Modern Slavery: an application of Multiple Systems Estimation

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Summary

- This paper reports on an exploratory analysis of the scale of modern slavery in the UK, using the statistical technique of multiple systems estimation. The findings should be treated as tentative, because the modelling includes assumptions which (though plausible) cannot be easily verified and uses data that inevitably has limitations.
- The analysis builds on the 2013 National Crime Agency (NCA) Strategic Assessment, which collates data from a wide range of sources to identify potential victims of human trafficking, but inevitably its coverage can be only partial.
- The figure of 2,744 potential victims of human trafficking included in the Strategic Assessment is based on a count of potential victims who have been encountered. However, this does not include potential victims who are not known to the NCA Strategic Assessment; the hidden nature of modern slavery makes it possible that there may be many such cases.
- By analysing the overlaps between cases that come to attention through various sources, a multiple systems estimation approach can be used to estimate the "dark figure" of cases that have not come to attention.
- This approach gives an estimate of between 10 thousand and 13 thousand, in total, of potential victims in the UK in 2013. This includes both the cases already known to the Strategic Assessment as well as the "dark figure".
- The model also indicates correlations (both positive and negative) between the different ways that cases come to light.

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The National Referral Mechanism and the NCA Strategic Assessment

Under the Council of Europe's Convention on Action against Trafficking in Human Beings every country has the obligation to locate and identify "potential victims of trafficking" (PVoTs). In the UK, this obligation is discharged by the National Referral Mechanism (NRM), introduced in 2009. The NRM is a framework for identifying victims and ensuring they receive the appropriate protection and support. It is run by the United Kingdom Human Trafficking Centre (UKHTC), which is part of the Organised Crime Command in the National Crime Agency (NCA). The NRM is also the mechanism through which the UKHTC collects data about victims.

The UKHTC's partners include police forces, the Home Office and other government departments, the UK Border Force, the Gangmasters Licensing Authority, international agencies, non-governmental organisations (NGOs) and many charitable and voluntary expert groups. The NRM collates data from most of these sources to produce statistics on PVoTs. These are published quarterly and are broken down into the sources of the various cases.

The National Crime Agency carries out a Strategic Assessment of the Nature and Scale of Human Trafficking[2]. In 2013, the Strategic Assessment identified 2,744 unique PVoTs, using information from the following three sources:

- Information on the NRM database about PVoTs who received a 'positive' or 'pending' conclusive decision that they were a victim of human trafficking.
- Intelligence held by the NCA.
- Responses to an intelligence requirement disseminated by the NCA to police forces, NGOs, Home Office agencies and local authorities.

Note throughout that the Strategic Assessment is a measure of potential rather than confirmed victims. These comprise individuals formally identified as victims by the NRM process plus individuals identified as potential victims by intelligence. The potential victims identified through intelligence have not been through a formal assessment to determine their actual victim status.

The dark figure

Most types of crime can be quantified through victimisation surveys such as the Crime Survey of England and Wales, and through police recording of crime. In the case of homicide, by definition there is no surviving victim and there is a separate recording mechanism. Modern slavery is also not easily amenable to quantification through victimisation surveys because many victims do not present to the

[2] NCA Strategic Assessment: The Nature and Scale of Human Trafficking in 2013. (Published 30 Sept 2014, ref 0093-UKHTC) Available at http://www.nationalcrimeagency.gov.uk/publications/399-nca-strategic-assessment-the-nature-and-scale-of-human-trafficking-in-2013/file

authorities. The Strategic Assessment is based on bringing together different sources on victims and therefore, despite all efforts, can only present a partial picture. There are several reasons for this:

- Modern slavery is a hidden crime and some victims may still be in servitude or be otherwise controlled.
- Many victims who escape from their situation may leave the country or start a different life without drawing attention to themselves.
- Victims may not come forward due to feelings of fear and shame.
- Some individuals may not be identified as victims by professionals who encounter them.
- Some victims may not even view themselves as victims of exploitation.

In addition, the NCA's coverage is not complete: only a limited number of agencies respond to the NCA's intelligence requirement (e.g. in 2013, 37 police forces and 4 NGOs responded to the intelligence requirement) so agencies may be aware of potential victims who are unknown to the Strategic Assessment. Overall, therefore, the NCA Strategic Assessment figure of 2744 PVoTs, has to be augmented by a potentially much larger "dark figure" of victims who have not come to NCA attention through any of its sources of information. The aim of this paper is to attempt to quantify this figure.

Multiple systems estimation (MSE)

An approach called multiple systems estimation (MSE) can be used to estimate the "dark figure" of potential victims that do not come to the Strategic Assessment's attention. MSE has been applied in various contexts of public policy sensitivity, for example to estimate the numbers of casualties in armed conflicts[3] and numbers of intravenous drug users[4].

The original version of multiple systems estimation is the mark-recapture estimate for estimating a population size, attributed to the Danish fisheries scientist C. G. Johannes Petersen (1860-1928). However, Goudie and Goudie (2007)[5] trace the origin of the estimator to human population estimates as early as 1662, and there is some doubt as to whether the first use in fishery studies was by Petersen or by others.

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[3] See, for example, Daniel Manrique-Vallier, Megan E. Price, and Anita Gohdes. "Multiple Systems Estimation Techniques for Estimating Casualties in Armed Conflicts" In Taylor Seybolt, Baruch Fischhoff, and Jay Aronson (eds) *Counting Civilian Casualties. An Introduction to Recording and Estimating Nonmilitary Deaths in Conflict,* pp.77–93. New York: Oxford University Press (2013).

[4] See, for example, R. King, S. M. Bird, A. M. Overstall, G. Hay and S. J. Hutchinson,. "Injecting Drug Users in Scotland, 2006: Number, Demography, and Opiate-related Death-rates" *Addiction Research and Theory* **21** 235–246. (2013).

[5] I. Goudie and M. Goudie. 2007. "Who captures the marks for the Petersen estimator?" *Journal of the Royal Statistical Society. Series A* **170**:825–839.

The basic idea is as follows: Suppose you want to estimate the number of fish in a pond. You catch a number of fish (say 100), mark them in some way, and then release them. Some time later you take a new catch (say another 100) and see how many of the second catch were part of the original first catch. If the overlap between the two catches is 20, for instance, the natural estimate of the whole population size is 500.

A mark-recapture approach was used in the 2011 census to estimate the undercount, the proportion of the population not "caught" by the initial census, by conducting a survey and assessing the overlap between the census and the survey[6].

Multiple systems estimation is the extension of this idea where there are more than two lists. Suppose, for example, there were five lists on which individuals can appear. Individuals may be on just one list, or on two, three, four or even all of them. For each combination of lists we can count the number of people that appear on those lists but not on the others. There are in fact 31 possible combinations we can observe, and from these we can estimate the number of individuals who are not on any list. This is the "dark figure". To apply MSE we need to know not just the number on each list, but also the size of all possible overlaps. This requires careful collation of all the data received.

In the fish example it was assumed that your chance of being in the second catch is not affected by whether or not you were in the first. When there are more than two lists we can relax this assumption and it is also possible to assess how much being on one particular list affects your chances of being on another.

Multiple lists in the NCA Strategic Assessment (2013)

In 2013, information about potential victims in the NCA Strategic Assessment came from a large number of separate source organisations. This information can be summarised into six lists based on the source organisation type:

LA: Local Authority

PF: Police force

GO: Government Organisation (mostly Home Office agencies e.g. UK Border Force, Gangmasters Licensing Authority)

NG: Non-governmental organisation

NCA: National Crime Agency

GP: The general public, through various routes

Of the 2,744 potential victims in the Strategic Assessment, some appeared on two, three or four of the lists. MSE can then be applied to estimate the figure of potential victims who do not appear on any

[6] See, for example, Pete Benton, "Trout, Catfish and Roach: The beginner's guide to census population estimates", http://www.ons.gov.uk/ons/guide-method/census/2011/the-2011-census/census-coverage-survey/trout--catfish-and-roach---the-beginner-s-guide-to-census-population-estimates.pdf

list, and hence to give an estimate of the total number of potential victims. Analysis was carried out using all six lists, and also combining PF and NCA into a single list (given the similarity between the police and NCA). The overall results were essentially the same so it is simpler to combine those two lists. The resulting data are presented in Table 1.

LA	X					X	X	X								X	X	X
NG		X				X			X	X	X				X	X	X	X
PF			X				X		X			X	X		X	X		X
GO				X				X		X		X		X	X		X	X
GP					X						X		X	X				
number	54	463	995	695	316	15	19	3	62	19	1	76	11	8	4	1	1	1

Table 1: The data consolidated into five lists. Each column shows the number of cases which fall in the combination of lists indicated by the cells marked. Columns corresponding to patterns which do not occur in the observed data are omitted.

The methodology fits a model which allows for individual list effects, and also for interaction between pairs of lists. The results can be summarised as follows:

- The estimated confidence interval for the actual population size (including the 2744 cases already known to the NCA) is from 10K to 13K, so this suggests that the Strategic Assessment is aware of roughly 20% to 30% of all the potential victims in the UK in 2013. (In round numbers, therefore, the dark figure is around 7k to 10k.)
- There is positive correlation between LA and each of NG and PF, so that being known to the local authority increases the chance of being known to NGOs or the police. This may reflect the existence of referral pathways for potential victims between these agencies, in particular in relation to children who do not need to consent to referral to the NRM (unlike adults), or joint operations between the local authorities and other agencies.
- There is negative correlation between GP and each of NG, PF and GO, so that cases brought to attention by the general public are less likely to be known to agencies (other than local authorities). This may reflect the fact that these referrals often lack the detailed information contained in referrals from public authorities. As an additional check the analysis was repeated with the GP list omitted; for further comments see the Annex below.
- There is some negative correlation between NG and GO, so there is some propensity for cases known to NGOs not to be known to Government agencies. This may reflect the reluctance of some NGOs to share information with public authorities.

These must be regarded as tentative conclusions, because the model is based on assumptions that (while sensible) cannot be easily verified and inevitably uses data that has some limitations. Care was taken to try to collate all the individuals between lists, but some individuals may still be incorrectly counted separately. Considerations of this kind may have the effect that the overall figure is slightly over-estimated.

Annex: Technical details

The analysis was carried out using the R package `Rcapture` as described by Baillargeon and Rivest (2007)[7]. The routine `closedp.Mx` was used to fit log-linear models, firstly considering main effects only, and then adding interaction effects stepwise, at each stage fitting the interaction which makes the biggest improvement in the AIC, until the AIC starts to increase again. It was found that the resulting model contains one interaction which has a very high standard error and is very far from statistically significant, and so this was dropped from the model. The model finally chosen for the five-list data contains six of the ten possible interactions: LA*NG, NG*GP, PF*GP, LA*PF, GO*GP and NG*GO, with an estimated total population size of 11313 with standard error 802. The deviance of the fitted model was 16.4 on 19 df. The routine `profileCI` then yields a 95% confidence interval [9918, 13046] with a maximum likelihood estimator of 11304. A table showing full details of the fit of this model is given at Table 2; the deviance residuals show that the model fits well. If the same approach is used for the six-list version of the data then the interactions fitted collapse to the same interactions as fitted in the five-list data, and the overall population estimate and confidence intervals are virtually identical.

Because of possible issues about matching particularly involving list GP, the analysis was repeated using four lists with the GP information omitted completely. The resulting estimates and confidence intervals were only slightly changed and so this provides reassurance of the robustness of the results.

```
Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.96919  -0.39529  -0.06652   0.14906   1.33782

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)9.05591    0.09305  97.320  < 2e-16 ***
LA         -5.08848    0.15254 -33.357  < 2e-16 ***
NG         -2.90507    0.09507 -30.558  < 2e-16 ***
PF         -2.14852    0.08809 -24.389  < 2e-16 ***
GO         -2.52177    0.09129 -27.624  < 2e-16 ***
GP         -3.30533    0.10827 -30.530  < 2e-16 ***
LA*NG       1.52395    0.27625   5.517 3.46e-08 ***
NG*GP      -2.92170    1.00582  -2.905 0.003675 **
PF*GP      -1.24675    0.31883  -3.910 9.21e-05 ***
LA*PF       0.92243    0.26209   3.519 0.000432 ***
GO*GP      -1.19052    0.36926  -3.224 0.001264 **
NG*GO      -0.55335    0.22399  -2.470 0.013495 *
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 9559.514  on 30  degrees of freedom
Residual deviance:   16.351  on 19  degrees of freedom
```

Table 2: R output showing coefficient estimates in the log-linear odds model, together with other information about the fit and the accuracy of estimation of the parameters.

[7] Sophie Baillargeon and Louis-Paul Rivest, "Rcapture: Loglinear Models for Capture-Recapture in R" *Journal of Statistical Software*, **19.5** (2007).