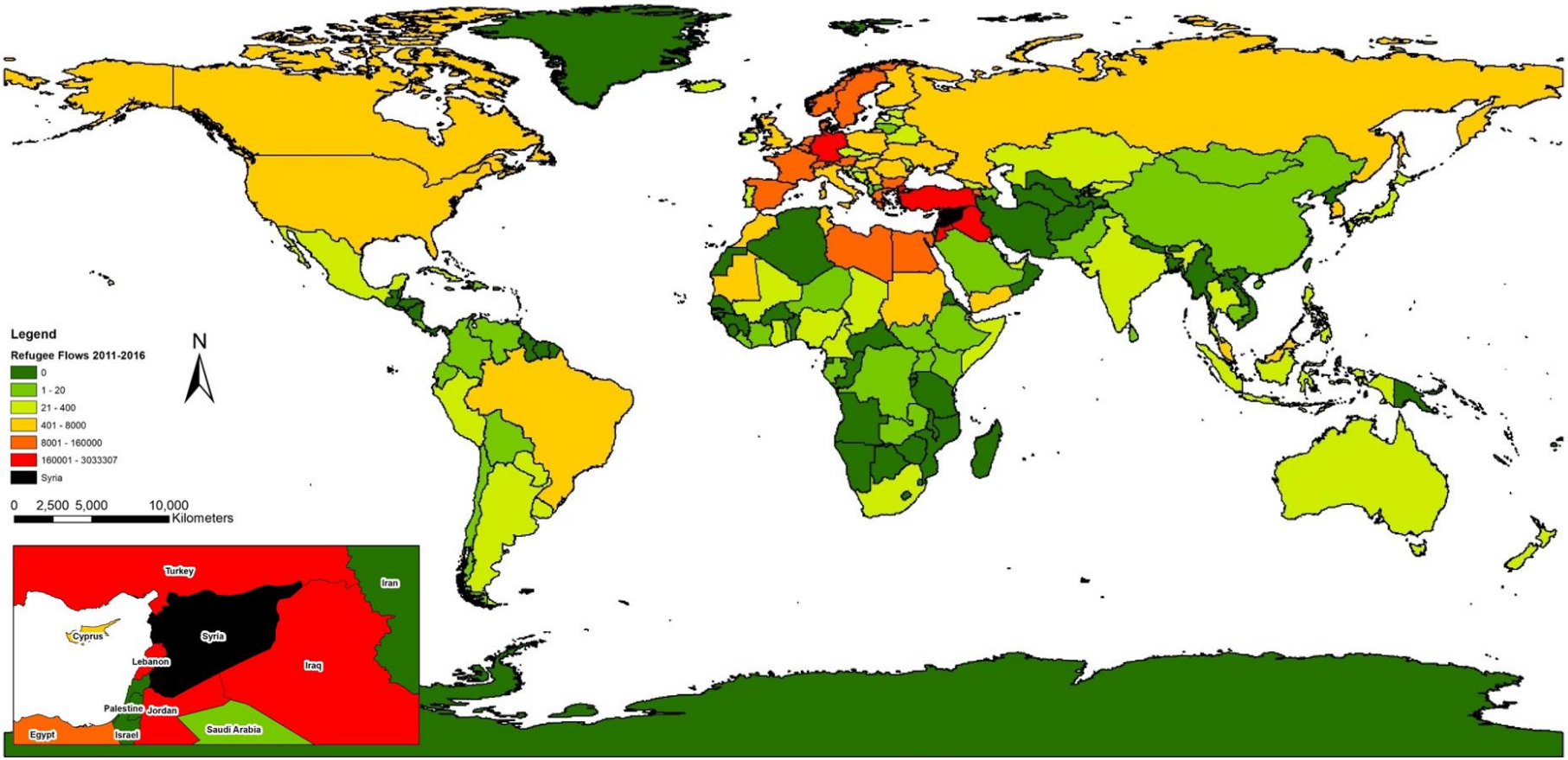
are generated by the UNHCR. However, from those countries available, we excluded a number of countries (in addition to Syria) for the following two reasons. First, some of the listed territories had very few (e.g., Antarctica) or no (e.g., Bouvet Island) residents and as such were not commonly referred to as countries, nor expected to be considered as destination choices for those fleeing Syria. Specifically, 63 territories with populations of less than 250,000 (which collectively accounted for only 0.001% of all Syrian refugees) were removed as possible destination choices from the model. Second, data were unavailable for one or more of the independent variables of interest for 83 countries. Again, these countries accounted for very few Syrian refugees (in this case 0.2% of the total). After these exclusions, 102 possible destination countries remained, with our dataset containing independent variables for all[5]. Cumulatively, these countries accounted for 84% of the world's population (excluding Syria). Figure 1 shows the cumulative observed flows for each country included in the analysis.

Table 1 provides summary statistics for each of the variables analysed, a brief description of how they were derived, and their provenance. A number of points are worth noting. First is the fact that distance is measured and tested in two ways. In one version, it is measured using the spatial distance between the capital city of each country and the capital city (Damascus) of Syria. However, to account for the diminishing effects of longer distances, we also include a second version, obtained by taking the natural logarithm of the distance, and we examine the use of both these alternatives. A further point relates to the measurement of crime, which is hampered by the absence of a universal definition (legal or otherwise) and its variation both between countries and over time. Moreover, crime is

territories. A such, it does not require minimum population thresholds or diplomatic recognition to designate 'country' status.

[5] Analyses were also conducted that included the 62 countries that had up to two missing values. For these countries, the missing data were imputed through estimation, such as taking the mean of the values of that country's nearest neighbours. These analyses revealed the same pattern of results as those reported below and hence are discussed no further.

Figure 1: Map of Syrian refugee flows, 2011-2016



typically measured in terms of particular types of offences, such as burglary and assault, the definitions of which – and the availability of data on them – varies considerably across countries. The one type of crime for which there is little or no variation in definition, and for which data tends to be available across countries, is homicide. As such, in the current study, we use the homicide rate (per 100,000 residents) to measure crime at the country level.

Lastly, no data were available on either the Syrian population resident in the destination countries, or the number of Syrians in each destination country due to unforced migration. This presented a challenge in terms of estimating the similarity (in terms of cultural composition) of the population in Syria and (the Syrian diaspora in) each of the destination countries. Given that around 87% of the population of Syria is Muslim (Central Intelligence Agency, 2011), we chose to use data on the Muslim population resident in each country which provides a measure of religious similarity. This was measured in two ways. First, as the raw number of Muslims within the population and, second, as the percentage of the population that is Muslim.

Analytic Model

Spatial interaction models can be estimated in a number of ways, depending on the modelling task. As well as the entropy-maximisation approach typically applied in Alan's work (e.g., Dennett & Wilson, 2016), other approaches based on regression are also common (e.g., Flowerdew & Atkin, 1982; Raymer, 2007). In this work, we follow the approach of Abel (2010) and employ negative binomial regression (NBR). This form of model is appropriate given that our dependent variable is a count of individuals that displays clear evidence of over-dispersion in terms of greater variability in its distribution compared to what would be expected for a Poisson distribution (see Table 1). In such circumstances, a Poisson model will fail to account for the over-dispersion and produce biased estimates, though it is worth noting that both approaches give the same results in the absence of over-dispersion. Our equation is specified as follows:

$$\mu = exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p)$$

Table 1

Variable (Unit)	Derivation (Source)	Mean	SD	Min	Max
Flow	Total number of Syrian refugees, 2011-2016 (UNHCR)	57,868	327,330	0.00	3,033,307
Distance (1000 kilometres)	Spatial distance to the capital city of each country from the capital of Syria	4.96	3.85	0.09	16.29
Distance (log 1000 kilometres)	The natural logarithm of the spatial distance between the capital cities	1.25	0.96	-2.45	2.79
Neighbouring country	If the country shares a land border with Syria	0.05	0.22	0.00	1.00
Armed conflict per year	The number of armed conflicts[6] per year, 2011-2016 (Uppsala Conflict Data Program)	0.28	0.60	0.00	3.50
Terrorism incident per year (100s)	The number of terrorist attacks[7] per year, 2011-2016 (Global Terrorism Database)	1.03	3.45	0.00	26.07
Homicide rate (per 100,000 population)	The intentional homicide[8] rate per 100,000 population, 2013 (or closest year when data for 2013 is missing) (United Nations Office on Drugs and Crime)	5.73	8.32	0.18	53.75
Average income (£1,000)	Median per-capita self-reported income, 2006-2012 (Gallup)	2.84	3.26	0.08	12.36
Unemployment (%)	Share of the labour force which is unemployed, 2013 (International Labour Organisation)	8.28	5.97	0.27	29.00
Raw size of Muslim population (1,000,000)	Estimated number of Muslims in each country, 2010 (Pew Research Centre)	11.67	33.94	0.00	204.85

[6] The Uppsala Conflict Data Program definition of an armed conflict is “a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths in a calendar year”.
[7] The Global Terrorism Database definition of a terror attack is "the threatened or actual use of illegal force and violence by a non-state actor to attain a political, economic, religious, or social goal through fear, coercion, or intimidation".
[8] The United Nations Office on Drugs and Crime definition of “homicide” is “unlawful death inflicted upon a person with the intent to cause death or serious injury”.

Percentage size of Muslim population (10%)	Estimated percentage of the population that is Muslim (Pew Research Centre)	2.67	3.77	0.00	9.99
Language similarity	If Syria and the other country share a common language spoken by at-least 9% of both populations, 2013 (CEPII Database, see also Head et al 2010).	0.14	0.35	0.00	1.00
Colonial ties	If Syria shares a colonial history (i.e. France and Turkey) (CEPII Database, see also Head et al 2010).	0.02	0.14	0.00	1.00
Civil liberties/political rights	Polity measure of the degree of democracy and autocracy in each country, 2013 (Integrated Network for Societal Conflict Research, see Marshall et al, 2018).	5.61	5.44	-10.00	10.00
Corruption	Corruption Perception index of the perceived levels of public sector corruption, 2018 (Transparency International).	45.32	20.28	8.00	91.00
Probability of being granted asylum (10%)	The number of approved Syria refugee asylum applications (including appeals) relative to the number of rejections, 2011-2016 (UNHCR).	8.24	2.68	0.00	10.00
Population (100 millions)	The size of the population in 2013 (or the nearest year when this data is missing) (World Bank)	0.59	1.87	0.00	26.07

Where μ is the total refugee flows from Syria, x_1, x_2, …, x_p are the predictor variables, and β_1, β_2, …, β_p are the regression coefficients. Our models were estimated using the built-in 'nbreg' command in Stata 14 (StataCorp, 2015).

Pairwise correlations conducted for the independent variables indicated some evidence of multicollinearity (e.g., between income and corruption). However, the omission of some or all of the variables that exhibited evidence of multicollinearity had little effect on the estimated results and so no variables are omitted in the analyses reported below.

RESULTS

For completeness, Table 2 shows the results from the NBR models calculated using both the distance (Model 1) and the logarithm of distance operationalizations (Model 2). The estimated coefficients are expressed as incidence rate ratios [IRR], which reflect the expected percentage change in flow to a country for every one-unit increase in the corresponding explanatory variable. Values above (below) one suggest that flows will be increased (reduced). The p-values indicate the statistical significance of the coefficient estimates for each variable with standard thresholds for significance displayed. We report the estimated dispersion parameters and their statistical significance to show that for both models the dependent variable is over-dispersed and hence that the NBR (rather than the Poisson regression) is the preferred model. Lastly, also shown in Table 2 are three model fit statistics for both models: the McFadden pseudo R^2 where larger values imply better fit and values of 0.2-0.4 represent an excellent fit (McFadden, 1979), and the Akaike Information Criterion (Akaike, 1973) and Bayesian Information Criterion (Schwarz, 1978) statistics which can be used to compare models. In both cases, smaller values are associated with improved model fit.

Overall, the pseudo R^2 values of 0.09 and 0.10 suggest both models fit the data reasonably well but that there are other factors that are not included here that could help to account for variation in flows. As noted above, one might anticipate that knowledge of the whereabouts of Syrian diaspora populations would improve model fit. Moreover, knowledge about the timing and availability of

formal and informal transportation networks connecting Syria and foreign countries could also improve model fit. Unfortunately, these data are not available here.

Table 2: Estimated results from NBR models of refugee flows from Syria

	Model 1		Model 2	
	IRR	p	IRR	p
Distance (1000 kilometres)	0.69	**		
Distance (log 1000 kilometres)			0.13	**
Neighbouring country	53.86	**	0.96	
Armed conflict per year	0.81		0.85	
Terrorism incident per year (100s)	0.91		1.00	
Homicide rate (per 100,000 population)	1.07		1.07	
Average income (£1,000)	1.71	**	1.87	**
Unemployment (%)	1.09		1.04	
Raw size of Muslim population (1,000,000)	1.02		1.00	
Percentage size of Muslim population (10%)	0.96		1.12	
Language similarity	20.65	**	9.11	**
Colonial ties	6.04		61.39	*
Civil liberties/political rights	1.15	*	1.17	*
Corruption	0.98		0.98	
Probability of being granted asylum (10%)	1.24	**	1.24	**
Population (100 millions)	1.10		1.27	
Dispersion	3.06	**	2.88	**
Log-likelihood	-763.00		-759.20	
Pseudo R^2	0.09		0.10	
AIC	1560.01		1550.41	
BIC	1604.63		1592.41	

** significant at 0.01 (one-tailed), * significant at 0.05 (one-tailed).

The AIC and BIC values suggest that model 2 provides a marginally better fit to the data. In terms of the effects of each variable, the findings were generally in line with expectation and similar for both models. As such, and based on the model fit statistics, in what follows, we focus on the findings from model 2. There was clear evidence of spatial interaction, with distance being negatively associated with refugee flows. Consistent with the literature on migration more generally, the data also suggest that refugees preferred countries with a higher average income, and that they had a preference to flee to those countries that shared colonial ties with, or for which the language spoken was similar to that of the Syrian population. Countries for which the likelihood of gaining asylum was higher were

also associated with higher rates of flows, as were those for which data suggest that civil liberties and political rights are a priority.

While the relative size of the Muslim population in a country was positively associated with refugee flows, the effect of this variable (or the raw number of refugees) was not statistically significant. Nor were the influences of conflict, crime, the rate of terrorist incidents, or the level of corruption, as measured by Transparency International.

DISCUSSION

Focussing first on the original results that we have presented here; our findings offer insight into the behaviours and decisions of Syrians forced to migrate due to the ongoing conflict within the country. While some results are aligned closely with those that would typically be observed for migration in general, others suggest the presence of distinctive influences in this context.

Aside from the anticipated negative effect of distance, we see similar results to those hypothesised for factors that would typically be associated with regular migration: most notably, more prosperous countries are preferred, which may be reflective of either the economic prospects of refugees themselves or living conditions more generally. The lack of significance for the unemployment variable may suggest that the latter of these is more likely.

The effect of cultural similarities is also evident as both linguistic similarities and historical colonial ties act as attractive factors for refugees. This may reflect the ease of assimilation in these countries, or indeed simply the level of familiarity of refugees with these prospective destinations. These factors are likely to mean that refugees have greater knowledge of these countries, and the conditions within them, which may in itself result in them being preferred over 'unknown quantities' elsewhere. One related factor that did not show significance here was the size of Muslim population in the destination country, though it is worth noting that this operationalisation of diaspora is relatively coarse and may not reflect the particular form that might apply to Syrian refugees.

One factor that is specific to the refugee context is the probability of being granted asylum in the host country. Although similar in some respects to the effects of visa policies for migration more generally (e.g., Castles et al, 2013), the context here differs because of the forced nature of migration: the identification of a viable destination is typically an imperative, rather than an aspiration. It is therefore unsurprising that countries with higher rates of acceptance are favoured. Nevertheless, the question of how such factors influence the decision to flee per se (rather than the destination) – a crucial one for policy – remains an open one, to be considered in future research.

Perhaps surprisingly, few significant effects were found in relation to the safety or security of destination countries. Of these factors, only the factor relating to civil and political rights was found to have an effect (a positive one). Of course, this may reflect the fact that these factors did not exert an influence over the migration process. However, it is also quite possible that the variables measured here simply do not reflect the security concerns that would be important to individuals in this position.

Furthermore, we should be careful not to interpret our results as reflecting a 'choice' on the part of refugees, as they might do in other modelling scenarios, such as regular migration or transport. By definition, forced migration involves a reduction in free choice, and the imperative to find refuge means that some decisions will simply be made out of necessity. Even if it is the case that some degree of choice is present, the lack of resources and time will necessarily require some prioritisation and/or compromise, of which a relative lack of security – but likely asylum – might be one example. As much as preferences, our results reflect the constraints to which refugees are subjected.

The work we have presented here exemplifies the use of spatial interaction modelling in a new context, and indeed in one with important real-world relevance. In these respects, we believe it continues a theme of research inspired by Alan's work, and in particular the kinds of new applications which the ENFOLDing project was set up to explore. We consider this work to be an extension of that effort, and believe it demonstrates the versatility and wide applicability of the approach.

Alan's work is distinguished by its real-world relevance, either in its commercial application or its policy relevance, with the latter exemplified by his work in chairing the UK Home Office Science Advisory Council, which provides support to the UK Home Office on the application of science and technology in UK policy. In this role, he promoted the role of science in government policy and planning, and its ability to offer insight into complex problems. The ongoing Syrian crisis exemplifies the kind of global problem in which this kind of insight is desperately needed, and in continuing this work we hope to contribute in a similar spirit.

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