

How can we estimate modern slavery globally?

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The estimation of prevalence has been an important part of the process of bringing the crime of modern slavery and human trafficking to wide public and policy attention. One of us produced an estimate for the UK which was pivotal in the process leading to the Modern Slavery Act 2015, which itself has spurred action in other countries. At that time, the estimated figure of 10 to 13 thousand UK victims commanded wide press attention (across the political spectrum), even though now it is recognized as a substantial underestimate. The United Nations has set a goal of ending modern slavery by 2030 and a requirement for robust measurement tools to achieve this goal.

The only large-scale estimate of modern slavery, presented with considerable background detail, is provided by the *Global Estimates of Modern Slavery (GEMS)*, produced by two United Nations agencies together with Walk Free, an international charitable human rights group which is “focused on the eradication of modern slavery, in all its forms, in our lifetime.” The overall estimate provided by the GEMS is that on any given day in 2021, there were 49.6 million people in modern slavery. This provides compelling evidence that action must be taken at a global level to end modern slavery.

The GEMS are considerably elaborated in Walk Free’s *Global Slavery Index (GSI)*, which is both an interactive website and a published report. The GSI produces an estimate for the prevalence

of modern slavery in each country, as well as a comprehensive description of what makes societies vulnerable to high rates of modern slavery. Walk Free carries out remarkable work to combat modern slavery and human trafficking, and we commend the reports as an excellent and detailed introduction to the field.

Measuring the scale of modern slavery is a tough and complicated task. Modern slavery abuses are often hidden, or they may occur in countries where collecting data is difficult due to political instability. Given the challenges in estimating the prevalence of modern slavery, we will discuss some aspects of the estimation process, and reflect on issues it raises more generally for statistical analysis in difficult and important areas.

Generating a Global Estimate

The GEMS and GSI are the result of an international undertaking using statistical models to combine data from national surveys in various countries with other relevant data sets. Globally, there are three individual estimates: forced labor, forced commercial sexual exploitation, and forced marriage. Each estimate is calculated using a bespoke method and different data sources:

- The prevalence of forced labour is directly estimated in 68 countries. For the remaining countries, the GEMS imputes figures through a weighted linear approach that uses mainly geographic variables.
- The prevalence estimates of forced commercial exploitation are generated based on the survey data and data from the Counter Trafficking Data Collaborative data set. The Counter Trafficking Data Collaborative data set is a global data set containing casework

data from 189 countries. The data set is used to estimate the ratio of forced labour cases to forced commercial exploitation cases in each country and then combined with the survey data and linear model.

- The forced marriage estimates are produced following a separate set of national surveys in 75 countries, with estimates in non-surveyed countries again being imputed using a different weighted linear model (in this case using geographic variables only).

The GSI goes further, by constructing a hierarchical Bayesian model for the prevalence of forced labour and forced marriage, and hence of modern slavery overall, in individual countries, based on a range of country specific factors.

National Surveys for Forced Labour

National surveys are the main data collection tool behind the GEMS and GSI. Surveys are a useful way to collect data about what is happening on the ground, especially if the surveys are well designed, and a representative sample of the world population is used. In order to produce a meaningful estimate a wide variety of countries need to be covered, capturing different economic and social levels. Figure 1 shows the countries that were surveyed. This is an improvement on the 2018 estimates as a more diverse range of countries was sampled.

Survey questions should be designed to get the most accurate and reliable information from respondents. During the survey, respondents were asked directly about the working and relationship conditions of themselves and their immediate family (parents, partners, and children). Globally, 77,914 people were surveyed about forced labour, but this increases to

628,598 when reports about immediate family members are included, though the GEMS explicitly acknowledge that proxy responses about family members may be less accurate, and downweights them in the analysis. Asking directly about experiences of forced labour might not always elicit the most accurate response, as respondents might not be willing to disclose information about themselves or their family members. Lack of disclosure may be due to social stigma or because family members are facilitating trafficking, alternatively, respondents may fear disclosing abuses puts them or their family members at risk.

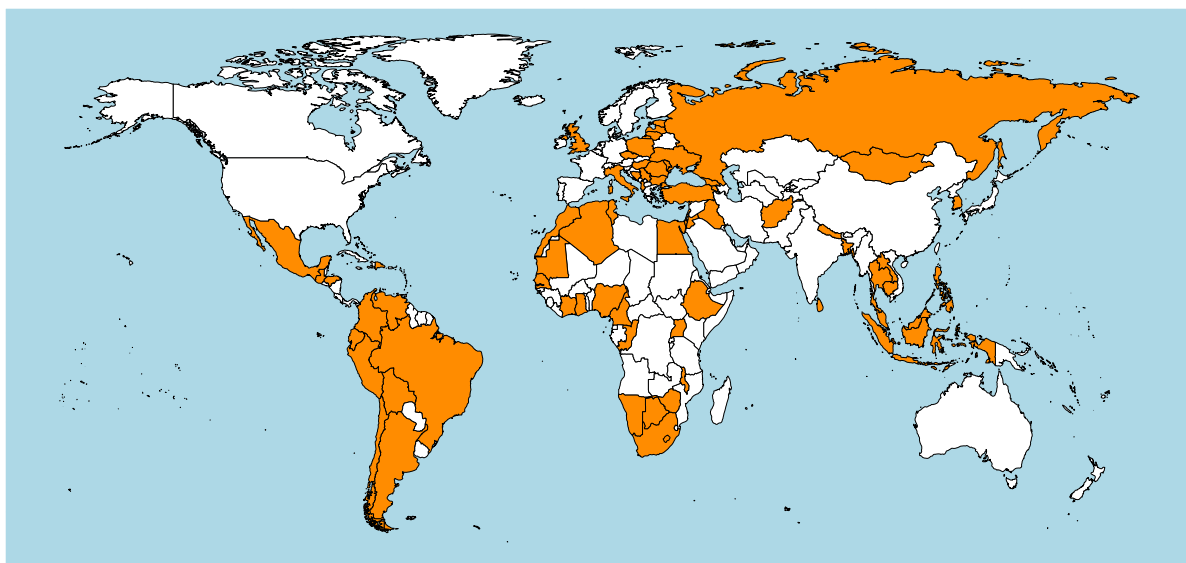


Figure 1: The countries surveyed for forced labour in the ILO-Walk Free Surveys conducted as part of Gallup World Poll surveys, 2017-2021.

Statistical Modeling

Turning the survey results and other data into an estimate for each country is a difficult task, and Walk Free are to be congratulated on their tenacity in doing this. They used a Bayesian hierarchical model to impute the prevalence of modern slavery in every country, including the non-surveyed countries, based on the data from the surveyed countries, as well as economic,

social, and political factors about each country. This is a different model from the weighted linear models used within GEMS for scaling up from the countries surveyed to regional and global estimates.

Walk Free’s model produces an individual level probability that each person in the world is a victim of modern slavery, and depends on characteristics of each person and the country they are in. A linear logistic model is used, modeling the log odds for each person as a linear combination with terms including of the demographics of the individual themselves, various predictors for the individual, and several vulnerability scores for their country. We will discuss these in turn.

The individual demographics include variables such as age and sex, but to get a better context a set of further predictor terms was included, first developed for the 2018 GSI. Table 1 shows the predictors used in the forced labour and marriage surveys. These values can be obtained for most countries from Gallup world polls, and imputed for the handful of countries that are not in the world poll data set. Walk Free carry out analysis to test for collinear terms and multivariate insignificance.

Predictor	Forced Labour	Forced Marriage
Age of primary respondent	✓	✓
Number of 15+ residents in household	✓	
Urban or rural	✓	✓

Gender	✓	✓
Education level	✓	✓
Marital level	✓	✓
Employment status	✓	✓
Life Today	✓	
Feelings about household income	✓	
Not enough money for food	✓	✓
Health problems	✓	

Table 1: The predictors used in the model.

The other important set of explanatory variables are ‘vulnerability dimensions’ for each country. The five dimensions are: governance issues, lack of basic needs, inequality, disenfranchised groups, and effects of conflict. The vulnerability dimensions each include a number of variables and attempt to include a range of nebulous or structural factors in the model. To give a flavor of the rather disparate variables included, examples include the number of mobile phone users, the existence of legislation on disability-based workplace harassment, and the presence of internal armed conflicts. The variables are all chosen because they are likely to have a significant impact on the prevalence of modern slavery, and the aim of Walk Free’s work is to quantify this impact through their fitted model. Walk Free have developed an interactive tool to view the five vulnerability dimensions for each country.

The model allows an individual probability of being a current victim of modern slavery to be assigned to everyone in a particular country. The prevalence estimate for each country is given by the sum of the probability over all the individuals. A warning is included stating that estimates have high variance, especially at regional level, although the report focuses on point estimates of prevalence rather than any kind of confidence interval.

Global vs Country Level Prevalence Estimates

Whereas the focus of the GEMS is on a global estimate and on estimates for 11 broad regions (e.g., Africa, Arab States, and Asia and the Pacific), the GSI provides a prevalence estimate for each country individually alongside a commentary on government responses, a good strategy to motivate national action. The basic approach of the GSI is to extrapolate from countries where surveys have been carried out for the GEMS to all other countries in the world. As far as possible, it would be sensible to choose countries which were themselves a representative sample of the global population, both geographically and in terms of social, economic, and political characteristics. Clearly this is easier said than done, and the 2018 GSI came in for some criticism because no surveys were carried out in Western Europe, North America, or developed Asia for the GEMS and so the GSI lacked survey data from highly developed countries. The updated country list for the forced labour component of the 2022 GEMS increased the number of countries surveyed from 48 to 68, and included the United Kingdom, Italy, and South Korea, which is a good step forward. However, unlike 2018, survey results from India were not included, and neither time has China been surveyed. Together these constitute a third of the world's population. They also both display distinct political and social features which may well

influence the extent of human trafficking and modern slavery and are not necessarily paralleled elsewhere. For this reason, the results of any extrapolation from surveys in other countries need to be treated with care.

Can Vulnerability Estimate Prevalence of Modern Slavery? A Case Study of the UK, Germany, and the Philippines

The GSI uses the hierarchical Bayesian model to generate prevalence estimates for each country. This borrows strength from countries that have been surveyed and includes extra information in the form of demographic and vulnerability variables. We now focus on vulnerability in the model.

The GSI uses 23 vulnerability variables grouped into five dimensions: governance issues, lack of basic needs, inequality, disenfranchised groups, and effects of conflict. Each factor feeds into its particular measure and a score for each measure is then created for each country.

The 23 variables are identified through Walk Free's extensive research program, working with experts and survivors of modern slavery across the world. This program is underpinned by a theory of crime prevention and human rights. To turn the dimensions into quantifiable explanatory variables that can be used in the model, scores are constructed based on principal factor analysis.

In the methodological paper that accompanied the 2018 GSI, the authors identify strong correlations between various vulnerability variables and the estimated prevalence of modern slavery. They provide evidence for vulnerabilities both for countries and for individuals. They themselves recognize the policy and operational significance of these vulnerabilities, allowing resources and interventions to be focused appropriately, helping us develop a deeper understanding of this terrible crime.

However, can the vulnerability dimensions be used for prevalence estimation in any particular country? Walk Free's work to construct the vulnerability dimensions certainly uncover societal, business, and legal factors that are highly related to modern slavery, but not all these relationships may be causal ones, nor need a significant correlation be so large as to make for accurate prediction. This makes constructing a predictive model for modern slavery using these dimensions challenging.

In the UK, a country that was surveyed, the GSI estimates that there 1.8 victims of modern slavery for every 1,000 individuals. In Germany, a country with similar demographics to the UK, the estimate is a third of the UK, at 0.6 victims for every 1,000 individuals. In the Philippines, a country that was surveyed, the estimated prevalence was 7.8 per 1,000 individuals, around five times higher than in the UK. These are all posterior means within a Bayesian approach. It seems surprising that Germany and the UK should have an incidence of modern slavery differing by a factor of three.

The scores for the vulnerability dimensions for the UK, Germany, and the Philippines are shown in Table 2. The Philippines is a lower middle-income country according to World Bank classifications, and had much higher vulnerability scores on every dimension than both the UK and Germany, which are both over four times the World Bank threshold to be regarded as high income. Apart from disenfranchised groups, where the UK scores considerably worse, the vulnerability scores for the UK and Germany are very similar, with the UK scoring slightly higher on two and slightly lower on two. In the absence of published details of the various model parameters, it is interesting to examine these scores more closely. The basic demography of the UK and Germany is very similar, certainly as compared to the Philippines and it can be seen that the only vulnerability dimension where there is any appreciable difference is “Disenfranchised Groups”. The remarkable difference in the point estimates for the UK and Germany appears to be driven by this factor. On the log or logit scale on which the prevalence is presumably modelled, the UK estimate is almost equidistant between Germany and the Philippines, and it is surprising that the other four country dimensions, and the general demographic data, have not pulled the UK further in the “Germany” direction, so this suggests that it is the Disenfranchised Groups variable which is doing most of the heavy lifting in the estimation.

Dimension	United Kingdom	Germany	The Philippines
Governance Issues	12.3	12.8	55.3
Lack of Basic Needs	25.1	21.5	53.5
Inequality	27.6	25.5	58.3

Disenfranchised Groups	30.2	18.4	60.2
Effects of Conflict	34.2	35.4	70.3
Estimated prevalence per 1,000	1.8	0.6	7.8

Table 2: The vulnerability scores for the United Kingdom, Germany, and the Philippines. Higher scores correspond with higher vulnerability.

Because the Disenfranchised Groups dimension seems to be so influential in the estimates, we probe it somewhat further. It depends on three variables, all new for the 2023 GSI, set out in Table 3. Of these three variables, two are publicly available. For LGBTI acceptance, the UK actually scores the highest, with Germany close behind. The figures for the “Employers prioritize nationals” variable come from a household survey, which asks people about their views on how employers should treat employees, rather than being based on legal provisions or quantitative data. These figures are not available, but the differences in the overall Disenfranchised Groups variable suggest that Germany scores in a beneficial direction for the overall prevalence estimate.

It is in social group equality that a considerable difference can be found. Walk Free obtained the social group equality figure from a set of measures called the Global State of Democracy Indices. The indices are made up of 157 measures, one of which is social group equality figure. Walk Free chose the social group quality out of the 157 measures as a result of their theoretical

framework of crime prevention and human security theories, as well as involvement from survivors.

The social group equality figure is produced by an organization called the V-Dem Institute. To construct the figure, V-Dem survey country experts on a wide variety of topics including social group equality. Experts provide answers on a Likert scale, and V-Dem use a Bayesian Item Response Theory model to estimate social group equality from all the experts' opinions.

Considering the UK, Philippines, and Germany, the UK score is closer to the score of the Philippines than it is to the German score. Without the remaining factor or the survey results, we cannot completely discern the contribution of the social group equality variable.

Nevertheless, the implication must be that the considerable, and surprising, difference in the UK and Germany's score is driven in large part by this single variable.

Variable	Source	Definition	UK	Germany	The Philippines
LGBTI acceptance	LGBTI Acceptance Index by UCLA School of Law measures social acceptance of LGBTI people in 175 countries.	The Index provides each nation with a score of 0 to 10 to indicate their level of acceptance. High number indicates high acceptance.	8.34	7.73	6.06
Social group equality	The Global State of Democracy Indices measure democratic trends at the country, regional and global	IDEA Global State of Democracy Indices Social Group Equality variable. Data for 166 countries. Answer Q:	0.643	0.933	0.385

	levels across a broad range of different attributes of democracy annually since 1975.	To what extent is there social group equality in regard to political power and civil liberties? Data is on a scale from 0-1 with 1 indicating high performance.			
Employers prioritise nationals	Data are from World Values Survey which asks survey questions in approximately 80 countries.	In response to question: Employers should give priority to (nation) people than immigrants. % of Agree and Agree Strongly response.	Not publicly available		

Table 3: The variables used in the 2023 GSI disenfranchised groups measure of the vulnerability dimension for the UK, Germany, and the Philippines. The first three columns are reproduced from the 2023 GSI supporting data.

To provide further insight, Table 4 shows the correlation between the scores for the vulnerability dimensions and the estimated log prevalence of modern slavery. The strong relationship between the log prevalence and the score for disenfranchised groups is clear, with countries with high scores for disenfranchised group scores having high estimated rates of modern slavery. The correlation for the other dimensions is weaker and in three cases considerably weaker.

Vulnerability Dimensions	Correlation to log estimation prevalence per 1,000
Governance Issues	0.565
Lack of basic needs	0.269
Inequality	0.299

Disenfranchised Groups	0.678
Effects of Conflict	0.176

Table 4: The correlation between the log estimated prevalence of modern slavery in each county and each of the vulnerability dimensions.

Through this case study, we have shown how each assumption made in the construction of the vulnerability profiles seems to affect the final prevalence estimate, with some assumptions having more considerable effects than others. The GSI explains in depth the process by which the profiles are constructed and are driven by survivor experiences.

Uncertainty in the Country Estimates

In any statistical modeling project, serious consideration needs to be given to the reporting of uncertainty. For the GSI 2023, uncertainty estimates are not publicly available. However, they were for the 2018 GSI and the methodology has not significantly changed since then.

To understand the magnitude of the modeling uncertainty for individual countries, we now consider the standard errors reported in the methodology paper for the 2018 GSI. For the United States, the estimate of total prevalence is 0.51% with a standard deviation of 0.33%. The paper suggests that to get a 95% prediction interval you would use $0.51\% \pm 0.66\%$, in other words that the actual value could be anywhere between -0.15% and 1.17% . This translates, roughly speaking, to a number of victims between -0.5 million and 4 million. Obviously, a negative prevalence is not possible, and it seems more appropriate, especially since the model

is linear in the log of the prevalence not the prevalence itself, to produce prediction intervals based on a lognormal distribution. If this is done, based on the given values for the posterior mean and standard deviation, the 95% prediction interval is (0.13%, 1.36%), in other words between about 0.4 million and 4.5 million victims.

The 2018 background paper found that the coefficient of variation (the ratio of the standard deviation to the mean) of the individual country estimates did not differ markedly between countries, and had an average value of 0.68. This is to be expected in a linear logistic model because one would expect the actual posterior distributions of the prevalence to follow, at least approximately, lognormal rather than normal distributions. If we used this value of the coefficient of variation within a lognormal model, it would indicate that 95% prediction intervals for the prevalence per thousand individuals, were 0.15 to 1.7 for Germany, 0.4 to 4 for the UK, and 2 to 22 for the Philippines. On their own, these are extremely wide intervals, but they only reflect the variability within the modeling. We have already seen that the explanatory variables are not necessarily exact observations of well-defined quantities, and that they have been selected by a process which includes considerable subjective input. Quantifying the uncertainty in that part of the process is not possible, but it can only have the effect of reducing the precision of country predictions. The overall conclusion is that the figures for any particular country can only be regarded as indicative order of magnitude figure, and that comparisons between countries, or between the changes over time in estimates for any individual country, have to be treated with great care. This is not surprising, nor does it detract from the value of identifying risk factors.

Identifying Sources of Uncertainty in the Estimates

Our detailed case study sets out some of the issues about uncertainty in the various estimates in the GSI, but also prompts a wider consideration of both the GEMS and the GSI.

Uncertainty in the estimation comes from three main sources. The first is in the collection of data. This source is unavoidable in any survey, as it comes from how respondents are sampled and the responses they give. Simple sampling error is the best understood aspect of uncertainty, but of course even that can be difficult to quantify because, despite all efforts, it is unlikely that the entire population will be sampled or that samples will be fully independent; and furthermore the design of asking respondents to report the experiences of family members may be hard to model. More difficult to assess is the accuracy of answers: for a variety of reasons, some respondents may not give 'truthful' answers, either about themselves or about their family members. Bound up with this is the whole matter of definition of modern slavery and human trafficking, and of forced marriage, neither of which are fully objective concepts.

The second source is the determination or estimation of the explanatory variables, including the vulnerability dimensions. The GEMS make use of chosen geographical and other variables for imputation, while Walk Free carry out an extensive program of research, involving survivors, to determine the most suitable variables. However, many of these variables are themselves the results of surveys or expert opinions, hence incurring their own uncertainty, which is difficult to quantify or to build into the modeling. Of course, the identification of vulnerability dimensions is of great value in its own right, and that is one of the excellent aspects of Walk Free's work.

The final source, by no means specific to these estimates, is model definition and selection. Uncertainty arises here, for instance, from the specification and fine-tuning of the statistical model, and the decisions about which explanatory variables are included in the model. Because there are so many possibilities to choose from, it is inevitable that fully including the model selection step in any assessment of uncertainty will increase the standard error (or equivalent) of estimation. Again, this effect may be difficult to quantify.

Taken together, all these sources of uncertainty indicate that the reported and derived prediction intervals for the GSI may themselves be conservative. Turning to the GEMS, it would seem rash to regard the estimates as showing definite increases or decreases since the previous GEMS. The figures should in our view be regarded as ballpark, order of magnitude, figures rather than accurate estimates. Given the deeply hidden nature of this crime, it could also be that the slight increase is in part due to greater public consciousness, which would encourage victims both to identify their experience as being of modern slavery, and to disclose it in a survey and to other family members.

The Need for a Global Slavery Index: Conclusion

The *Global Estimates of Modern Slavery 2022* and the *Global Slavery Index 2023* are the most comprehensive prevalence estimates of modern slavery to date. In particular the GSI provides the world with the clearest understanding of what makes a person, and a country, vulnerable to this awful crime. Through a unique combination of Bayesian modeling, large scale surveys, and

a survivor-engaged vulnerability framework, Walk Free are creating a path to track efforts to end modern slavery. Nevertheless, the estimates provided both by GEMS and GSI are subject to uncertainties and errors of several kinds, not all of which are easily quantified. Does this affect Walk Free's key aim?

Although the various estimates are only point estimates, they are supported by considerable detail about the way that has been obtained, for example allowing us to provide the discussion in this paper. It is to be hoped that some sort of anonymized (or even partly synthetic) detailed data set based on the surveys could be put into the public domain as material for researchers. This would allow for validation of the results, magnified impact of the work, and a better understanding of possible statistical uncertainties. Nevertheless, the primary aim of the work is to raise public and policy awareness of the main issue, and to give detailed background into the factors associated with higher prevalence, whether through correlation or cause. The purpose of statistical studies like these is not the same as a clinical trial, for example, where the aim may be to show that a new treatment is better or safer than an existing one. In that context, a proper assessment of uncertainty is an essential part of the analysis; but for a global or national figure for the incidence of modern slavery, where the work is a call for action to energize governments, businesses and the general public, a single figure with all the supporting discussion is a very important achievement. As statisticians, we should perhaps rethink our attitudes to whether it is always necessary to produce confidence estimates or error bars, or whether that depends on the particular context.

As we have already discussed, the underlying uncertainty is probably such that it is risky to draw conclusions about individual countries, rather than, say, groups of countries with similar characteristics. Also, it could be that a longer series of estimates is needed before conclusions can be drawn about trends over time. While it may not give accurate prediction, the detailed study to determine risk factors that may or may not be directly causal certainly provides a framework for better understanding. Walk Free summarize this very well: “The countries estimated to have the highest prevalence of modern slavery tend to be conflict-affected, have state-imposed forced labour, and have weak governance. The countries with the lowest prevalence of modern slavery are those with strong governance and strong government responses to modern slavery.”

Despite the uncertainty involved, the GEMS and the GSI are powerful statistical tools in supporting the UN’s goal of ending modern slavery by 2030. Producing and documenting the GSI requires Walk Free to make some difficult and imperfect assumptions, but the result is nonetheless an interesting and well evidenced discussion, especially because of the detailed discussion about government actions linked to the individual prevalence estimates. These estimates are still incredibly important in driving policy at national and international levels.

The GEMS figure is an increase of some 10 million on the corresponding figure estimated for 2016. Does this mean that the problem is getting worse, or that we are getting better at seeing it, or just that both estimates are rather approximate and not quite methodologically comparable? Should we regard the figure in the tens of millions as a statistical estimate in the

usual sense, or — no less importantly — as a ball-park figure which is a call for action and attention? And, more broadly, how as statisticians should we regard figures which we know are liable to many sources of error but nevertheless reveal an important truth? This highlights how statisticians need to better understand how to present and use statistics that involve some doubt. As a community, we should consider carefully how statistical thinking should be informing policy decisions even in circumstances where accurate estimation is not possible.

Suggested Reading

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