SYMPOSIUM: MODELLING MODERN SLAVERY RISK

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Authors

Jacqueline Joudo Larsen is a criminologist and Head of Research for the Walk Free Foundation, who has led the organization's ground-breaking work on measuring modern slavery. Jacqueline is a co-author of the Walk Free Foundation's *Global Slavery Index* and co-author of the *Methodology of the Global Estimates of Modern Slavery: forced labour and forced marriage*, a collaboration with the International Labour Organization and International Organization for Migration. During a 15-year career in research, Jacqueline has focused on social justice and human rights issues, with a particular interest in unpacking the causes of crime, understanding vulnerability and resilience, and using that information to drive policy change. She previously led research on human trafficking, victimization of international students, sexual assault and violent extremism at the Australian Institute of Criminology.

Pablo Diego-Rosell, PhD, is a senior consultant at Gallup, currently collaborating with Walk Free on the development and implementation of the survey programme underpinning the *Global Slavery Index*.
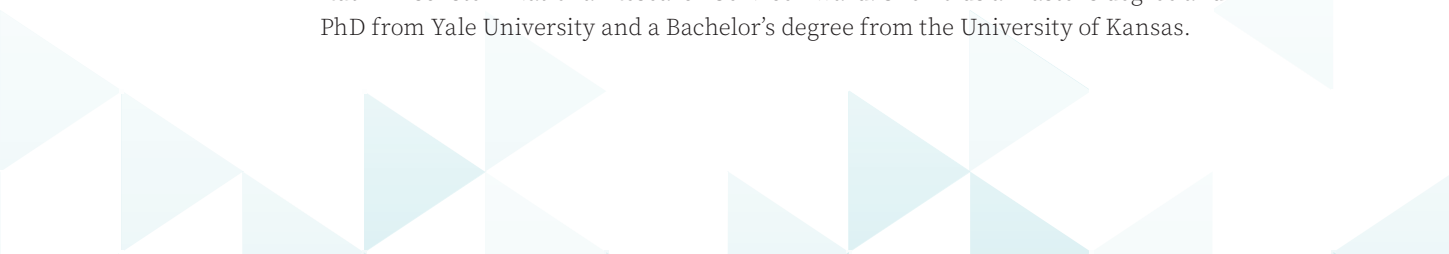
Laura Gauer Bermudez is the Director of Research and Development at the Global Fund to End Modern Slavery where she leads the Fund's Prevalence Return on Investment (PROI) strategy. Laura has 15 years of experience working globally with governments, NGOs and multilateral institutions focused on the intersections of migration, child protection, gender equality and economic development. Laura draws upon her years of experience in NGO operations and agency-based research, blending that expertise with academic training in social science research methods. She holds master's degrees in International Public Policy from Johns Hopkins University and Social Work from Washington University in St. Louis, respectively. She is currently completing her PhD in Social Work at Columbia University.

Shannon Stewart is a Senior Data Scientist at the Global Fund to End Modern Slavery. Dr Stewart has more than 10 years' experience in research, modelling and statistics. Most recently, she used a graph modelling approach to research the business structures supporting North Korean overseas labour networks, which she contributed to the book *People for Profit: North Korean Forced Labour on a Global Scale*. As a Research Scientist at MIT, she researched economically-motivated adulteration in the global supply chain and led the development of machine learning and statistical models that measure risk of corporate and economic crimes. She was a recipient of a Ruth Kirschstein National Research Service Award. She holds a Master's degree and PhD from Yale University and a Bachelor's degree from the University of Kansas.

Sir Bernard W Silverman is a statistician whose research has ranged widely across theoretical and practical aspects of statistics. He is recognized as a pioneer of computational statistics, researching the ways that computing power has changed our ability to collect, analyze, understand and utlize data. He has collaborated in many fields in the physical, life and social sciences, and with various areas of industry and government. Following an academic career at several universities, he was full-time Chief Scientific Adviser to the UK Home Office from 2010 to 2017. He is now freelance, with roles including research, charity trusteeship, consultancy, and advice to Government, and holds a part-time appointment as Professor of Modern Slavery Statistics at the University of Nottingham.

Dr Kelly A Gleason is Data Science Lead for Delta 8.7—The Alliance 8.7 Knowledge Platform at the Centre for Policy Research at UN University. She is a quantitative social scientist and programmer with a focus on visualizing and communicating complex data. She works on building online knowledge tools that encourage evidence-based policymaking by translating data and promoting scientific literacy on issues related to forced labour, modern slavery, human trafficking and child labour. She has a PhD in Political Science from the University of Wisconsin-Milwaukee.

Dr James Cockayne is Director of the Centre for Policy Research at UN University, founder and lead of the Delta 8.7 project, and heads the Secretariat of the Financial Sector Commission on Modern Slavery and Human Trafficking. He has a PhD in War Studies from King's College London. His latest book is *Hidden Power: The Strategic Logic of Organized Crime* (Hurst/OUP, 2016).

Introduction:

In July 2018, the Walk Free Foundation released the latest *Global Slavery Index (GSI),* which presents estimates for the number of victims of modern slavery in 167 countries. Using data from the Gallup World Poll's module on modern slavery, which was conducted in 48 countries, individual and country-level risk factors, and data from the GSI Vulnerability Model, Pablo Diego-Rosell, a senior researcher at Gallup, and Jacqueline Joudo Larsen, the head of research for the Walk Free Foundation, developed a model to generate predicted probabilities of modern slavery on the individual and national levels.

Pablo Diego-Rosell and Jacqueline Joudo Larsen expand upon their methodology in a recent article. Delta 8.7 asked Diego-Rosell and Joudo Larsen to discuss their innovative methodology for modelling the risk of modern slavery in our first symposium. We also invited four other data science experts—Laura Gauer Bermudez and Shannon Stewart from the Global Fund to End Modern Slavery, Bernard W Silverman from the University of Nottingham and Kelly A Gleason from Delta 8.7—to discuss the benefits and limitations of their approach. Diego-Rosell and Joudo Larsen were then given the opportunity to respond to all of the interventions.

About Delta 8.7 Symposia:

Delta 8.7 symposia offer experts the opportunity to discuss technical details of their research and receive commentary from the wider research and anti-slavery community. Researchers are then able to give a response to the previous commentaries

received. We hope these symposia will spark further conversations and build the dialogue around research and data in the fight to eradicate forced labour, modern slavery, human trafficking and child labour.

AN INTRODUCTION TO MODELLING THE RISK OF MODERN SLAVERY

Jacqueline Joudo Larsen
Criminologist and Head of Research, Walk Free Foundation

Pablo Diego-Rosell
Senior Consultant, Gallup

While there are more people living in slavery now than at any point in human history, its measurement has become more difficult than ever as its illegal status has led to the crime becoming more hidden. The emergence of new and diverse forms of the crime have further increased the difficulty of arriving at a reliable estimate. Given the experience of measuring similarly "hidden" crimes, such as sexual assault and domestic violence through random sample population surveys, the Walk Free Foundation adopted this approach in an effort to develop reliable national estimates of modern slavery.[1,2,3,4,5] Since 2014, a total of 54 nationally representative household surveys have been implemented through the Gallup World Poll across 48 countries. These surveys underpin the first global effort to model and predict the risk of modern slavery.

Although there is more data available on modern slavery since Walk Free first adopted national surveys to measure modern slavery, the challenge remains that surveys cannot be conducted in every country. In order to produce the most reliable estimates possible for the 167 countries covered in the *2018 Global Slavery Index*, an extrapolation methodology using hierarchical Bayes models was developed.[6] This statistical approach takes into account respondent-level survey data and country-level predictors in order to estimate country averages. These estimates are obtained using Bayes theorem, which helps completing the necessary computations, and can be used to incorporate prior knowledge about the prevalence of modern slavery. The analysis summarized here builds upon previous extrapolation-based approaches,[7] making it possible to estimate the risk of modern slavery at the individual and country-level and inform prevalence estimates beyond the sample of 48 countries.

[1] Bureau of Justice Statistics, "Data Collection: National Crime Victimization Survey (NCVS)". Available at https://www.bjs.gov/index.cfm?ty=dcdetail&iid=245.

[2] Office for National Statistics, "Crime and Justice". Available at https://www.ons.gov.uk/peoplepopulationandcommunity/crimeandjustice.

[3] Albert Biderman and Albert Reiss, "On Exploring the 'Dark Figure' of Crime", *The Annals of the American Academy of Political and Social Science*, vol. 374, No. 1 (November 1967).

[4] Sylvia Walby, "Towards international standards for data collection and statistics on violence against women", Proceedings of the United Nations Economic Commission for Europe meeting on gender statistics, online publication, 2006.

[5] Jan van Dijk, John van Kesteren and Paul Smit, *Criminal Victimisation in International Perspective: Key findings from the 2004-2005 ICVS and EU ICS*, Scientific Research Documentation Centre of the Netherlands (2007).

[6] Pablo Diego-Rosell and Jacqueline Joudo Larsen, "Modelling the Risk of Modern Slavery", online publication, 17 July 2018. Available at https://ssrn.com/abstract=3215368.

[7] Sheldon X. Zhang and Kyle Vincent, "Strategies to Estimate Global Prevalence of Trafficking for Sexual Exploitation", *Change*, vol. 30, No. 3 (October 2017).

Predicting the risk of modern slavery

The analysis was based on survey data collected through the Gallup World Poll and country-level data from Walk Free Foundation's vulnerability model.[8] Data from the modern slavery surveys was used to estimate the risk model and a broader set of surveys was used for extrapolation purposes.

The process of estimating the prevalence of modern slavery in 167 countries began with identifying individual and country-level variables that have a significant relationship with forced labour and forced marriage at the individual level. On the individual level, demographic factors such as age, gender and employment status, as well as socio-economic and psychographic risk factors, such as feelings about household income, life evaluation scores and negative experienced affect, help predict risk, as well as country-level vulnerability factors.

Several models, each with a larger number of predictor variables, were tested before the "base" model was identified as the model achieving the best balance between predictive accuracy and geographic coverage. Multi-level models were then fitted in order to extrapolate results beyond the sample of 48 countries. Based on the individual-level risk factors identified, as well as country-level vulnerability scores, a hierarchical Bayes modelling approach was used to accurately predict the forced labour and forced marriage status of individuals. Average weighted predicted probabilities were then calculated using the best-fitting predictive model to estimate the average prevalence of modern slavery at the country level.[9]

Implications for policy and next steps

Second, we have shown that a hierarchical Bayes modelling approach can be used to accurately predict the forced labour and forced marriage status of individuals and the average prevalence of modern slavery at the country-level. This is an important finding, but increased identification of victims in the surveys would allow for the expansion of our predictive models and further enhance the accuracy of our predictions.

Our analysis is not without limitations inherent to any cross-sectional research endeavour. We cannot ascertain the direction of causality, and it is quite possible, for example, that forced labour engenders lower life evaluation scores, rather than life evaluations being a protective factor. Another important consideration is that the worldwide coverage of the prediction data is not matched in the model estimation data. The latter includes a subset of countries that were selected based on criteria that leads to the exclusion of countries in Western Europe, Northern America and developed Asia[10]. Essentially, this means that we cannot test whether the risk factors identified in our sample behave the same way in these regions.

Having said this, the current model is modest in scope and the risk factors unlikely to vary greatly across regions, that is, being female will remain a risk factor for forced marriage; being in a situation of poverty will remain a risk factor for forced labour. Data in developed countries would refine our understanding of risk factors in both low- and high-risk countries, building out our understanding of modern slavery and how best to tackle it.

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[8] Gallup, "How Does the Gallup World Poll Work? Measures the Attitudes and Behaviors of the World's Residents," online publication. Available at https://www.gallup.com/178667/gallup-world-poll-work.aspx.

[9] Bayes hierarchical linear model with weak priors, 7 demographic predictors, 6 "Base" variables from the World Poll, one country-level predictor (Weighted Vulnerability Score), country-level random intercepts, and a cross-level interaction between currently owning a business and region (South Asia vs rest).

[10] The modern slavery module was only deemed suitable for face-to-face interviewing. Among these countries, those with high expected prevalence and/or large populations were prioritized, and lastly, countries were selected to provide a sufficient sample within each of the strata used for global estimation (see International Labour Office & Walk Free Foundation (2017). Methodology of the global estimates of modern slavery: Forced labour and forced marriage. ILO: Geneva.

THE BENEFITS AND LIMITATIONS OF MODELLING THE RISK OF MODERN SLAVERY

Laura Gauer Bermudez
Director of Research and Development,
Global Fund to End Modern Slavery

Shannon Stewart
Senior Data Scientist,
Global Fund to End Modern Slavery

Pablo Diego-Rosell and Jacqueline Joudo Larsen present a model that uses a hierarchical Bayesian approach[11] to estimate the risk of modern slavery at the national level using responses to household surveys conducted by Gallup.[12] Based on previous work by the Walk Free Foundation, the authors identify five major categories of vulnerability risk factors: governance, access to social services, inequality, disenfranchisement and conflict. From these, they select 18 variables from a larger group of 157 to include in the model, considering both theoretical and practical implications. Given the cross-sectional nature of the data, variables could show both direct or inverse relationships with forced labour and forced marriage. Using this risk model, the authors then generate a predicted probability of modern slavery by country, where sufficient data is available.

Diego-Rosell and Joudo Larsen's effort is significant and benefits the modern slavery community in several ways. The extensive explanation of statistical methods demonstrates a thoughtful approach to modelling modern slavery risk using existing survey data. As we seek to move the sector towards data-driven action, this commitment to quantitative rigour is particularly important. Risk modelling is necessary to inform the design and targeting of modern slavery prevention programmes so they more efficiently

and effectively mitigate risk. Further, the inclusion of psychographic assessments adds further benefit to the analysis, placing value on respondent perceptions in addition to standard demographic assessment metrics.

However, this approach also has a number of limitations. First, the model uses cross-sectional data, meaning the relationships between risk variables and outcomes may be bi-directional. For instance, higher negative experience index scores and difficulty living on present income are associated with a higher likelihood of being engaged in forced labour in the present model. It is quite plausible that engagement in forced labour has caused those outcomes for the respondent versus those characteristics being predictive of entry into forced labour. The authors recognize this limitation, which remains a challenge for predictive analytics within the social sciences more broadly.

In future work, researchers could benefit from selecting variables of interest that are more static and less subject to the potential inverse relationships that make the operationalization of these findings challenging. Further, due to the uncertainty around the causal direction of these relationships, significant limitations exist with respect to the authors' extrapolation of findings from their risk model towards prevalence estimation. The modern slavery sector must take care when interpreting or extrapolating results from cross-sectional data, acknowledging the inherent uncertainty that comes with predictive modelling and continuing to craft improved models and refine methods.

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[11] Diego-Rosell and Joudo Larsen, "Modelling the Risk".

[12] Gallup, "Gallup World Poll", online publication. Available at https://www.gallup.com/services/170945/worldpoll.aspx.

The second limitation of the findings is the lack of potential application. Modelling modern slavery risk at the global level can be problematic if variables are prioritized for their suitability to standardization across national-level data sets, posing the risk that they be too generic to be actionable. Nuanced and highly contextualized risks factors exist that a set of indicators designed to be relevant globally may not be able to capture. The examination of HIV risk in a public health setting can offer parallels, as research has shown demographic risk factors to be highly variable by region. For instance, adolescent girls and young women in Southern Africa are proportionately at far higher risk of HIV infection[13] than women and girls of the same age in any other location[14]. Similarly, in this context of modern slavery, the authors' standardized indicators across multiple countries/regions may lose the nuance required to be explanatory, particularly when aiming to address modern slavery within a specific geographic/industry nexus.

Another finding in the study that demonstrates this limitation is that education and youth development were found to be associated with lower levels of forced marriage. While this relationship is again subject to the challenge of bi-directionality, should further research establish these variables as predictors of forced marriage, they are also known indicators of a wide range of poor outcomes including violence victimization, disease and food insecurity. Such generic indicators can certainly support a broader global development narrative, but they are likely less insightful for modern slavery actors. Future efforts may want to consider engaging with end-users of a model to determine what type of data would be helpful for targeting programmes aimed at preventing or reducing modern slavery; this approach would blend traditional academic and modern data analytic approaches in a way that could be highly actionable.

Despite these limitations, the analysis and results still warrant dialogue. While certain correlates are unsurprising—such as women being at lower risk of forced labour or higher levels of education being associated with lower rates of forced marriage—one finding in particular may be novel for the modern slavery community: individuals with higher scores on a Community Engagement Index have lower probability of being associated with forced labour and forced marriage. While this relationship is, again, subject to the limitation of being inversely correlated, it poses a unique suggestion about the potential power of social inclusion and community support as protection against modern slavery and warrants further investigation.

Overall, Diego-Rosell and Joudo Larsen's work represents a valuable first step to systematically identify vulnerabilities to modern slavery. Their effort lays very important groundwork from which the sector can learn, modify and improve – particularly as we seek to model risk at a more micro-level, interrogate vulnerability within specific industries and geographies, and identify findings to compel legislators, policy-makers, business leaders and civil society to action.

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[13] Rachel C Dellar, Sarah Dlamini and Quarraisha Abdool Karim, "Adolescent girls and young women: Key populations for HIV epidemic control", *Journal of the International AIDS Society*, vol. 18, No. 2 (February 2015).

[14] Priscilla Idele and others, "Epidemiology of HIV and AIDS Among Adolescents: Current Status, Inequities, and Data Gaps", *Journal of Acquired Immune Deficiency Syndromes*, vol, 66, No. 2 (July 2014).

DEMONSTRATING RISKS IS NOT THE SAME AS ESTIMATING PREVALENCE

Bernard Silverman
Professor of Modern Slavery Statistics, University of Nottingham

It is a great pleasure to have the chance to comment on the paper by Pablo Diego-Rosell and Jacqueline Joudo Larsen.[15] They identify strong correlations between various risk factors 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,[16] allowing resources and interventions to be focused appropriately, helping us develop a deeper understanding of this terrible crime.

My main concern is with a different issue: prevalence estimates for individual countries. Can the risk model be used for prevalence estimation in any particular country? The risk-factor model is good for *explanation*, but that does not mean it can be used reliably for *prediction* or *estimation*. Contrary to the authors'

Appendix D - Estimated Risk of Forced Labour, Forced Marriage, and Modern Slavery in 148 World Poll countries (Mean and Standard Deviation)[*]

COUNTRY (Sorted in Descending Order of Risk of MS)	FORCED LABOUR		FORCED MARRIAGE		MODERN SLAVERY	
	Mean	SD	Mean	SD	Mean	SD
Syrian Arab Republic	1.47%	3.35%	3.41%	3.21%	4.88%	3.35%
Central African Republic	2.00%	3.38%	2.78%	2.63%	4.78%	3.38%
South Sudan	1.53%	3.19%	2.90%	2.72%	4.42%	3.19%
Somalia	1.31%	2.30%	2.11%	1.86%	3.42%	2.30%
Iraq	1.60%	2.00%	1.74%	1.55%	3.34%	2.00%
Congo, Democratic Republic of the	1.24%	1.97%	1.83%	1.63%	3.06%	1.97%
Chad	1.20%	1.76%	1.52%	1.30%	2.72%	1.76%
Sudan	1.10%	1.70%	1.59%	1.40%	2.69%	1.70%
Afghanistan	0.61%	1.89%	1.82%	1.78%	2.43%	1.89%
Yemen	1.03%	1.42%	1.26%	1.19%	2.28%	1.42%
Cambodia	1.26%	1.34%	0.94%	0.91%	2.20%	1.34%
Burundi	1.21%	1.58%	0.92%	0.85%	2.13%	1.58%
Congo	1.28%	1.34%	0.64%	0.54%	1.92%	1.34%
Libya	0.88%	1.04%	1.02%	0.82%	1.90%	1.04%
Guinea	0.89%	1.24%	0.99%	0.90%	1.88%	1.24%
Nigeria	1.03%	1.15%	0.82%	0.68%	1.85%	1.15%

[*] *Appendix D from Diego-Rosell and Joudo Larsen "Modelling the Risk of Modern Slavery"*

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[15] Diego-Rosell and Joudo Larsen, "Modelling the Risk".

[16] Jacqueline Joudo Larsen and Pablo Diego-Rosell, "An Introduction to Modelling the Risk of Modern Slavery," *Delta 8.7*, 10 December 2018.

assertion that the model can be used to accurately predict prevalence at the country level, the prevalence estimates for individual countries are extremely imprecise.

This imprecision is set out, partially, in the authors' Appendix D. For the United States, for example, the estimate of total prevalence is 0.51 per cent with a standard deviation of 0.33 per cent. Section 3.4 of the paper suggests that to get a 95 per cent prediction interval you would use 0.51 per cent ± 0.66 per cent, in other words that the actual value could be anywhere between −0.15 per cent and 1.17 per cent. This translates, roughly speaking, to a number of victims between −0.5 million and 4 million. Obviously, a negative prevalence is not possible, and some sort of transformation is appropriate to make the posterior distribution more symmetrical, but the principle is the same: the model cannot be used to make individual country predictions to any useful degree of accuracy. This is not surprising, nor does it detract from the value of identifying risk factors.

A further demonstration is given by looking in detail at Figure 6 (bottom right).

Figure 6: Actual vs. Fitted Prevalence (Bayesian models)[*]
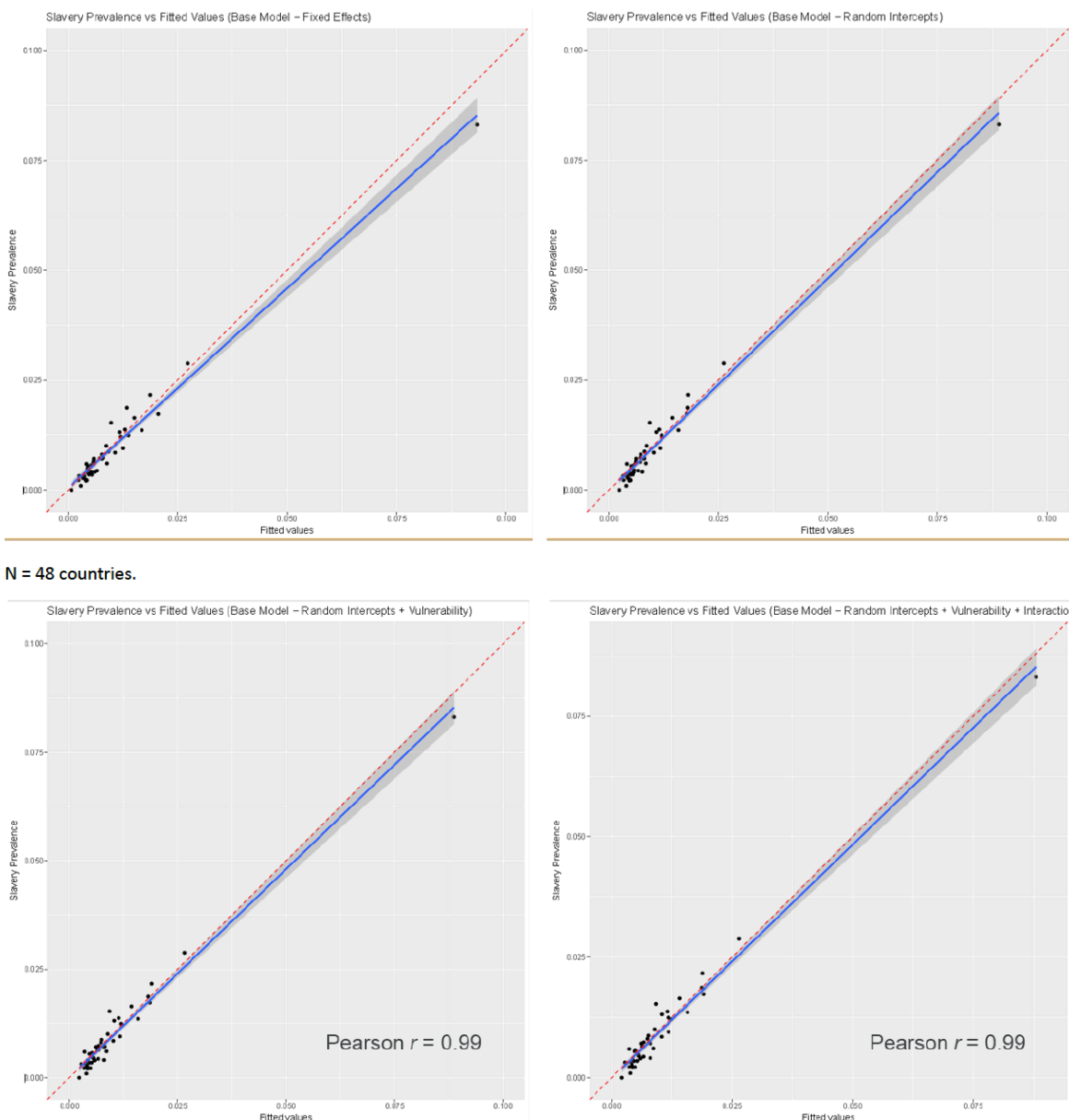
N = 48 countries.

N = 48 countries.

[*]*Figure 6 from Diego-Rosell and Joudo Larsen "Modelling the Risk of Modern Slavery"*

Even if the single point with very large prediction and prevalence (Uganda) is left out, the remaining points have a correlation of about 0.95, so an *r* value of 0.97. But the residuals from the diagonal line—which for those points is virtually identical to the line fitted by linear regression—have a standard deviation of 0.2 per cent. So, even on the countries for which the data have been fitted, if a country has mean predicted prevalence *z* per cent, a confidence interval for the actual prevalence is (z±0.4) per cent. This calculation does not take account of all the details of the model, but the accuracy, or inaccuracy, is in the same ball-park as in Appendix D. Although there is large correlation, the individual predictions are very inaccurate.

It is unfortunate that the *Global Slavery Index (GSI)* 2018 report[17] itself is silent on the precision of the individual estimates. It is poor statistical practice to give an estimate without also saying how accurate you think it is. Therefore, I am delighted that the authors' background paper contains more information about precision.

However, there are two other matters that increase further the imprecision of the individual prevalence estimates. None of the 48 countries surveyed is in developed Asia, Western Europe or North America. Predictions for such countries are based on extrapolation from countries in different parts of the world, and therefore are subject to an additional layer of unquantifiable uncertainty. It may well be that such developed countries

have higher—or lower—levels of resilience to certain risks; we simply cannot tell from these data. Indeed, at the other end of the spectrum, certain "high-risk" countries also have specific characteristics not present in the training set.

Secondly, if I understand correctly, the surveys asked about interviewees and their immediate family, and so each interview essentially yielded information on a small group of people. It is not clear if the obvious dependencies between individuals in a family were accounted for in the model fitting, but if they were not then there is another source of imprecision.

The authors were generous with me in giving me the exact coordinates of the points in Figure 6, but in closing may I make a plea for much more release of data and methodology. I very much hope that they will release the actual program scripts in Stata and R, and also the original data, suitably anonymized.

The basic principle behind open data and open research is that anyone should be able to reproduce the published results. This is essential to verify the research itself and would put the work on the sort of rigorous level that is nowadays standard. More to the point, it would provide a rich resource for others to build upon the foundation that the authors have given—and it would also set a welcome example for other work in this important field.

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[17] The Walk Free Foundation, *"The Global Slavery Index 2018"*.

FACING CHOICES WHEN MODELLING MODERN SLAVERY RISK

Kelly A Gleason
Data Science Lead, Delta 8.7

The work by Pablo Diego-Rosell and Jacqueline Joudo Larsen represents a remarkable step forward for the scientific study of modern slavery. First, through the Walk Free foundation's collection of nationally representative data on forced labour and forced marriage in collaboration with Gallup World Poll, we have seen the evidence base substantially enriched, providing researchers with the necessary building blocks for the *2017 Global Estimates of Modern Slavery*.[18] In "Modelling the Risk of Modern Slavery"[19] the authors further enhance our understanding of factors influential to slavery vulnerability at the individual and national levels of analysis. The multistage modelling exercise presented in this paper showcases an impressive level of technical rigour expanding the horizon of methodological approaches in the area of modern slavery.

As in all models of any phenomena, researchers face choices regarding empirical strategy and a range of limitations based on those choices. Choosing to press beyond the exploratory or explanatory towards extrapolation and prediction is a bold move that can open doors to new knowledge. Along with that innovation comes concern about whether prediction is appropriate or possible at this early stage when the data environment is as sparse and unevenly developed as it is in this particular field. To that end, I have centred my discussion on the choices the authors made in terms of model selection and estimation method.

Model Selection

When selecting independent variables to include in a predictive (or explanatory) model, the approach used by quantitative researchers often falls into one of two camps: theory-driven or data-driven modelling.[20] The more classical approach in the social sciences is theory-driven. We build models of the world that shave down all of the noise and complexity in order to isolate the main causal mechanisms we hypothesize are responsible for the change in the phenomena we are interested in predicting, in this case, modern slavery risk. Normally, we have an idea about primary influences, which are spelled out in our hypotheses. These main influences are measured and tested within models with many other variables that are assumed to have some effect on the phenomena or outcome of interest.

More recently, with ever-increasing computing speeds, using data to find the answer to questions has become far more exploratory and less driven by stories about how we see the world. There is arguably nothing fundamentally wrong with taking a more inductive, exploratory approach to model selection. It can be messier than data-driven approaches when it comes to understanding why some characteristic or factor has an influence on the outcome. The added advantage to the data-driven approach is that it does not rely on the way an individual or institution sees the world. Instead, selecting the best model of prediction is based on statistical evidence of model fit.

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[18] International Labour Organization and the Walk Free Foundation, *"Global Estimate of Modern Slavery: Forced Labour and Forced Marriage"*, 2017.

[19] Diego-Rosell and Joudo Larsen, "Modelling the Risk".

[20] Lin Qiu, Sarah Kian May Chan and David Chan, "Big data in social and psychological science; theoretical and methodological issues", *Journal of Computational Social Science*, vol 1, No. 1 (January 2018).

The model selection strategy presented in the paper takes a middle ground approach. As the Gallup World Survey instrument collects information on 157 variables, there are a lot of choices when it comes to establishing a model. The approach used by Diego-Rosell and Larson is to assess each variable's correlation with forced labour or forced marriage subsequently discarding variables one by one if a significant effect is not apparent. In the next stage the variables found to have a significant bivariate correlation with the forced labour or forced marriage are entered in groups and those found insignificant are excluded.

The problem with the approach is that variables can appear to have no correlation with one another because the relationship between them is more complex,[21] possibly nonlinear or interactive. Furthermore, when including variables in a model, the effect on the outcome is largely dependent on the other variables that are also included in the right-hand side of the model. So, for example, if age was included as a predictor in a model with other characteristics, such as years of education, income or political preference, the influence of age might be wiped out by the effects of other variables. Age may then be discarded as a non-influential characteristic when it actually predicts an outcome pretty well.

That said, it seems extremely unlikely to me that research this technically thorough would make obvious errors like the one in my example. However, the justification of model selection would be strengthened by adhering to the more traditional modelling approach informed by more robust theory, which the authors acknowledge, or by using more advanced, data-driven model selection techniques, such as various model averaging approaches or fully automated model selection using regression methods or random forest modelling.[22]

Estimation Technique

The choice to employ Bayesian estimation instead of the more common frequentist approach, which is based around hypothesis testing, requires better explanation.

Bayesian statistics differ from frequentist statistics in that they have the ability to incorporate prior information about the world, which seems appealing. We might hypothesize that gender has an influence on risk of forced marriage. In the frequentist approach, the null hypothesis—gender does *not* have an influence on forced marriage—is assumed to be true until we have evidence to the contrary. A Bayesian approach rests on prior information suggesting gender *does* have such an influence.

Correct usage of Bayesian modelling is thus predicated on the existence of solid prior information.[23] Do we have enough solid prior information about the risk of modern slavery to justify using this information to guide risk models? I think it would be difficult to convince researchers in this space that there is and that the approach is not biasing. The authors also point out that the results of the Bayesian modelling align with the frequentist version of the hierarchical models. If the less complex modelling has the same traction, the Bayesian approach is not necessary and may even overcomplicate the analysis and interpretation and communication of the findings.

[21] Willki Sauerbrei, Norbert Holländer and Anika Buchholz, "Investigation about a screening step in model selection", *Statistics and Computing*, vol. 18, No. 2 (June 2008).

[22] Leo Breiman, "Random Forests", Statistics Department, University of California, Berkeley, January 2001.

[23] Philip B Stark, "Constraints versus Priors", *Journal on Uncertainty Quantification*, vol. 3, No. 1 (July 2015).

Conclusion

Attempting to present results of an innovative model, whether explanatory or approaching prediction, on slavery risk is a foundational step towards knowing more about which individuals may require greater social protections, which communities may be more vulnerable and which countries may face the largest challenges. Extending the model to make inferences about countries where there is very limited information presents challenges. The authors are appropriately very transparent about the limitations in the paper.

Pressing on with analysis despite imperfect data environments has inspired the use of novel proxies, instrumental variables and a range of statistical modelling approaches. Innovating in the pursuit of estimating individual risk to modern slavery is moving the field forward. As long as the current limitations are presented clearly so we can attempt to overcome them, I am confident that future research in the field will build off of this important and ground-breaking work.

MODELLING THE RISK OF MODERN SLAVERY
A RESPONSE

Jacqueline Joudo Larsen,
Criminologist and Head of Research,
Walk Free Foundation

Pablo Diego-Rosell,
Senior Consultant, Gallup

Estimating the prevalence of modern slavery is important for understanding the scale of these crimes. Despite being at an early stage of development, prevalence estimates are a critical factor in encouraging the interest of governments and funding bodies and galvanizing action. Our approach to estimation was developed with these overarching objectives in mind, together with the need for a clear, replicable method that will only be strengthened as more data becomes available.

Contributors to this symposium have raised several important points about the risk factor model we presented, including the suitability of the model for prediction, data gaps in developed countries, the choice of Bayesian over frequentist inference, reliability of prior information, usefulness of global data and data-sharing.

Professor Silverman notes that the risk factor model is good for explanation but raises concern over its use in prediction.[24] As we noted, this work is at an early stage and the data gaps for developed countries have been acknowledged. While a greater degree of precision is a priority in future iterations, we do not agree that there is no utility in the current country-level predictions. In the example given of the United States, knowing that the number of victims could be as high as 4 million is a substantial improvement on current efforts to estimate national prevalence.

There is certainly some way to go in improving precision in the model but to do so, further sources of data are required. We don't claim this is the best possible model, rather that it is the best possible model based on available data. In fact, generating estimates of the prevalence of modern slavery has revealed gaps in the data available at the regional level. Walk Free Foundation continues to invest in national surveys, refining measures of vulnerability, and seeking alternative forms of measurements in developed countries through techniques, such as multiple systems estimation, to ensure substantial improvements can be made to future models. In addition to this, research on specific sectors or regions will add a great deal of valuable information to models such as ours.

The decision to adopt a Bayesian approach over a frequentist one was questioned by Dr Gleason,[25] who noted that researchers in the field would not find the prior information on modern slavery reliable. Although frequentist inference is a more familiar among social scientists, we used a Bayesian framework primarily for computational reasons. The available data deals with rare events that in a frequentist approach may lead to singularities in matrix inversions. A Bayesian approach can be successful even when there is complete separation in logistic regression.[26] Besides the computational advantages, a Bayesian approach also allows us to incorporate basic prior knowledge about the prevalence and distribution of modern slavery.

For example, few would suggest that all possible risk values are equally likely. We agree with Dr Gleason that there is scant prior information on

[24] Bernard W Silverman, "Demonstrating Risks Is Not the Same as Estimating Prevalence", *Delta 8.7*, 12 December 2018.

[25] Kelly A Gleason, "Facing Choices When Modelling Modern Slavery Risk," *Delta 8.7*, 13 December 2018.

[26] Andrew Gellman and others, "A weakly informative default prior distribution for logistic and other regression models", *The Annals of Applied Statistics*, vol. 2, No. 4 (2008).

modern slavery, which motivated the decision to assign independent weakly informative priors for model intercepts and regression coefficients, using a t density function with 7 degrees of freedom and scale 2.5. Future iterations of this modelling approach will be able to incorporate prior information using the Bayesian approach.

Bermudez and Stewart warn that models which are based on variables chosen because of their availability across national data sets may lead to findings that are "too generic to be actionable".[27] This is a valid assertion, but a necessity given this work is undertaken for the purpose of measuring vulnerability and estimating prevalence of modern slavery across 167 countries for the *Global Slavery Index*. Identifying global level risk factors helps shape the overarching framework for policy responses. Vulnerability to modern slavery is affected by a complex interaction of factors related to the presence or absence of protection and respect for rights, physical safety and security, access to the necessities of life such as food, water and health care, and patterns of migration, displacement and conflict. At its most basic interpretation, this level of analysis confirms that modern slavery cannot be addressed in isolation but that it should be addressed alongside other fundamental rights issues highlighted in the Sustainable Development Goals.

There is value for modern slavery actors in identifying that, for example, education and youth development are associated with lower levels of forced marriage. The success of long-term solutions in this field essentially rests on driving systemic change and building resistance among vulnerable populations. This finding reinforces the need to focus on access to education among vulnerable populations – an entirely actionable finding for frontline organizations and an

intervention that many already incorporate into their anti-slavery programming.[28]

Having said that, we acknowledge that global models of risk can only go so far. Our own findings demonstrate the added value that regional analysis brings. In developing and testing the models, regional variation was found for "business ownership";[29] this was a significant predictor of forced labour in South Asia and Sub-Saharan Africa and thought to be due to the greater number of necessity entrepreneurs in developing countries. As noted above, research on specific sectors or regions will add substantially to our knowledge about modern slavery and in doing so, lead to improved modelling.

Finally, the replicability crisis in the social sciences has led to increased focus on transparency and this issue was raised by Professor Silverman. The sharing of data underlying global estimates is complicated by multilateral partnerships, which require a joint decision on sharing data, and the need to maintain the trust developed with governments and non-profit organizations. Assurances that data will be anonymized and protected are not always enough.

Notwithstanding these pragmatic considerations, Walk Free Foundation is committed to transparency. In the case of the study that is the subject of this symposium, the data, code and other relevant files were shared with an independent statistician for review, and a detailed technical paper was made available via the SSRN Electronic Journal. More broadly, our methods are developed and refined with an expert working group, pre-briefings on methodology are given to interested parties, a detailed methodology paper is published in the *Global Slavery Index*, and a great deal of our data is made freely available.

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[27] Laura Gauer Bermudez and Shannon Stewart, "The Benefits and Limitations of Modelling the Risk of Modern Slavery", *Delta 8.7*, 11 December 2018.

[28] Tekle-Ab Mekbib and Mitike Molla, "Community based reproductive health (RH) intervention resulted in increasing age at marriage: The case of Berhane Hewan Project, in East Gojam zone, Amhara region, Ethiopia", *Ethiopian Journal of Public Health*, vol. 4, No. 1 (2010).

[29] Diego-Rosell and Joudo Larsen, "Modelling the Risk".

The contributors to the symposium highlighted aspects of the analysis presented in "Modelling the Risk of Modern Slavery" that are important areas for refinement, and we are grateful for their careful consideration of this paper. While significant advancements in the measurement of modern slavery have been made in a relatively short period, this is very much a field in the earliest stages of development. Ultimately, the analysis under discussion sits at the forefront of estimation in this field. As a result, it comes as no surprise that the areas for refinement that we and the other contributors have identified are not unlike those encountered in the initial stages of measurement in other fields. The health sector, for example, faced a paucity of data with demand for better data growing throughout the 1980s and 90s, leading to the adoption of sample surveys[30] as the primary tool for understanding the extent of health status, risk factors and responses, particularly in developing countries.

Even in the health sector, a field that many think of as data-rich, there remain challenges that are reminiscent of those we face in measuring modern slavery, including the inadequacy of country-reported data, the need to fill data gaps, and to ensure that there are independent and objective assessments. The speed with which we have encountered these issues and taken steps to address them in our field is encouraging, as is the increasing level of genuine collaboration – shown through the establishment of Alliance 8.7, the development of joint global estimates,[31] and creation of data platforms such as, Delta 8.7 and The Counter Trafficking Data Collaborative. Such collaboration is critical to ensure the end of modern slavery.

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[30] Carla AbouZahr, Ties Boerma and Daniel Hogan, "Global estimates of country health indicators: useful, unnecessary, inevitable?", *Global Health Action*, vol. 10, sup. 1 (May 2017).

[31] ILO and Walk Free, "Global Estimates".

WHAT WORKS? *5 LESSONS LEARNED ON SLAVERY RISK FOR POLICY ACTORS*

James Cockayne,
Director, United Nations University Centre for Policy Research

Project Director, Delta 8.7

One year ago, the UK National Audit Office released *Reducing modern slavery*, a landmark review of the governance and effectiveness of key parts of the UK's anti-slavery activities. Launching that report, Amyas Morse, the head of the Office, noted that:[32]

> The campaign to drive out modern slavery is in the early stages. So far it is helping to establish the scale and international nature of this issue. To combat modern slavery successfully,

however, government will need to build much stronger information and understanding of perpetrators and victims than it has now.

Good policymaking requires the wise allocation of scarce resources. And understanding risk is central to allocating resources and ensuring policies and programming will be more effective and more efficient.

With this "Symposium on Modelling Modern Slavery Risk," leading anti-slavery experts discussed the benefits and limits of an innovative model for predicting risk of slavery on the individual and nation levels. Beyond the science, the Symposium also offers five lessons for policy actors:

1. We are on the verge of breakthroughs allowing risk-informed policies and programming

The paper by Jacqueline Joudo Larsen and Pablo Diego-Rosell that motivated this Symposium[33] demonstrates the feasibility of modelling slavery risk. As they acknowledge,[34] and the contributions from Bernard Silverman,[35] Laura Gauer Bermudez and Shannon Stewart,[36] and Kelly Gleason[37] explore, there are limits to our understanding of risk right now, and to the predictive capabilities of the model Joudo Larsen and Diego-Rosell have developed.

But those limits can be overcome. Joudo Larsen's and Diego-Rosell's research points to the possibility that individual factors such as age, gender, employment status, feelings about household income and about one's life *may* be predictors of slavery risk. As research continues, our certainty about whether they or other factors *are* predictors will increase.

And as our understanding of the reliability and strength of such factors in predicting slavery

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[32] National Audit Office, "Reducing modern slavery," website, available at https://www.nao.org.uk/report/reducing-modern-slavery/.

[33] Diego-Rosell and Joudo Larsen, "Modelling the Risk".

[34] Joudo Larsen and Diego-Rosell, "An Introduction to Modelling the Risk".

[35] Silverman, "Demonstrating Risks".

[36] Gauer Bermudez and Stewart, "The Benefits and Limitations".

[37] Gleason, "Facing Choices".

outcomes improves, policies, programmes and interventions can be better tailored and targeted. For policymakers, this means that anti-slavery work will become both more effective *and* more efficient, making the case for investment in anti-slavery efforts easier and easier to make.

2. Limits on data quality, sharing and modelling are holding us back

The Symposium contributions also make clear, however, that limits on data quality and in modelling continue to hold us back. Joudo Larsen and Diego-Rosell arguably use the best available global estimates of slavery at the national level. That data, combined with the Joudo Larsen-Diego-Rosell model, gives us arguably the most powerful predictive model available right now: but it is also a system that produces striking oddities, seeming to predict, for example, that the number of victims of modern slavery in the United States will be anywhere between "-0.5 million and 4 million". Clearly, policymakers need data and models that give them greater clarity. As the contributions to this Symposium make clear, this is an important step in that direction, but we have some distance to go.

Even where good data *is* available, there are real and continuing barriers to sharing it. As

forthcoming and collaborative as they have been, key parts of the data and methods that Joudo Larsen and Diego-Rosell rely on are proprietary. Business remains a key source of funding of slavery risk analysis, and in fact may become a *bigger* player, as states impose new reporting and due diligence obligations on companies. If the result is a fragmented evidence base, trapped behind corporate walls, our understanding of slavery risk will be held back. Anti-slavery investments will be less effective and less efficient. Everyone loses out.

A more effective approach would be to encourage the development of common methodologies and open data, and to invest in systems for data sharing and collective learning. To invest, in other words, in science.

3. Steps are being taken to reduce those constraints

The good news here is that the trend is clearly in the right direction. This Symposium itself is testament to the emergence of a cadre of practitioner-scholars with serious statistical credentials who are helping to strengthen the scientific foundations of policy and practice in the field.

The Call to Action to End Forced Labour, Modern Slavery and Human Trafficking includes important commitments to data sharing (paras 1(ii), 1(vi), 2(ii)). Delta 8.7 has recently begun rolling out country data dashboards to make the best available evidence available worldwide.

The International Conference of Labour Statisticians (ICLS) recently adopted new survey standards that will lead to better, more comparable data on forced labour prevalence in the years ahead.[38]

And the Alliance 8.7 Pathfinder process will allow countries such as Albania, Chile, Madagascar, Nepal, Nigeria, Peru, Sri Lanka, Tunisia, Uganda and Viet Nam to benefit quickly from new scientific insights developments.

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[38] International Conference of Labour Statisticians, "Resolution concerning the statistics of work, employment and labour underutilization".

4. The field is ripe for digital disruption

Nonetheless, the pace of progress is slow – too slow to meet the targets set out in Target 8.7 of the Sustainable Development Goals. The survey standards set out by the ICLS will deliver high quality, comparable data – but only in five to ten years. And the survey methods underlying this approach, and existing *Global Estimates*, cost millions of dollars to execute. This is one reason that governments have begun experimenting with other techniques, such as multiple systems estimation (MSE) – but MSE is also constrained by what data is already available.

Like many high-cost, slowing moving analytical processes, slavery prevalence estimation and risk analysis is thus ripe for digital disruption. Already the Global Fund to End Modern Slavery is experimenting with using social media and mobile technology for survey dissemination, promising

significant cost reductions. Delta 8.7 has successfully used machine learning to estimate official development commitments to fight slavery.[39] And computational analysis offers a path for rapid acceleration of the kinds of modelling begun by Joudo Larsen and Diego-Rosell.[40]

For these reasons, Delta 8.7, the Computing Community Consortium, the Alan Turing Institute, Rights Lab, Tech Against Trafficking and the Global Security Initiative at Arizona State University will convene a two-day conference in February 2019. Code 8.7 will bring together the anti-slavery community and the computational science, artificial intelligence, machine learning and tech communities, to think about how to accelerate our understanding of modern slavery and what works to fight it.

5. There's no time to lose

If governments are serious about meeting Target 8.7, around 9,000 people need to be removed *each day* from the ranks of those affected by forced labour, modern slavery and human trafficking, according to the best available estimates. Right now, we simply don't know how close we are to achieving that aggressive rate of reduction.

The pieces in this Symposium make clear that we are on the verge of significant scientific breakthroughs in understanding what is likely to make someone vulnerable to modern slavery –

and in tailoring programming and policies accordingly. Achieving those breakthroughs requires continued investment in the science of anti-slavery, and a willingness to think laterally – and digitally.

And ultimately it will require the kind of honest debate and scientific rigour that all the contributors to this Symposium have so admirably modelled. At Delta 8.7, we look forward to continuing to provide a space for that debate, and for translating it for policy actors.

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[39] Kelly A Gleason and James Cockayne, "Official Development Assistance and SDG Target 8.7: Measuring Aid to Address Forced Labour, Modern Slavery, Human Trafficking and Child Labour", United Nations University Centre for Policy Research, September 2018.

[40] Scott E Page, "Why 'Many-Model Thinkers' Make Better Decisions", *Harvard Business Review*, 19 November 2018.