Student Research Journal

Issue 6

Curated Highlights Magazine

University of BRISTOL

BILT
Bristol Institute for Learning and Teaching

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Contents

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PRO VICE-CHANCELLOR'S FOREWORD

I was honoured to be asked to write the foreword for the BILT Student Research Journal. Central to research is the need to communicate the findings, and at the heart of academic communication, are peer-reviewed journals and particularly the importance of the growing trend towards open-access journals. The foresight and commitment of the students in creating this journal in 2019 are really worth highlighting, as it goes from strength to strength to illustrate the breadth and depth of research by students at the university. As part of such a comprehensive university, whether your research is interdisciplinary or in a single discipline, you have the opportunity to hear from so many other disciplines during your research education.

Last year, Professor Jessop highlighted how this journal is run by students for students, and I too think this is the really exciting aspect and is beneficial in so many ways. Whether your career pathway remains in academia, continues research or takes another pathway, concise communication to your peers of what one is doing and working with them in this journal process is extremely valuable.

It is so important to implement continuous improvement and reflective practice. The addition of a DOI and a special section on global concerns ensures that the journal is current and relevant to a wider audience. The record applications for editorial board members (160) and 75 peer reviewers illustrate the interest in participating in the journal. From my time at UKRI, where I oversaw work on peer review, I am aware that it is not easy to get people to "volunteer" to be editors or peer reviewers, and the success here indicates that this journal is liked and supported by the student community.

The additions of Declaration and Agreement, awards for outstanding editors and authors, encouragement of use of ORCID accounts and training handbooks for editors and authors, all add to why Jay has proudly stated that the journal is "More Professional, has Wider Participation, and offers Deeper Insights from Students!"

Almost 180 abstracts were submitted from 11 subject areas, and almost 55 of these have been published due to the tremendous effort of the subject editors and peer reviewers, alongside the wonderful authors submitting such interesting work. My final congratulations are to Amy Palmer (Senior Education Developer at BILT), Caroline Harvey (Coordinator at BILT), Jay Liu (Editor-in-Chief), Shichun Gu (Deputy Editor-in-Chief of Hard Sciences), Lilian Sudi (Deputy Editor-in-Chief of Social Science), and Olivia Bell (Copy Editor) on producing yet another excellent journal in 2025. It's always a hard act to follow the previous year's journal, but it is a sign of a successful journal when each new group of editors and authors rise to the challenge and long may that continue. I look forward to learning a lot whilst reading the papers and will reach out to the authors to find out more. It is a real pleasure of a role like mine to hear about the research and innovation at this wonderful university, which is made so great by the students and researchers, and indeed all the staff who work and study here.

Professor Guy Poppy
Pro Vice-Chancellor for Research and Innovation

EDITOR-IN-CHIEF'S FOREWORD

In a world grappling with complexity, uncertainty, and rapid change, the pursuit of knowledge stands as both anchor and compass. This 6th edition of the BILT Student Research Journal stands not only as a testament to academic excellence but as a celebration of student ambition, discipline, and vision. Since its founding in 2019, the Journal has embodied a vision of empowering students to step beyond the classroom and into the realm of scholarly impact.

This year, we have carried that legacy forward with renewed purpose and a bold expansion of scope, depth, and professionalism. We expanded our disciplinary horizons, welcoming work on climate change, AI, geopolitical conflict, technology developments, and other urgent global issues through several new subjects. We introduced a rigorous second round of peer review and reinforced ethical research practices with declarations on AI use, authorship, and integrity. We implemented DOI indexing for each paper of the journal, brought in MRes and PhD students to enrich the editorial ecosystem, and introduced recognition awards for excellence in authorship and editing.

Behind these developments is a record-breaking editorial team: over 100 students were selected from across disciplines from 160 applications, forming the most diverse and capable editorial board in our history. We trained them not just to review or edit papers, but to grow as scholars, collaborators, and future leaders in academia. This Journal now represents more than research—it is a movement. A movement toward more professional, inclusive, and socially relevant academic publishing led by students, for students. A platform where the curiosity of student authors meets the critical eye of peer reviewers. Where passion is sharpened by process. And where ideas, polished by care, take flight into the academic world.

To every student author who dared to put their work forward: thank you. To every editor, peer reviewer, and advisor who gave your time and skill: this edition is yours. And to our readers, may these pages not just inform but ignite. I would like to express my appreciation to my managers, Amy Palmer and Caroline Harvey, who provided invaluable support to me and the development of the journal. As a result of collaborative commitment and efforts, the whole editorial board carefully selected and edited 53 papers out of 178 submissions across 11 subjects. The future of research is here—and it's student-powered.

Welcome to the 6th BILT Student Research Journal (2025), I hope you all enjoy reading it.

Chaojie (Jay) Liu
BILT Student Fellow and Editor-in-Chief

Meet Chaojie (Jay) Liu
Jay is a PhD researcher in finance at the University of Bristol, focusing on the intersection of artificial intelligence and financial markets. His research explores themes such as robo-advising, investor behaviour, and machine learning, with an emphasis on improving financial decision-making and social welfare. He holds an MSc in Economics and Finance with Distinction and a BSc in Finance, both from the University of Bristol. He is also a mentor, society president, and active contributor to academic and public discourse on the future of finance.

You can find Jay at www.chaojieliu.com or jay.liu@bristol.ac.uk

DEPUTY EDITOR-IN-CHIEFS' FORWORDS

Hard Sciences

As the Deputy Editor-in-Chief of the 6th Student Research Journal, I would like to take this chance to introduce you to the Hard Sciences subjects. Thanks to the contribution of the BILT members over the past five years, we have received hundreds of exciting abstracts this year. We have included literature reviews, project works, and collaborated research within the five subjects. Biology features great articles on evolution and ecosystems, while Chemistry and Medicine provides information on new technologies and tackling healthcare issues. EMT (Engineering, Mathematics and Technology) encourages transforming practical skills into advancing fields in everyday life. Other interdisciplinary perspectives are covered in the Special Section. This year, we initiated another new subject, Psychology, to address the overwhelming interest in this field. With its evolving importance, Psychology offers insight into social behaviours and mental well-being. Get ready to be inspired, and I hope you enjoy this journal as I did.

Shichun Gu, Deputy Editor-in-Chief of Hard Science

Meet Shichun Gu

Shichun is a Cellular and Molecular Medicine PhD focusing on respiratory tract viruses. With a Virology and Immunology Master, she specialises in sequencing, multi-omics and reverse genetics. Her work emphasises the importance of detecting minor mutations and identifying accessory proteins' functions.

Social Sciences

When I joined the editorial board for this sixth edition of the BILT Student Research Journal, I was looking for a connection to ideas, to community, and to the kind of hopeful thinking that often lives in student spaces. What I found was so much more. Working with this journal reminded me that there's clarity in collective curiosity. Each submission we received was a testament to the power of student research, not just in the findings, but in the courage it takes to ask important questions in the first place. This journal results from months of thoughtful collaboration, generous peer review, and honest conversations. It was built with intention, compassion, and care, values just as important in academia as methodology or theory. To the contributors: thank you for trusting us with your work. To my fellow editors and reviewers: thank you for your commitment to integrity and inclusion throughout this journey. And to our readers: I hope these pages spark something in you, whether it's a new idea, a feeling of being seen, or the confidence to share your voice.

Lilian Sudi, Deputy Editor-in-Chief of Social Sciences

Meet Lilian Sudi

Lilian is an MSc student in Environmental Modelling and Data Analysis, with a background in engineering and sustainable development. She has over eight years of experience in the water and energy sectors across sub-Saharan Africa. Her work focuses on using data-driven tools and climate modelling to inform policy and build climate resilience. Passionate about the intersection of AI, sustainability, and education, she also advocates for women in STEM and previously served as the Communications Director and lead editor for WomEng Newsletter.

SUBJECT PAPERS

The following pages will showcase the most outstanding paper from each subject area. Carefully curated by our dedicated subject editors and peer reviewers, these works reflect the depth, creativity, and academic rigour of our contributors. We hope you find them as engaging and thought-provoking as we did.

Subject Biology

Subject's Foreword

It has been an honour to serve as Subject and Deputy Subject Editor of Biology for the BILT Student Research Journal this year. We're proud to present the excellent research and reviews by University of Bristol students, supporting their journey into scientific academia.

While past issues explored broad topics, this year's articles mainly focus on ecological systems, plant and animal activity, and environmentally impactful agricultural practices—reflecting the urgent need for research in the face of climate change. Some pieces also offer interdisciplinary insights through comparative biology and biomimicry.

We commend the authors for their strong research and writing, and thank our expert peer reviewers for their invaluable feedback. The editorial team worked hard to ensure all articles met high international standards.

Completing this process alongside academic and personal commitments is no small feat, and we extend heartfelt thanks to the Editor-in-Chiefs for their continued support. We hope this issue inspires further scientific inquiry and student engagement with research publication.

Ushma Pandia, Subject Editor (Biology)

Alexandros Fragkidis, Deputy Subject Editor (Biology)

Meet Ushma Pandia

Ushma Pandia is currently pursuing a Master's degree in Molecular Neuroscience at the University of Bristol. Having previous experience as a scientific editor and a passion for efficient and reliable science communication, she was glad to take on the role of Biology Subject Editor for the Student Research Journal. It was an enlightening experience for her to read and review papers covering such a vast array of topics under biology. Her personal research interests include disorders of the brain and understanding their cellular and molecular underpinnings. She hopes to gain essential work experience in research laboratories within the field of neuroscience and further her career in scientific research.

Meet Alexandros Fragkidis

Alexandros Fragkidis is currently a Deputy Subject Editor for Biology at the Student Research Journal, where he helps coordinate the peer review process and supports young researchers in publishing their work. He is a biology graduate from the University of Leeds and is currently pursuing an MSc in Molecular Neuroscience at the University of Bristol. He is particularly interested in how the brain functions at a molecular level and how disruptions in these processes can lead to neurological diseases. His next step is to pursue a PhD and contribute to impactful research aimed at understanding and eventually treating neurodegenerative conditions.

The Effect of Microclimate on Bird Species Richness in Three Woodland Types Across Leigh Woods, Bristol

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Abstract

British biodiversity is facing significant decline, with woodland birds being notably impacted by habitat and climate changes, particularly microclimate conditions. Microclimate parameters are strongly influenced by local vegetation. This study aimed to examine the effect of interactions between microclimate parameters and woodland type on bird species richness in a managed British woodland (Leigh Woods National Nature Reserve, Bristol) at dawn, midday and dusk. iButton temperature and humidity loggers and Wildlife Acoustic Song Meter Micros were deployed to record microclimate and bird call data, which was analysed with woodland type using general linear mixed models (GLMMs). The study hypothesised opposing effects for temperature and relative humidity, proposing them to be stronger in plantation stands than semi-natural ancient woodland (SNAW). The results indicated considerable variability and partially supported the hypotheses, suggesting plantations as the preferred bird habitat amid rising temperatures, and reduced relative humidity in SNAW. Both time-of-day and ecosystem management strategies are suggested to partially explain reported variation. Future investigations should integrate habitat and time-series data, and examine species-specific trends to inform optimal woodland management practices for woodland bird conservation. Overall, this investigation emphasises the importance of research examining the impacts of fine-scale climate changes on species of conservation concern.

Keywords: Microclimate, Woodland Type, Woodland Biodiversity, Bird Species Richness, Acoustic Monitoring

Introduction

Across the UK, biodiversity is rapidly declining[1]. Woodland bird species are among those most severely impacted, with populations having declined by 38% in England since 1970[2]. Owing to their environmental sensitivity and trophic level, birds act as important bioindicators of ecosystem change[3]. Both climate and woodland habitat changes are key drivers of woodland bird decline[4, 5], highlighting the need to identify optimal strategies to support woodland bird communities to ultimately maintain woodland biodiversity and ecosystem function.

The role of microclimate – the fine-scale climatic conditions within a localised area – in determining an organism's survival is increasingly recognised[6]. Parameters such as air temperature, relative humidity, precipitation, wind speed and direction, and solar radiation all fluctuate diurnally and are strongly affected by local topography and vegetation[7, 8]. Although the effects of microclimate are understudied in endotherms like birds, there is clear evidence showing significant impacts to their physiology and behaviour, and thus survival[9].

For birds, warming temperatures can induce physiological stress due to increases to energy expenditure and water loss[4, 5, 10]. In comparison, the effects of relative humidity, defined as the percentage of water vapour in the air relative to its maximum at a specific temperature (Met Office, n.d.), are often overlooked in field research but may still be significant. Hence, microclimate parameters are valuable to consider in bird conservation efforts.

In wooded ecosystems, structural and vegetational diversity promotes microclimate heterogeneity[6, 8]. Old-growth forests are often hypothesised to buffer the stresses of global climate change by providing more stable microclimate refugia (microrefugia) for forest-dwelling species, including birds, as opposed to plantations[4, 12-14]. However, studies concurrently reporting microclimate and animal species data remain scarce[5] as climatic conditions are largely inferred from broad macroclimate measures, overing the conditions experienced by individual organisms[6,7, 15]. Nevertheless, remote in-situ sensor advancements are enabling fine-scale research to be conducted in complex ecosystems, transforming the field of microclimatology[16].

This study aimed to determine the effect of microclimate on bird species richness in the three woodland types in Leigh Woods National Nature Reserve: Semi-Natural Ancient Woodland (SNAW), Broadleaf Plantations on Ancient Woodland Sites (PAWSB), and Conifer Plantations on Ancient Woodland Sites (PAWSC). Leigh Woods, located in Bristol, is a well-visited 200-hectare woodland, with 125-hectares managed by Forestry England[17]. Given its significant conservation value, popularity and extensive records, it offers a unique setting for ecological investigations.

Since physiological and behavioural stresses are induced by increasing temperature, significantly negative effects of temperature on bird species richness were hypothesised, with increasing temperature decreasing species richness. In contrast, significantly positive effects of relative humidity on bird species richness were hypothesised, as lower humidity is associated with higher temperatures, creating drier environments[18]. Finally, these effects were proposed to be stronger in PAWS than SNAW based on the a priori old-growth forest hypothesis.

Methods

Study site

In 2023, past research contributors sampled 18 randomly stratified 20 x 20-meter plots across three woodland types in Leigh Woods, Bristol – SNAW, PAWSB and PAWSC (Figure 1). SNAW consists of native trees and shrubs, being forested since 1600 AD or earlier, while PAWS (Plantations on Ancient Woodland Sites - Broadleaf and Conifer) have been replanted but preserve some undisturbed ancient features, including soil and fungi[17]. PAWSB are characterised by broadleaved trees, most commonly including beech (*Fagus sylvatica*) and ash (*Fraxinus excelsior*). Contrastingly, PAWSC are composed of conifer trees, including Corsican pine (*Pinus nigra subsp. laricio*), European yew (*Taxus baccata*) and larch (*Larix decidua*). Evidence of tree thinning was observed at 80% of SNAW and 40% of PAWSC plots, with no recent management apparent across PAWSB.

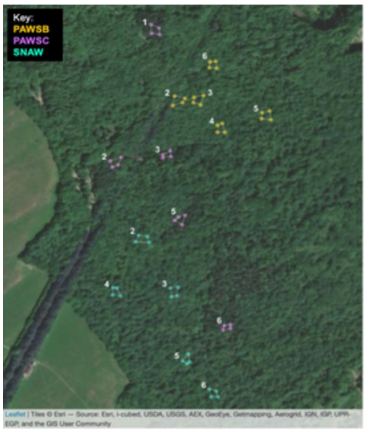


Figure 1. Mapped coordinates of 15 plots (each 20 x 20-meters) across three woodland types in Leigh Woods, Bristol. Each coloured circle marks one of the four corners of each plot. The key indicates the colour corresponding to each woodland type: Plantations on Ancient Woodland Sites – Broadleaf (PAWSB) in gold, Plantations on Ancient Woodland Sites – Conifer (PAWSC) in purple and Semi-Natural Ancient Woodland (SNAW) in turquoise. The numbers represent the plot number within each woodland type. Created with leaflet19 using R version 4.4.220.

Data collection

Data were collected over 12 days (22/10/2024 – 02/11/2024), with timings reported in British Summer Time. We deployed iButton DS1923 Hygrochron Temperature/ Humidity Data Loggers (n=18) to record hourly temperature, measured in degrees Celsius (±0.5°C), and percentage relative humidity (±0.6%) values at each plot. Each logger was housed in a 15-millilitre clear waterproof container with 12 holes for ventilation. Each iButton case was mounted 1.5 meters above the ground to the most central tree within each plot, on the north side to avoid exposure to direct sunlight5. On the same tree, we fastened one Wildlife Acoustics Song Meter Micro using zip-ties at 2-meters height which recorded 10-minute hourly audio samples. Recordings were analysed using BirdNET-Analyzer-1.4.0 to identify bird species from their calls, setting a confidence threshold of 0.5 to minimise inaccurate identifications[21].

Data analysis

Owing to recording errors, three plots (SNAW1, PAWSB1 and PAWSC4) were omitted. Bird species richness was calculated from each audio recording, defined by the number of different bird species identified. Statistical analysis was then conducted using R version 4.4.2[20].

Six random intercept general linear mixed models (GLMM) were created using glmmTMB[22] to examine the interaction effects of microclimate parameters and woodland types, GLMM were created using glmmTMB[22] to examine the interaction effects of microclimate parameters and woodland types, as fixed effects, on bird species richness at three time points – dawn (0800 hours (hrs); n=180), midday (1200 hrs; n=180) and dusk (1600 hrs; n=180).

Filtering for specific time points overcame temporal autocorrelation in the time-series data. Date was included as the random effect to account for daily correlations and utilised random intercept GLMMs to examine the influence of our fixed effects rather than their variability across dates. For each GLMM, the assumptions were verified using the performance package[23]. High multicollinearity was observed for interactions between our fixed effects; however, analysis proceeded to investigate the interaction effects to explore the potentially biologically meaningful relationship between microclimate parameters and woodland types, rather than focusing on precise outcome predictions. Poisson distribution with a log-link function was selected as the best fit for all models. The GLMM summaries were reported with PAWSB woodland type as the reference group. ggplot2[24] was employed to visualise our GLMMs, combining all temperature and all relative humidity models to create two figures with shaded confidence intervals of 95% to represent the uncertainty associated with each relationship. Using the emmeans package[25], post-hoc pairwise comparisons were performed to compare the microclimate parameters effects across woodland types, applying the Tukey adjustment for multiple testing.

Results

Temperature

The effects of interactions between temperature (°C) and woodland type on bird species richness were modelled at dawn, midday and dusk (Figure 2). At dawn, the interaction between temperature and SNAW had a significantly negative effect on bird species richness, indicating fewer species were present in SNAW plots as temperature increased (Estimate=-0.147, SE=0.0471, z=-3.035, $p<0.01$; Table 1). In contrast, no significance on bird species richness was identified between the interaction of temperature and PAWSC (Estimate=0.0468, SE=0.0449, z=-0.953, $p>0.05$; Table 1) and PAWSB (Estimate=-0.00402, SE=0.0453, z=-0.089, $p>0.05$; Table 1). Post-hoc comparisons (Table 2) revealed that increased temperature significantly reduced bird species richness to a greater extent in SNAW than PAWSB ($p<0.01$); however, no significant difference between PAWSC and PAWSB ($p>0.05$) or PAWSC and SNAW ($p>0.05$) were detected.

At midday, interactions between temperature and woodland type had no significant effect on bird species richness for PAWSB (Estimate=-0.00132, SE=0.0679, z=-0.0190, $p>0.05$; Table 1), PAWSC (Estimate=0.112, SE=0.0982, z=1.15, $p>0.05$; Table 1) or SNAW (Estimate=-0.102, SE=0.109, z=-0.925, $p>0.05$; Table 1). Additionally, post-hoc comparisons (Table 2) revealed no significant differences between the effect of temperature on bird species richness at any woodland type (all $p>0.05$).

Similar to midday, no significant effect of interactions between temperature and woodland type on bird species richness were detected at dusk for PAWSB (Estimate=-0.0737, SE=0.0650, z=-1.13, $p>0.05$; Table 1), PAWSC (Estimate=-0.0834, SE=0.106, z=-0.789, $p>0.05$; Table 1) or SNAW (Estimate=-0.102, SE=0.111, z=1.082, $p>0.05$; Table 1). Post-hoc comparisons (Table 2) also found no significant differences between any woodland types (all $p>0.05$).

Relative humidity

The effects of interactions between relative humidity (%) and woodland type on bird species richness were modelled at dawn, midday and dusk (Figure 3). At dawn, the interactions between relative humidity and woodland type had no significant effect on bird species richness for PAWSB (Estimate=0.0128, SE=0.0224, z=0.572, $p>0.05$; Table 1), PAWSC (Estimate=0.0281, SE=0.0226, z=1.25, $p>0.05$; Table 1) or SNAW (Estimate=0.0106, SE=0.0237, z=0.445, $p>0.05$; Table 1).

Additionally, no significant differences between woodland types were detected (all $p>0.05$; Table 2). At midday, the interaction between relative humidity and PAWSC had a significantly positive effect on bird species richness, with richness increasing with increasing temperatures (Estimate=0.0551, SE=0.0230, z=2.39, $p<0.05$; Table 1). In comparison, no significant effect between relative humidity and woodland type on bird species richness were detected for PAWSB (Estimate=-0.0217, SE=0.0207, z=-1.05, $p>0.05$; Table 1) or SNAW (Estimate=0.0437, SE=0.0225, z=1.94, $p>0.05$; Table 1). Post-hoc comparisons (Table 2) revealed that increasing relative humidity increased bird species richness to a signficiantly greater extent in PAWSC than PAWSB ($p<0.01$) however, no significant difference between

SNAW and PAWSB ($p>0.05$) or SNAW and PAWSC ($p>0.05$).

At dusk, the interaction between relative humidity and PAWSB had a significantly positive effect on bird species richness (Estimate=0.0463, SE=0.0204, z=2.28, $p<0.05$; Table 1). Additionally, significant interaction effects on bird species richness were also detected between relative humidity and PAWSC (Estimate=-0.0420, SE=0.0191, z=-2.20, $p<0.05$; Table 1) and SNAW (Estimate=-0.0474, SE=0.0205, z =-2.31, $p<0.05$; Table 1) however, these effects were negative, indicating that less bird species were present under higher relative humidity. Post-hoc comparisons (Table 2) revealed no significant differences between the effect of relative humidity at any woodland type (all $p>0.05$); however, the difference between effects at PAWSB and SNAW was marginally significant ($p=0.054$).

Discussion

As climate change and habitat loss pressures continue to drive global biodiversity changes, understanding the interaction of microclimate and habitat structure is vital for informing effective species conservation and management strategies. This research examines the effects of temperature and relative humidity within different woodland types to provide insight into their influence on bird community composition in Leigh Woods.

Temperature

The effect of interactions between temperature and woodland types on bird species richness showed limited significance. The significant negative effect of the interaction between temperature and SNAW detected at dawn shows partial support for the hypothesised negative effects of temperature on bird species richness, given the associated physiological and behavioural stress. However, this effect was unexpectedly significantly stronger with SNAW than PAWS, contrasting the hypothesised stronger effects in PAWS than SNAW. Similar negative responses to warming temperatures have been identified in forest-associated bird species[4, 5, 9, 26]. However, researchers have also identified the potential of old-growth forests to reduce and even reverse these negative trends[4], opposing the findings of this investigation.

The thinning observed in 80% of SNAW plots likely explains the statistically significantly negative effect on bird species richness by reducing ancient woodland, canopy cover and associated microrefugia. Yet, this effect is only observed at dawn, a critical time for bird species to perform dawn choruses and forage for resources. Thinning may amplify solar radiation penetration, leading to faster temperature increases at dawn[27]. At thinned SNAW plots, this temperature increase may account for the reduced bird species richness compared to PAWS, increasing heat stress and reducing the sound propagation of bird calls. Furthermore, the absence of thinning across PAWSB may explain its significant difference to SNAW.

Contrastingly, the consistent non-significant effects of temperature and woodland type interactions indicate that temperature has minimal influence on bird species richness across Leigh Woods, thereby rejecting the hypothesis. Birds, as endotherms, can regulate their bodily temperature to endure climatic fluctuations[4, 9], potentially accounting for the predominantly non-significant effects of temperature increases.

Rising temperatures may mean negative impacts on bird species become more pronounced. Our findings raise particular concern for the conservation of SNAW-associated birds. Future research should focus on species-specific distribution models that integrate microclimate and habitat data to predict the most suitable conditions for each species[9, 28, 29]. Increasing the frequency of plots sampled, expanding the study site and extending the data collection period would improve the robustness of these predictions. This would enhance our understanding of species-specific trends, which may be overlooked by the simplistic nature of species richness, to better inform targeted conservation strategies for species of concern.

Overall, the effects of temperature and woodland type on bird species richness are largely inconsequential. While they provide some suggestion that PAWS are more favourable than SNAW for bird communities amid rising global temperatures in Leigh Woods, this correlation is highly time dependent. Future research examining specific species as well as time series data would offer more insight.

Relative humidity

The effects of relative humidity exhibited substantial variation. The hypothesis positing positive effects of relative humidity on bird species richness is partially accepted by the positive effects reported in PAWSC at

Table 1. Exact p-values for the summaries of general linear mixed models (GLMMs) investigating the effect of interactions between microclimate parameters and woodland type on bird species richness at three time points in Leigh Woods. Values were taken from three time points: dawn (0800 hours (hrs); n=180), midday (1200 hrs; n=180) and dusk (1600 hrs; n=180). The woodland types investigated were Plantations on Ancient Woodland Sites – Broadleaf (PAWSB), Plantations on Ancient Woodland Sites – Conifer (PAWSC), and Semi-Natural Ancient Woodland (SNAW). All results are compared to each GLMM's reference group – woodland type PAWSB. The level of significance was set to 0.05, with significant P-value indicated by an asterisk (*). Statistical analyses were conducted using R version 4.4.220.

Microclimate parameter	**Time point**	**Woodland type comparison**	**P-value**
Temperature	Dawn	PAWSB - PAWSC	0.6064
		PAWSB - SNAW	0.0068 *
		PAWSC - SNAW	0.0648
	Midday	PAWSB - PAWSC	0.4823
		PAWSB - SNAW	0.6244
		PAWSC - SNAW	0.1380
	Dusk	PAWSB - PAWSC	0.7096
		PAWSB - SNAW	0.5251
		PAWSC - SNAW	0.1717
Relative humidity	Dawn	PAWSB - PAWSC	0.4267
		PAWSB - SNAW	0.8964
		PAWSC - SNAW	0.6975
	Midday	PAWSB - PAWSC	0.0440 *
		PAWSB - SNAW	0.1283
		PAWSC - SNAW	0.8541
	Dusk	PAWSB - PAWSC	0.0707
		PAWSB - SNAW	0.0542
		PAWSC - SNAW	0.9472

Figure 2. The effects of interactions between temperature (°C) and woodland type on bird species richness in Leigh Woods at dawn, midday and dusk (n=60 per relationship). Woodland types include Plantations on Ancient Woodland Sites – Broadleaf (PAWSB) in gold, Plantations on Ancient Woodland Sites – Conifer (PAWSC) in purple, and Semi-Natural Ancient Woodland (SNAW) in turquoise. Each panel in the figure focuses on data collected from a specific time point: dawn (0800 hours (hrs)), midday (1200 hrs), and dusk (1600 hrs). Each circular point represents an observed data point, while each regression line reveals the fitted model's predicted relationship between the fixed effects with Poisson error distribution. The shaded regions reflect the model's uncertainty, representing 95% confidence intervals. Created using ggplot224 and R version 4.4.220.

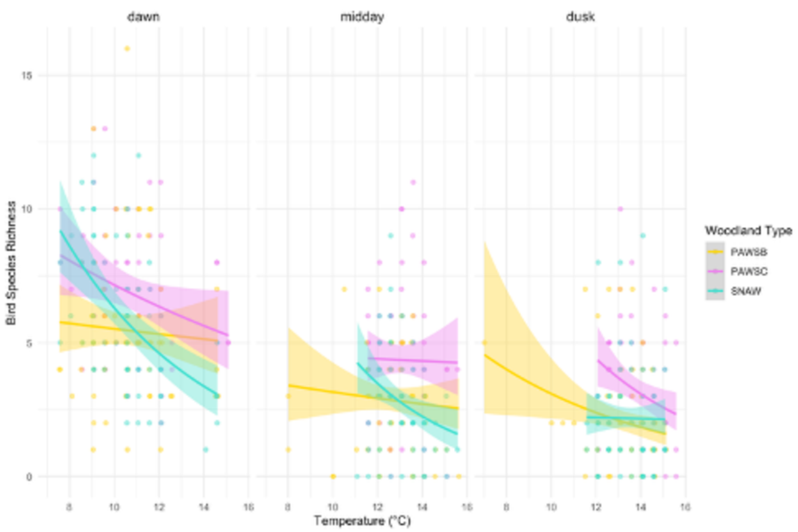
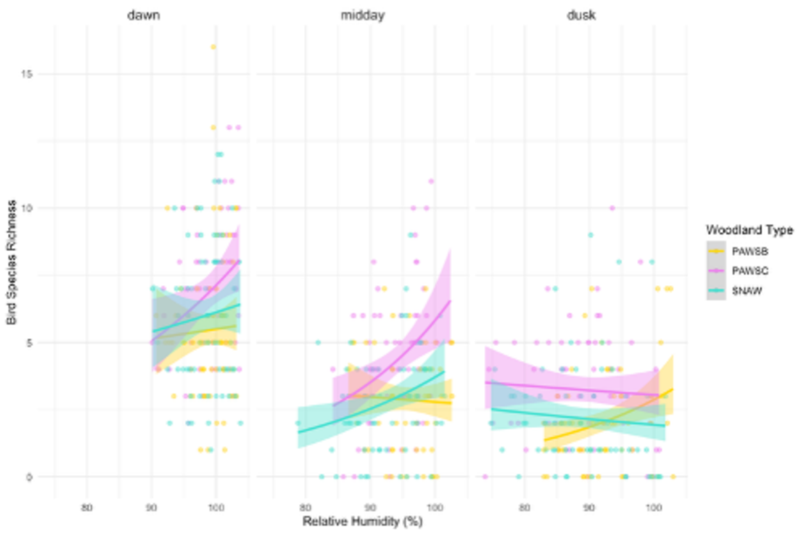


Figure 3. The effects of interactions between relative humidity (%) and woodland type on bird species richness in Leigh Woods at dawn, midday and dusk (n=60 per relationship). Woodland types include Plantations on Ancient Woodland Sites – Broadleaf (PAWSB) in gold, Plantations on Ancient Woodland Sites – Conifer (PAWSC) in purple, and Semi-Natural Ancient Woodland (SNAW) in turquoise. Each panel in the figure focuses on data collected from a specific time point: dawn (0800 hours (hrs)), midday (1200 hrs), and dusk (1600 hrs). Each circular point represents an observed data point, while each regression line reveals the fitted model's predicted relationship between the fixed effects with Poisson error distribution. The shaded regions reflect the model's uncertainty, representing 95% confidence intervals. Created using ggplot224 and R version 4.4.220.



midday and PAWSB at dusk. However, the negative effects detected at dusk in both PAWSC and SNAW reject this hypothesis. Additionally, no significance was detected between PAWS and SNAW post-hoc comparisons, further contradicting the hypothesis of stronger effects for PAWS.

These variable findings highlight the complex temporal interactions between relative humidity and woodland habitat. As global warming reduces relative humidity levels18, the positive effects on bird species richness may become exacerbated, threatening bird species in drier environments. In opposition to temperature-based recommendations, SNAW appears to be the most suitable habitat for relative humidity microrefugia for bird communities in Leigh Woods. Yet, as limited research has focused on the effects of relative humidity in similar ecosystems, conclusions are preliminary.

Furthermore, the accuracy and dispersion of data loggers may have contributed to the reported variation. While the accessibility of remote microclimate sensors continues to rise[16], cost and size reductions may compromise their accuracy[6]. Such inaccuracies may have been exaggerated by the plastic logger housings, which, despite possessing ventilation holes, likely fostered their own microclimatic conditions. Calibrating the loggers within their cases would have advanced the confidence in data collected.

Additionally, the relatively short sampling period (12 days) may limit the generalisability of findings across seasons. In contrast, sampling the microclimate parameters and audio data at the same location was a strength of this investigation, overcoming the critique of insufficient and coarse logger coverage being mismatched with animal data[5, 10]. Although our plot-based sampling technique was deemed ecologically relevant to the mobile avian subjects, it may not have fully captured the fine-scale microclimate variations. In future research, remote animal-borne sensors could be tagged to birds, providing data for the exact microclimates they experience[30]. Additionally, combining longer-term bird distribution and microclimate data with topographic and vegetational information, like three-dimensional woodland structure maps generated via LiDAR technology[31], could overcome poor logger coverage[6] and effectively inform optimal woodland management practices.

Conclusion

Studying microclimate effects on bioindicator species is vital for understanding fine-scale climate change impacts. The effects of interactions between microclimate and woodland type on bird species richness at dawn, midday and dusk were examined, revealing woodland- and time-dependent variation, and providing partial support for the hypotheses. With increasing early-morning temperatures, PAWS may be more beneficial for bird species conservation than SNAW in Bristol's Leigh Woods. In contrast, SNAW is suggested to provide improved relative humidity microrefugia; however, supporting research is limited. The variability detected restricts comprehensive and generalisable conclusions, indicating the need to acknowledge the potential influences of microclimate logger inaccuracies and coverage, and seasonality on findings.

This investigation uniquely integrates microclimate and acoustic biodiversity data to assess bird species richness, providing preliminary insight into microclimate and woodland type effects on bird populations in a managed UK woodland. Amid the ever-growing threats of climate change, investigations integrating microclimate and habitat data, time-series analysis and bird species-specific trends are vital for guiding optimal woodland bird conservation strategies.

Meet the Author

Charlotte Risbey is a final-year BSc Biology undergraduate student at the University of Bristol, with a particular interest in ecosystem responses to land-use and climate change, and the role of conservation practices in mitigating anthropogenic impacts. In the 6th BILT Student Research Journal, she has contributed two papers—a literature review evaluating the effectiveness of wildflower strips for insect pollination services in England, and a research paper investigating the impacts of microclimate and woodland type on bird species richness in Leigh Woods. After graduation, she will continue to pursue these interests by undertaking a Master of Research in Geography at the University of St Andrews.

Subject Business Studies

Subject’s Foreword

At the heart of today’s most significant global shifts are crucial business decisions. This year’s Business Studies section reflects that reality, presenting research that engages directly with these complex challenges. From global supply chain disruptions to evolving cryptocurrency regulations, the papers offer analytical depth and practical relevance. They are both problem-focused and opportunity-driven, providing insight into a rapidly changing world.

This publication would not have been possible without the dedication of our peer reviewers, whose evaluations ensured academic excellence. We are also grateful to Editor-in-Chief Jay Liu, Deputy Editor-in-Chief Lilian Sudi, and the authors for their resilience and commitment throughout the revision process.

To our readers: these selected papers highlight the intellectual rigour and curiosity of our student community and reaffirm the role of business research in shaping informed, strategic responses to real-world challenges. We hope they inspire continued reflection, inquiry, and action within the evolving landscape of Business Studies.

Netra Domewale, Subject Editor (Business Studies)
Sharan Khemlani, Deputy Subject Editor (Business Studies)

Meet Netra Domewale

Netra is pursuing a master’s in International Business and Global Strategy at the University of Bristol. With a civil engineering background, she approaches complex problems with structure and creativity. Passionate about global challenges and growth strategies, she has led relief efforts in Indian villages and advised Indonesian micro-entrepreneurs during crises. Through reflective blogging, she explores purpose-driven living and envisions people-first businesses where invisible voices are heard and performance aligns with purpose.

Meet Sharan Khemlani

Sharan Khemlani is an MSc student in Economics, Finance and Management at the University of Bristol, where she also represents her course cohort. With a background in business and finance, she brings practical insight to her role with the Student Research Journal, focusing on organisational behaviour, innovation, and HR. She’s actively involved in inclusion work across the university as a Race Inclusion Advocate and Future Research Leader, supporting efforts to amplify underrepresented voices. Recently elected as the next Postgraduate Education Officer at Bristol SU, Sharan is passionate about creating a more inclusive, engaging, and student-led research environment.

The Impact of the 2021 Cryptocurrency Ban in China: An Event Study Analysis

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Abstract

This study examines the market impact of China's comprehensive cryptocurrency ban announced in May 2021, employing an event study methodology. The investigation is motivated by the need to understand how major regulatory interventions affect cryptocurrency markets, given their growing significance in the global financial ecosystem. Using daily price data for Bitcoin and Ethereum, we analyze abnormal returns (AR) and cumulative abnormal returns (CAR) around the announcement date. The analysis reveals significant negative market reactions, with Bitcoin experiencing a CAR of -70% and Ethereum -87% during the 30-day post-event window. Our findings suggest that this ban had a more severe and persistent impact compared to previous regulatory actions, reflecting the market's heightened sensitivity to comprehensive regulatory measures. The results demonstrate the substantial influence of major regulatory interventions on cryptocurrency market stability and provide important implications for policymakers considering cryptocurrency regulations. Furthermore, the study highlights how regulatory actions in one jurisdiction can generate significant spillover effects across global financial markets.

Keywords: Cryptocurrency Regulation, Event Study, Bitcoin, Ethereum, China, Market Reaction

1. Introduction

Since the launch of Bitcoin in 2008, the cryptocurrency industry has developed rapidly, attracting substantial attention as a digital alternative to traditional assets (Urquhart, 2016). Cryptocurrencies are complex peer-to-peer digital currency systems which allow investors to conduct direct internet transactions without going through financial institutions (Nakamoto, 2008). The transparency, speed of transactions, low transaction costs, and trading in unregulated systems have made them popular among certain investor groups (Blau, 2017; Zhang & Gregoriou, 2020).

Due to the unique decentralized nature of cryptocurrencies, governments worldwide have been cautious in their regulatory approaches, with varying attitudes and frameworks. While some countries have embraced cryptocurrencies with supportive regulations, others have taken restrictive stances. China has been particularly stringent in its approach to cryptocurrency regulation. As the world's second-largest economy and once the largest Bitcoin trading market (Riska Dwi & Nadia, 2018; Duggan, 2020), China's regulatory decisions have significant implications for global cryptocurrency markets.

China's regulatory approach to cryptocurrencies has evolved through several key phases (Chohan, 2019). In December 2013, the Chinese government issued its first significant regulatory measure with "The People's Bank of China, along with Five Ministries, issues a Notice on preventing Bitcoin-Related Risks" which categorized Bitcoin as a virtual commodity rather than a currency and prohibited financial institutions from engaging in Bitcoin-related activities. (People’s Bank of China, 2013). This was followed in September 2017 by the "Announcement of Seven Ministries on Preventing the Risks of Token," which banned Initial Coin Offerings (ICOs) and cryptocurrency-to-fiat exchanges (People's Bank of China, 2017).

The most comprehensive measure came on May 18, 2021, with the "Announcement on Preventing the Risks of Speculation in Virtual Currency Trading" issued by the People's Bank of China (People's Bank of China, 2021). This announcement marked a significant escalation in China's regulatory stance, declaring all cryptocurrency-related business activities illegal and prohibiting mining activities within mainland China. This comprehensive ban represents China's most forceful attempt to curtail cryptocurrency use and trading within its jurisdiction.

Understanding the impact of such major regulatory announcements on cryptocurrency markets is crucial for several reasons. First, it provides insights into market efficiency and information transmission in the rapidly evolving cryptocurrency ecosystem. Second, it offers valuable empirical evidence on the effectiveness of regulatory interventions in digital asset markets. Third, it helps investors and policymakers understand the potential consequences of similar regulatory actions in other jurisdictions.

Building on previous research that has examined the effects of regulatory announcements on cryptocurrency prices (Chohan, 2019; Shanaev et al., 2020; Zhang & Gregoriou, 2020), this study focuses specifically on China's 2021 comprehensive ban. We employ an event study methodology to analyze how this regulatory intervention affected the prices of two major cryptocurrencies: Bitcoin and Ethereum. By quantifying the abnormal returns and cumulative abnormal returns around the announcement date, we aim to provide a detailed assessment of the market's reaction to this significant regulatory event.

The remainder of this paper is organised as follows: Section 2 reviews the relevant literature on cryptocurrency regulation and market reactions. Section 3 describes the data and methodology employed in this study. Section 4 presents the empirical results and discusses their implications. Finally, Section 5 concludes with a summary of key findings, global market implications, policy recommendations, and suggestions for future research.

2. Literature Review

2.1 Global Regulatory Environment of Cryptocurrencies

The regulatory landscape for cryptocurrencies varies significantly across countries, reflecting different approaches to balancing innovation and risk management. El Salvador made history in 2021 by becoming the first country to recognize Bitcoin as legal tender, followed by the Central African Republic in 2022 (Alvarez et al., 2023). Several countries, including Switzerland, Singapore, and Malta, have stablished specialized regulatory frameworks to attract cryptocurrency-related businesses (Blandin et al., 2019). Meanwhile, the United States, Japan, Canada, Australia, and several European nations have endeavored to integrate cryptocurrencies within their existing financial regulatory systems (Houben & Snyers, 2018).

In contrast, some countries have adopted prohibitive approaches. China's stance has been particularly stringent, with a series of increasingly restrictive measures culminating in the comprehensive ban of 2021 (Chao, 2022). India has shown fluctuating regulatory positions, initially banning cryptocurrency services in 2018, having this overturned by the Supreme Court in 2020, then introducing the Cryptocurrency and Regulation of Official Digital Currency Bill in 2021 (Yadav, 2021). Other countries with restrictive approaches include Bolivia, Pakistan, Nigeria, and Turkey (Girasa, 2023; Ali et al., 2021; Okpalaojiego, 2021; Yılmaz, 2022). The Figure 1 shows the current global crypto regulations status (The Law Library of Congress, 2021).

2.2 Regulatory Impact on Cryptocurrency Markets

Several studies have examined the impact of regulatory announcements on cryptocurrency markets. Chohan (2019) found that negative policy announcements typically depress cryptocurrency prices, while supportive policies tend to boost prices, indicating effective policy transmission in these markets. Similarly, Shanaev et al. (2020) observed that cryptocurrency policy announcements from major countries cause significant market reactions, with negative news having a greater impact.

Focusing specifically on China's regulatory actions, Zhang & Gregoriou (2020) studied the 2017 ICO ban and found sharp price retractions following the policy announcement, though the impact diminished over time. Griffith & Clancey-Shang (2023) compared the effects of the 2017 and 2021 bans, concluding that the latter had a more significant impact on cryptocurrency markets.

Research by Su et al. (2023) documented strong correlations between abnormal returns and the cryptocurrency market following regulatory events. Chen & Liu (2022) found that negative policy announcements led to deteriorating market sentiment, amplifying abnormal price volatility, though they also noted that China's cryptocurrency trading restrictions alone were insufficient for comprehensive market control.

Following China's bans, significant market adjustments occurred. After the 2017 ban, Chinese exchanges like Huobi rapidly moved operations overseas to avoid compliance risks (Rapoza, 2017). The 2021 mining ban led to a significant shift of mining activities to Kazakhstan and the United States, increasing mining costs and carbon emissions (Griffith & Clancey-Shang, 2023).

2.3 Regulatory Effect on Cryptocurrency Development

From a broader perspective, cryptocurrency regulations represent an attempt to balance innovation with stability. Moderate regulation can help purify market ecology, enhance investor confidence, and promote industry maturity (Cumming et al., 2019). However, strict regulatory constraints might stifle innovation, distort resource allocation, and exacerbate market segmentation (Auer & Claessens, 2021). Peng (2023) found that regulatory uncertainty reduces cryptocurrency investment, highlighting the "double-edged sword" effect of regulatory policies.

The decentralized nature of cryptocurrencies limits the effectiveness of single-country regulation, raising important questions about balancing national sovereignty with market autonomy (Uyumaz & Woldemaryam, 2023). When comparing regulatory approaches across different regions, geographical and cultural factors appear to influence policy decisions. Asian countries like Japan and South Korea have implemented more structured frameworks, while European nations have generally taken a more balanced approach (Nabilou, 2019; Pieters & Vivanco, 2017).

The contrast between North American and Eastern Asian regulatory philosophies is particularly notable. The United States has primarily focused on securities law compliance and consumer protection, whereas China prioritized financial stability and capital control concerns (Campbell-Verduyn & Hütten, 2019). These regional variations in regulatory approach contribute to market fragmentation and create arbitrage opportunities across jurisdictions.

Establishing a regulatory framework that balances efficiency and inclusiveness remains a challenge for both academia and industry. As cryptocurrency markets mature, the development of international coordination mechanisms will be crucial for addressing the inherent cross-border nature of these digital assets (Zetzsche et al., 2020).

3. Data and Methodology

3.1 Event Study Method

This study employs the event study methodology to examine the impact of China's 2021 cryptocurrency ban on Bitcoin and Ethereum prices. The event study method, derived from the Efficient Market Hypothesis, establishes a statistical relationship between expected market returns and unexpected changes in actual returns, and is used to examine the short-term impact of specific events on asset prices (MacKinlay, 1997).

Cryptocurrencies like Bitcoin and Ethereum have formed efficient and liquid global trading markets, with price movements responding to new information in a timely manner, which meets the basic requirements of the efficient market hypothesis (Akyildirim et al., 2020; Fassas et al., 2020; Zhang & Gregoriou, 2020). Additionally, major regulatory policies such as bans represent unexpected events with clear temporal anchors, making it possible to identify and measure price reactions (Auer & Claessens, 2018; Shanaev et al., 2020).

3.2 Event Selection

This study focuses on the "Announcement on Preventing the Risks of Speculation in Virtual Currency Trading" issued on May 18, 2021, by the People's Bank of China. This announcement declared all business activities related to virtual currencies illegal financial activities and prohibited cryptocurrency mining activities within mainland China, marking the most comprehensive cryptocurrency ban in China's regulatory history.

3.3 Event Window and Data

To comprehensively evaluate market reactions before and after the announcement, we establish three windows:

Estimation Window (-100, -10): Covers trading days from 100 days before to 10 days before the event date (February 7, 2021, to May 8, 2021). This window is used to estimate normal expected returns.

Event Window (-9, +9): Includes 19 trading days from 9 days before to 9 days after the event date (May 9, 2021, to May 28, 2021). This is the core research interval for examining immediate market reactions.

Post-Event Window (+10, +30): Covers the period from 10 to 30 days after the event date (May 29, 2021, to June 17, 2021), allowing us to examine longer-term impacts.

We obtain daily closing price data for Bitcoin and Ethereum from CoinMarketCap.com, a widely recognized authoritative source for cryptocurrency data (White, 2015). As of March 2024, Bitcoin's market capitalization stood at $1,371 billion USD (approximately 52% of the total cryptocurrency market), while Ethereum's was $421 billion USD (approximately 16% of the market) (CoinMarketCap.com, 2024).

The illustration of the windows of event timeline sees on below figure.

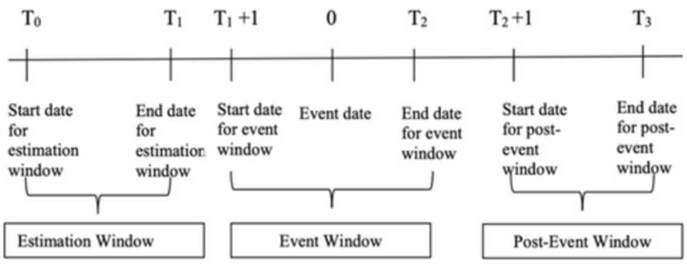

Figure 2. Event Study Timeline Illustration

3.4 Research Model

Following established methodology (Hashemi Joo et al., 2020), daily returns are calculated by taking the first difference in the logarithm of daily closing prices:

$$R_t = \ln(P_t) - \ln(P_t - 1)$$

Cumulative Abnormal Returns (CAR) represent the sum of all abnormal returns over a specified period, providing insights into the aggregate impact of an event over time. A negative AR indicates that the actual return was lower than expected, suggesting a negative market reaction, while a positive AR indicates the opposite.

The Abnormal Return, Expected Return, and Cumulative Abnormal Return are expressed as: where AR_{it} is the abnormal return at day t, R_{it} is the daily return of crypto on day t and $E(R_{it})$ is the expected daily market return. $[t_1, t_2]$ is the event

$$AR_{it} = R_{it} - E(R_{it})$$

$$E(R_{it}) = \frac{1}{N} \sum_{t=T_0+1}^{T_1} R_{it}$$

$$CAR = \sum_{t=t_1}^{t_2} AR_{it}$$

window interval. In this study, the event window is [-9, +9], the post event window is [+10, +30].

To test the significance of abnormal returns, we use the parametric tests proposed by Serra (2007). The standardized statistic is:

$$AR^*_{it} = \frac{AR_{it}}{S(AR_{it})}$$

where $ARit$ is defined above, $S(AR_{it})$ is the standard deviation of the residuals, and $AR_{it}\star$ is the standardizing abnormal returns. Therefore, to test if there are abnormal returns before and after the event, we propose the research hypothesis:

N_0: Abnormal return is zero

N_1: The abnormal return is not zero

Under the null hypothesis, assuming that the error term follows a normal distribution the, $AR_t\star$ statistics obey the t-distribution with degree of freedom T_{i-2}. It's important to acknowledge that this methodology has certain limitations. The Constant Mean Return Model assumes stable expected returns based on historical data, which may not fully account for changes in market conditions unrelated to the event being studied. To address these limitations, we control for general market trends by focusing specifically on the deviation from expected returns and by examining two cryptocurrencies to identify consistent patterns.

4. Empirical Results and Discussion

4.1 Market Reaction to the 2021 Cryptocurrency Ban

Based on the mean return in the estimation window, the normal expected returns for Bitcoin and Ethereum were approximately 0.004 and 0.009, respectively. The return models for the 2021 event can be expressed as:

$$R_{t,BTC} = 0.004 + u_{t,BTC}$$

$$R_{t,ETH} = 0.009 + u_{t,ETH}$$

Where R_{3t} is the return of the crypto in day t on the third event, the abnormal return AR_{3t} can be expressed as u_{3t} in the event window. The standardised abnormal returns are obtained the same as:

$$AR^*_{3t} = \frac{u_{3t}}{S(u_{3t})}$$

where AR_{3t} is defined above, $S(u_{3t})$ is the standard deviation of the residuals u_{3t}, and $AR_{3t}\star$ is the standardising abnormal returns.

The results of the $AR_{3t}\star$ statistics, Return, Abnormal Return and Cumulative Abnormal Returns are shown in the table in Appendix. The AR and CAR Graphs see on Figure 3,4 below.

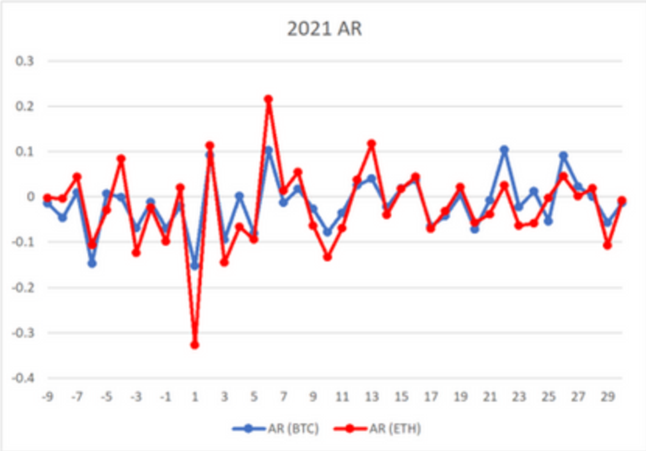

Figure 3. Abnormal Returns Graphs in 2021

Figure 4. Cumulative Abnormal Returns Graphs in 2021

Our analysis reveals significant market reactions to China's 2021 cryptocurrency regulation. Six days before the event date, Bitcoin showed a negative AR of -15% with a statistically significant ARBTC⋆ of -2.217 at the 10% significance level. Bitcoin also experienced negative ARs of -7% three days before and one day before the event. These patterns suggest information leakage and negative market expectations prior to the official announcement.

The first day after the event showed an AR_{BTC}⋆ of -15% with a significantly negative AR_{BTC}⋆ of -2.294.

Additional negative AR_{BTC}⋆ values of -9% and -8% occurred on days 3 and 5 after the event, indicating the policy's negative impact on Bitcoin prices. Interestingly, temporary positive rebounds occurred on the second and sixth days after the event, with AR_{BTC}⋆ values of +9% and +10%, respectively. This pattern of sharp declines followed by partial rebounds is consistent with previous studies (Su et al., 2023).

Ethereum displayed similar patterns but with greater sensitivity to the regulatory announcement. The CARs for both cryptocurrencies showed continuous downward trends during and after the event window, demonstrating the regulation's long-term negative impact. Bitcoin's CAR reached its lowest value of -70% on day 21, while Ethereum's CAR continued to decline throughout the post-event window, reaching -87% by day 30.

Comparing these results to the -48% (BTC) and -60% (ETH) CARs observed after the 2017 ban, our findings confirm that the 2021 ban had a more drastic impact on the market, consistent with Griffith & Clancey-Shang (2023).

4.2 Comparison with Previous Regulatory Events

When comparing market reactions across China's three major cryptocurrency bans (2013, 2017, and 2021), our findings reveal an interesting progression. The 2013 ban triggered a significant negative impact on Bitcoin prices, with a dramatic CAR of -90% thirteen days after the announcement before stabilizing. The 2017 ban generated a milder response compared to both the 2013 and 2021 events, with prices entering a relatively stable range after a 10-day decline.

The 2021 ban, which is the focus of this study, elicited the most intense and persistent market reaction. Unlike previous events where prices tended to stabilize or partially recover within a relatively short timeframe, the CARs for both Bitcoin and Ethereum continued to decline for a full month following the 2021 announcement. This sustained negative trajectory suggests that market participants viewed this regulatory action as substantially more impactful than previous measures.Several factors likely contributed to the market's severe response to the 2021 ban:

Comprehensive scope: The 2021 ban was more comprehensive and stringent than previous measures, explicitly declaring all cryptocurrency-related business activities illegal and prohibiting mining activities throughout mainland China.

Evolving market context: By 2021, the crypto-currency ecosystem had matured significantly, with greater institutional participation and mainstream adoption. This evolution may have made the market more sensitive to major regulatory interventions.

Global regulatory climate: The 2021 ban occurred amidst increasing scrutiny of cryptocurrencies by regulators worldwide, potentially amplifying concerns about a broader regulatory crackdown.

Market capitalization: The cryptocurrency market had grown substantially by 2021, with much higher valuations and greater economic significance than during previous regulatory events, potentially magnifying the impact of regulatory changes.

Mining significance: China was the dominant global center for cryptocurrency mining before the 2021 ban. The prohibition of mining activities represented a fundamental shift in the operational landscape for cryptocurrencies, particularly Bitcoin.

Our analysis also reveals that Ethereum consistently exhibited greater volatility and sensitivity to regulatory news compared to Bitcoin. This pattern was evident across all three regulatory events but was most pronounced in response to the 2021 ban. This difference may reflect Ethereum's broader use cases beyond simple value storage, making it potentially more vulnerable to regulatory restrictions on cryptocurrency applications and development activities.

5. Conclusion

This study examined the impact of China's comprehensive cryptocurrency ban announced in May 2021 on Bitcoin and Ethereum prices using an event study methodology. Our findings reveal significant negative market reactions to this regulatory intervention, with Bitcoin experiencing a CAR of -70% by day 21 post-announcement, while Ethereum showed an even more dramatic CAR of -87% by day 30. These figures substantially exceed the market impacts observed following earlier regulatory interventions in 2013 and 2017.

Our analysis detected significant negative abnormal returns in the days preceding the official announcement, suggesting potential information leakage or market anticipation. We also observed that Ethereum consistently displayed greater sensitivity to regulatory news than Bitcoin, experiencing more extreme price fluctuations in response to the 2021 ban.

China's 2021 cryptocurrency ban had far-reaching implications beyond its borders. Prior to the ban, China dominated global Bitcoin mining with approximately 65% of the network's hash rate.

Following the ban, mining activities dramatically shifted to other countries, particularly the United States, Kazakhstan, and Russia, fundamentally altering the geographic concentration of mining power. The ban also led to significant shifts in global trading patterns, with formerly China-focused exchanges establishing stronger presences in other Asian markets.

Interestingly, we observed temporary increases in the correlat-ion between cryptocurrency returns and traditional financial assets in the aftermath of the ban, suggesting that major regulatory shocks can trigger changes in the relationship between cryptocurrencies and conventional asset classes. China's decisive action also appears to have emboldened regulators in other jurisdictions, as evidenced by an increased frequency of cryptocurrency-related regulatory announcements globally in the following six months.

Based on our findings, policymakers considering cryptocurren-cy regulations should prioritize transparent communication and gradual implementation to mitigate market disruptions. Rather than comprehensive bans, a targeted approach focusing on specific risk areas may achieve regulatory objectives while minimizing market disruptions. Given the cross-border nature of cryptocurrency markets, international regulatory coordination is essential to prevent regulatory arbitrage.

While this study provides valuable insights, several limitations should be acknowledged. The event study methodology has inherent constraints when applied to highly volatile markets, and cryptocurrency prices are influenced by numerous variables that are challenging to isolate completely. Our study focused on Bitcoin and Ethereum, and the impact on smaller cryptocurrencies may differ. Additionally, while we examined a 30-day post-event window, the longer-term impacts may take months or years to fully materialize.

Future research could extend this analysis to a broader range of cryptocurrencies, employ alternative methodologies, and examine longer-term impacts. Comparative studies of regulatory approach -es across different jurisdictions could provide further

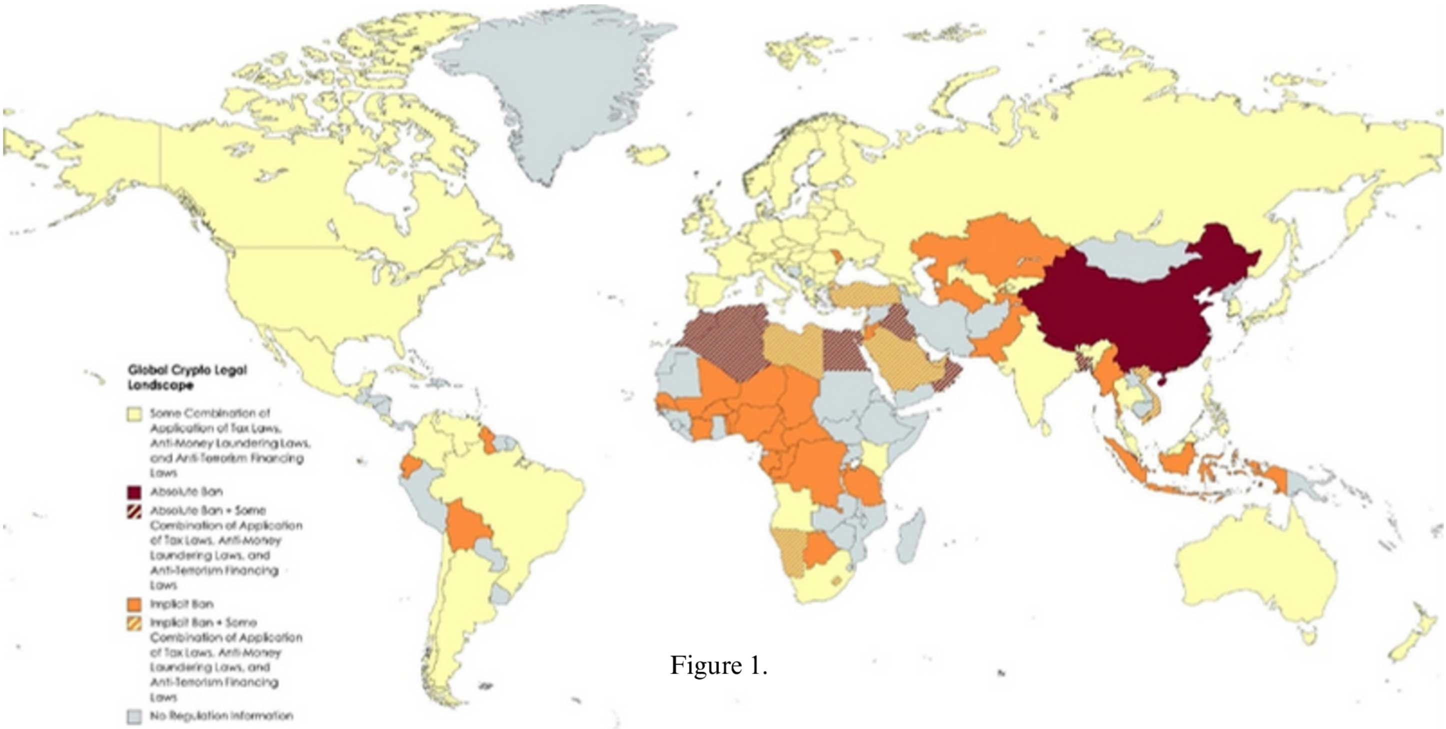

Figure 1.

insights into optimal regulatory strategies for the rapidly evolving cryptocurrency ecosystem.

Meet the Author

Pengjian Chen is currently pursuing an MSc in Financial Technology with Data Science at the University of Bristol and has a background in finance. As an Economics Subject Editor for a university student research publication and through internships at commercial banks, Pengjian combines financial knowledge with real world financial markets. His research examines regulatory impacts on cryptocurrency markets, with particular focus on how policy interventions affect market dynamics and investor behavior. This event study analysis of cryptocurrency regulations offers insights for both market participants and policymakers navigating the evolving digital asset landscape. His work contributes to the understanding of cross-border regulatory effects.

Subject Chemistry and Medicine

Subject's Foreword

The Chemistry and Medicine board received an overwhelming thirty submissions this year, which is a true testament to this University's commitment to outstanding research and education. We are very pleased with the calibre of work we have had the opportunity to review and are proud to present this year's selection of works to our readers. These selected research articles reflect an emphasis on interdisciplinary and innovative ideas that utilize emerging technologies to seek out new solutions or to shed new light on issues to improve patient welfare and health outcomes. As such, we hope you find this research as enlightening as we have. We would like to thank our wonderful peer reviewers who shared their expertise during the review process, as well as our Editor-in-Chief and Deputy Editor-in-Chief who do so much to curate this knowledge into one journal. Lastly, we thank the authors for sharing their findings with the greater scientific community, and we thank our readers for supporting student research.

Samantha Siomko, Subject Editor (Chemistry and Medicine)
Wiam Mohammad, Deputy Subject Editor (Chemistry and Medicine)

Meet Samantha Siomko

Samantha Siomko is currently completing a PhD at the Bristol Veterinary School investigating the implications of the gut microbiome in defence against bacterial pathogens in calves and piglets. She has previously published work on microbiome-mediated immunity in amphibians, and she has worked globally on projects at the intersection of animal health, infectious disease, and ecology. When not in the lab, she enjoys finding adventures in nature, travel, and books, and she never misses an opportunity to pet a dog. Samantha believes in the importance of science communication and values collaborative growth with fellow early-career researchers.

Meet Wiam Mohammad

Wiam Mohammad is a third-year Dental Surgery student with a strong passion for medical research and innovation. She currently serves as Deputy Subject Editor for Chemistry and Medicine, where she explores the art of assembling high-quality scientific literature. Her work reflects a keen interest in the intersection of dentistry, systemic health, and evidence-based innovation. This year, she was awarded the BILT Award for Best Research in Innovation at the Student Research Festival. She is especially passionate about making research accessible, relevant, and impactful—both in the clinic and beyond.

Exploring the Impact of Social Connection on Patient Wellbeing

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Abstract

Around a third of people in industrialised countries are affected by loneliness. This has been shown to adversely affect health. Amid rapid technological advancements, recognising the importance of human connection is pivotal in the medical profession. This review explores the impact of social connection on patient wellbeing, suggesting improvements to patient-centred care. Literature was searched by looking for keywords in titles and abstracts: ("Social connection" OR "Human connection") AND ("Wellbeing") AND ("Hospital" OR "Patient"). Papers selected required sufficient relevancy to the topic and collection of empirical data from a patient population.

Patient-HCP relationships foster confidence and emotional validation within the patient, but can also harm patient well-being. During the COVID-19 pandemic, personal protective equipment limited the development of patient-HCP relationships, leading to reported feelings of isolation, evidencing the importance of building rapport. Additionally, technology could connect inpatients with loved ones, improving their health outcomes. Collaborative models of care can connect patients with similar experiences, showing to be empowering. Review findings indicate that social connection generally enhances patient well-being and may guide approaches to improve care. Investigating the correlation between socialisation and wellbeing, as well as the optimal balance between connection and privacy in long-stay care settings, could benefit patient care.

Keywords: Social Connection, Human Connection, Well-being, Patient

Introduction

Social connection is an umbrella term which encompasses the structure, functions, and quality of social relationships[1]. For patients, this could involve social interactions with healthcare professionals (HCPs), involvement of loved ones in their healthcare experience, or connecting with fellow patients. In an age where advanced technologies may outperform humans in many aspects, as can be seen in dermatology[2], it is necessary to assess the importance of human connection in healthcare.

The World Health Organisation defines wellbeing as "a positive state experienced by individuals" which "encompasses quality of life and the ability of people and societies to contribute to the world with a sense of meaning and purpose"[3], thus encapsulating the physical, psychological, emotional, and social aspects of one's being. This holistic view on medicine is important as these different components of human health are interconnected, so looking after one aspect may enhance the other aspects of one's health.
Around a third of people in industrialised countries are affected by loneliness; many studies show that loneliness has vastly damaging effects on health[4, 5].

This analysis will evaluate current research, identifying ways in which patients can feel connected and how this affects wellbeing, as well as looking at evidence that technology and human interaction can co-exist within the medical field. Gaining a deeper understanding of the relationship between these two factors may ultimately lead to a more holistic patient–centred approach to care.

Method

Literature was identified using Ovid and PubMed, and a Boolean search was carried out on titles and abstracts using the following key words: ("Social connection" OR "Human connection") AND ("Wellbeing") AND ("Hospital" OR "Patient"). Filters identified articles published in the last 20 years, in the English language, and studying the human subject. Six articles were identified from Ovid and 27 from PubMed. Four duplicates were found, leaving 29 articles. Out of the 29 articles, 11 were relevant to this review. The reasons for exclusion are as follows: nine did not study the relationship between human/social connection and wellbeing; seven did not focus on patients; one was not available for access; and one was a protocol thus no evidence could be provided. Additional literature was found from the reference list of appropriate articles.

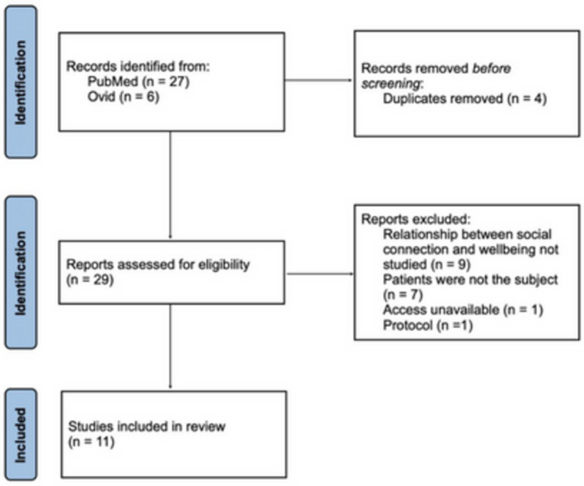


Figure 1: PRISMA flow diagram depicting the selection of literature [6].

Results and Discussion

Four themes were identified: patient-HCP relationship; in the face of COVID-19; technology to connect; and collaborative care models.

Patient-HCP Relationship

Natvik et al.'s study in 2022 highlights the spectrum of effects from different types of HCP interaction on patient wellbeing[7]. In the context of post-bariatric surgery, the responsibility of patients to follow practitioners' lead was heavily emphasised. As there may have been an imbalance in the aspirations of both parties, patients and practitioners tried avoiding conflict which led to greater distance. Despite this human interaction experienced when exchanging information about post-surgical care, some patients still felt disconnected from their HCP. On the other hand, the positive power HCPs may have on how a patient feels can be illustrated when a patient revealed that receiving approval from his doctor made him "feel good" and satisfied with his own health-maintaining endeavours.

Hall et al. carried out a study on women during labour and wrote that positive human connections helped the mother "keep it together" during birth. One participant spoke about a doctor, who she had not known previously but was assisting her birth, looking into her eyes and the participant knew that the doctor was present with her. This connection was described as an anchor, and it empowered her during a challenging time[8]. Despite this, the study noted that the effects of human connection could also detract from confidence, suggesting that not all forms of human connection will be of benefit. This could be seen when HCPs excluded a participant from important conversations, failing to support her agency during her own labour, which led to feelings of isolation and discomfort. The context of this research is critical, as the process of childbirth pushes the boundaries of physical and mental resilience, thus, the effects of human connection may be heightened.

This delicate balance of finding the right level of social connection between patients and their HCPs is echoed in literature. Airosa et al. looked at the impact of connection between nurses and patients via tactile massage[9]. A participant nurse stated that through these massages, "you enter the person's aura or space, and you take part in those feelings", which offered a way to ease the pain and suffering of the patient by enhancing recognition of their emotions. Touch is important as it can play a powerful role in physical and psychological wellbeing [10]. Alternatively, Nan et al. stated that "reduced chat time" was associated with elevated wellbeing for some, suggesting that optimal levels of social connection vary between people and a balance is needed[11]. A separate study found that two-thirds of patients interviewed would prefer to stay in single rooms due to increased comfort and privacy and found that this would outweigh disadvantages[12.] To further improve patient care, additional research, such as using surveys, is required to discover the balance between the need for time alone and social connection especially in long-stay clinical settings.

All studies mentioned thus far are qualitative, which may limit representability due to smaller sample sizes and decreased comparability. However, they capture the diverse subjective experiences of patients in detail.

In the Face of COVID-19

During the years that followed 2020, the COVID-19 pandemic became a major barrier to everyday social interaction[13]. Relevant research conducted during the COVID-19 pandemic is significant as much of the global population experienced sudden social isolation at this time[14], thus the effects of social connection may be more pronounced.

According to a study by Bench et al. on patients recovering from life-threatening COVID-19 infection, human connection was found to be important in recovery. During this time, societal restrictions added to the challenge of recovery, especially as the need for personal protective equipment became a barrier to building trust and rapport within patient-HCP relationships. However, acts of kindness from HCPs resulted in patients feeling cared for as individuals, with eye contact and touch becoming more important[15]. A similar study reinforces that human connection is a likely factor in leading to successful recovery following discharge[16].

Emard et al. carried out a study focusing on cancer patients during COVID-19, for whom social distancing was particularly important, so access to social coping resources was diminished. This study allowed patients to connect virtually during a time of isolation, and findings show that social connection was correlated with improved psychological coping of external stressors[17]. However, no direct causal relationship was established, highlighting the need for future research in studying social connection's direct effect on patient well-being. Confounding factors like pre-existing mental health conditions were not considered, potentially affecting the study's reliability.

Technology to Connect

As seen in Emard et al.'s study design, the COVID-19 pandemic led to increased technology use to improve accessibility for people to stay connected[18.] McEwan et al.'s study in 2022 investigated the effects of active engagement with nature through group online sessions on wellbeing amongst patients with long-COVID, who could also benefit from technology-driven accessibility. These sessions involved "sharing circles" where participants could learn from each other's experiences, allowing the chance for individuals to connect. Compared to the control period, survey results after each session showed statistically significant differences ($p < 0.01$) with a 78% increase in feelings of social connection and a 49% decrease in anxiety[19].

Although increased social connection correlates with improved wellbeing, it remains unclear whether the social connection boosts wellbeing or if individuals with improved wellbeing, in this context due to nature connection, naturally form stronger connections with each other. Direct causation cannot be inferred with certainty. To note, 27% of initial participants dropped out after the control period and thus attrition bias may skew results.

In 2017, Guo et al. studied the use of technology as a means of social connection within palliative care and identified that technology usage allowed patients to feel calmer and overall better[20]. The study noted that 84% of days spent online by participants involved "keeping in touch with someone". A correlation between social connection and improved wellbeing was suggested, though additional statistical analysis is required to quantify the impact. Additionally, through increased connectivity, families of patients could share in important decision making and keep informed about the patient's situation, which can ensure better care. This can be reflected in the implementation of Martha's rule in 2024, which "gives patients and their loved ones the right to request an urgent review of the person in hospital's treatment" and has since seen one in five reviews triggered by this rule leading to potentially life-saving escalation of patient care[21]. Another study by Guo et al. in 2016 emphasised this, with palliative patients and their family members reporting that communication using technology supported the patient's quality of life and care[22]. Again, the use of qualitative data enhanced the ability to understand patient perspectives.

Collaborative Care Models

Collaborative care models (CCMs) are an approach to healthcare which involves patients in each other's health journeys. This is suggested to enhance patient wellbeing as a possible effect of increased social interaction with like-minded patients who have shared experiences.

In 2024, Loy, Prisco and Parikh investigated the impact of shared medical appointments and saw how social connection could improve the patient's experience[23]. Post-programme, patients expressed how their goals and symptoms were adequately addressed, and began implementing positive lifestyle changes in diet, exercise, sleep, and stress management. Use of a control group may make findings from the shared medical appointments group more significant.

Sulaiman et al. explored the role of peer support in mental illness recovery and observed that patients gained a sense of connection with like-minded individuals who empowered each other in their needs, and created a space where patients did not have to worry about stigma but rather could validate each other's experiences[24]. Enhanced social connections were identified to be a major element of recovery for these patients. These feelings of peer empowerment may have a similar positive impact on the patient as that described by Hall et al. regarding the connection between a woman in labour and her HCP. Due to the inclusion criteria, most included studies are based in English-speaking countries, however, this study focused on a Malaysian population, suggesting that the impact of social connection is perhaps not limited by cross-cultural differences. In a similar study by Pinfold et al., social connectedness was discovered to help individuals move on in their recovery journey whilst providing a sense of belonging and meaning to life[25].

Though both peers and HCPs can serve as a source of empowerment for patients, social connection between like-minded patients and may hold a significance that cannot be replicated by HCPs. This could be due to the deeper mutual understanding and compassion derived from their shared experience. In turn, patients may feel more deeply supported by one another. This suggests that by using CCMs, care may become more holistic and patient-centred.

Conclusion

This review suggests that increasing social connectedness can be beneficial for patient population.Relationships built between patients and HCPs play an important role in increasing patient confidence and heightening their sense of emotional emotional validation. During COVID-19, a time of sudden global social isolation, studies found that human connection was important in recovery and improved psychological coping of external factors. Technology could be used to connect patients with others, increasing involvement of families within patient care which largely enhanced care outcomes. Finally, the use of CCMs saw patients feeling empowered, resulting in positive health behaviours and outcomes. Connecting with others who have had shared experiences allowed the patient to feel more personally understood and validated. However, a balance in the range of social connection was important to note, dependent on each individual's social needs.

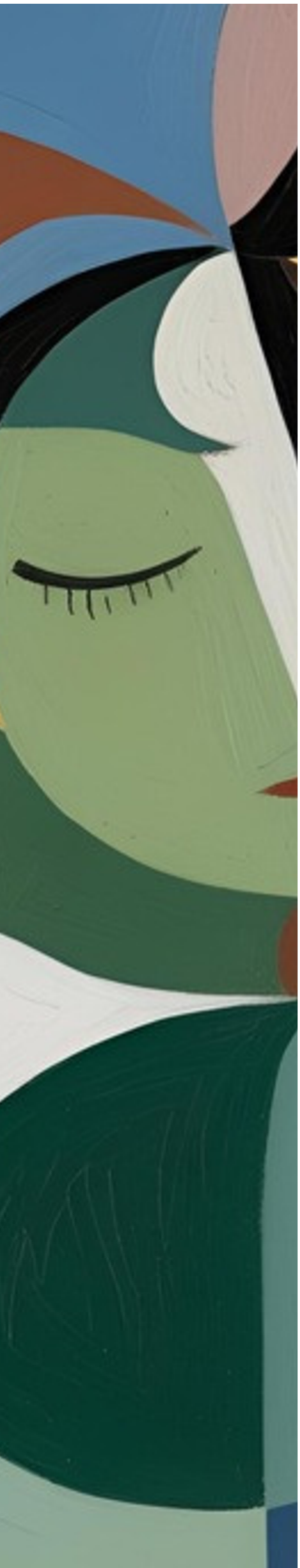
Many different patient populations have been examined in this review, thus substantiating the generalisability of these findings. Going forwards, this review may be used to guide medical practitioners in a more holistic approach to improve patient wellbeing. Systemically, improvements may be seen if more patient support groups in hospitals and community settings are implemented, and if there is increased support for technology use amongst patients in long-stay care settings to connect them to their loved ones. Whilst this study is limited to anecdotal evidence, it could provide an insight into future wellbeing improvement strategies and the importance of accounting for patient heterogeneity in preferences towards building relationships with HCPs.

There is a need to increase research to explore the direct impact of social connection on patient wellbeing. Further research looking into the optimal balance between social connection and privacy in long-stay clinical settings may also benefit future patient care. Additionally, there is space to further explore the effect of personal protective equipment use on how connected a patient may feel during their healthcare experience.

Meet the Author

A second-year Medicine student, Alice wrote this piece following a three-week student-selected component undertaken earlier this year. The project encouraged students to examine wellbeing through fresh perspectives, including a workshop on loneliness and the importance of connection—with oneself and with others. Inspired by these insights, her paper explores the impact of social connection on patient wellbeing, aiming to enhance our understanding of how to optimise patient care.

Subject Economics



Subject's Foreword

The BILT Student Research Journal offers University of Bristol students a platform to refine and publish their academic work. This edition's Economics section features five exceptional papers selected from nearly a dozen submissions. Covering topics from behavioral economics to monetary theory, these studies combine theoretical insight with practical relevance to today's socioeconomic issues.

Our selection prioritized methodological rigor, originality, and contribution to economic discourse. Whether you're an economics enthusiast or drawn to historical or theoretical angles, these papers offer valuable perspectives.

We congratulate the authors on their dedication and engagement with the peer review process, which elevated the quality of their work. We also recognize the high caliber of submissions not included due to space limitations. Lastly, we thank our peer reviewers for their thoughtful feedback and commitment to academic excellence.

Pengjian Chen, Subject Editor (Economics)
Jakub Wilczewski, Deputy Subject Editor (Economics)

Meet Pengjian Chen

Pengjian Chen currently works as the Economics Subject Editor in BILT Student Research Journal at the University of Bristol, where he is dedicated to promoting the publication and exchange of high-quality student economic research. In this capacity, he oversees the solicitation of manuscripts, manages the peer review process, and coordinates publication workflows, working closely with the editorial team to ensure the journal consistently maintains rigorous academic standards. With a background in finance and currently pursuing a Master in Fintech with Data Science, Pengjian utilizes a global perspective to assess economic issues. Throughout his career, he has not only acquired practical experience in the financial sector but has also made contributions to academic development epically in crypto market and policy research. His proficient in multiple languages and has cross-cultural communication skills, which helps him to devote himself to international academic exchanges and research in global financial markets.

Meet Jakub Wilczewski

Jakub Wilczewski is a second-year economics and management student (BSc) originally from Poland but moved to the United Kingdom when he was two years old. He has served on the governing body of a local secondary school for over a year. He has also won the economics debate competition hosted by the School of Economics and has been accepted into Yonsei University in South Korea for his study abroad year. In his spare time, he enjoys playing city builder and management games, as well as practicing his juggling skills and improving his sudoku completion time.

The Sleep-Income Paradox: Balancing Health and Earnings

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Abstract
Sleep is essential for health and well-being, yet its economic impact remains unclear. This study examines the relationship between sleep duration and income, incorporating economic and medical perspectives. In economic theories, increased sleep reduces available working hours, potentially leading to lower income. In contrast, the medical perspective suggests that sufficient sleep enhances productivity, which should translate into higher earnings. Using survey data on sleep patterns, working hours, income levels, and demographic factors—analyzed through regression models—this study initially finds a negative correlation between sleep duration and income when working hours are not controlled, with an additional hour of sleep per week associated with a 1.9% wage decrease. However, after controlling for working hours, this linear relationship disappears, revealing a significant nonlinear pattern. The results indicate that while increased sleep negatively affects income primarily through reduced working hours, moderate sleep (around 7.8 hours per night) enhances productivity and income when working hours remain constant. Beyond this optimal range, excessive sleep may have a detrimental impact on performance.

Keywords: Income, Productivity, Empirical Study, Work-life Balance, Labor Economics

Introduction
Sleep is a universal necessity to which all individuals must allocate time. A key question in labor economics concerns how sleep patterns might influence an individual's labor market outcomes, particularly in terms of productivity and earnings. Existing research has explored the relationship between sleep duration and worker compensation. According to the neoclassical model of labor-leisure choice, allocating more time to sleep reduces the number of waking hours available for labor. Unless individuals exhibit an exceptionally strong preference for consumption, the model predicts that increased sleep will generally be associated with reduced labor supply, leading to lower earnings. Consequently, this framework suggests a negative correlation between sleep duration and wages.

In contrast to the predictions derived from economic theory, findings from medical research frequently indicate a positive association between sleep and worker productivity. Adequate sleep is widely regarded as essential for optimal cognitive functioning and efficiency, suggesting a potentially beneficial link between sleep duration and labour market outcomes. Early contributions in this area, such as the work of James et al. (1983), provided some of the first statistical evidence supporting a positive relationship between sleep and wages. More recently, Gibson and Shrader (2014) estimated the causal effect of sleep on earnings, reporting that an additional hour of sleep is associated with an average wage premium of approximately 16%.

This study investigates the relationship between sleep and income to evaluate the validity of the theoretical perspectives outlined above, I employed survey data provided by the University of Bristol for the course EFIM20010 Applied Quantitative Research Methods. The dataset includes information on individuals' sleep patterns, working hours, and income levels, as well as demographic variables such as age, gender, and education. In the initial regression analysis, a negative correlation between sleep duration and income was observed when working hours were not controlled for. This negative association remained statistically significant even after adjusting for age, gender, and education, indicating that an additional hour of sleep per week was associated with a 1.9% reduction in wages. However, once working hours were accounted for, the linear relationship disappeared, revealing instead a significant non-linear association.

In conclusion, the findings suggest that the predominant effect of increased sleep on income is negative, primarily due to its association with reduced working hours—consistent with the economic perspective. However, there is also partial support for the medical viewpoint: when working hours are held constant, increased sleep within an optimal range (approximately 7.8 hours per night) appears to enhance productivity and is associated with higher wages. Conversely, excessive sleep beyond this threshold may negatively impact performance.

Data Summary

Cross-sectional data from 532 randomly selected participants are used to examine the association between annual income (variable: salary) and hours of sleep per night, measured weekly (variable: sleep). Nineteen observations with zero salary values—potentially due to non-working participants or missing data—were excluded from the regression analysis to better align with the research objectives. The control variables include age, education, gender (a dummy variable coded as male), and minutes worked per week (variable: totwrk). The descriptive statistics are summarized in Table 1.

Table 1: Descriptive Statistics

	salary	sleep	age	educ	male	totwrk
Obs	532.000	532.000	532.000	532.000	532.000	532.000
Mean	9,995.563	54.324	38.318	12.731	0.551	2,160.545
Median	8,163.549	54.192	36.000	12.000	1.000	2,300.000
SD	9,245.442	7.183	11.233	2.694	0.498	933.405
Min	-	24.750	23.000	1.000	-	-
Max	106,882.700	78.250	65.000	17.000	1.000	6,415.000

Table 1 shows that salary exhibits the highest dispersion relative to its mean, while sleep has a much lower dispersion, with a standard deviation of 7.183 and a mean of 54.324. This indicates that while individuals' sleep duration varies, its variation is relatively small compared to the significant variation in earnings. The dispersion of totwrk is moderate, with a standard deviation of 933.405 and a mean of 2,160.545. Additionally, the mean salary is substantially higher than the median, suggesting a skewed distribution. Taking the logarithm of salary can help normalize its distribution. The visual distributions of the main variables are illustrated in Figure 1 below.

Table 2: Correlation Coefficients

	salary	sleep	age	educ	male	totwrk
salary	1.000					
sleep	-0.187	1.000				
age	0.068	0.053	1.000			
educ	0.194	-0.064	-0.250	1.000		
male	0.418	-0.086	-0.031	0.050	1.000	
totwrk	0.508	-0.324	-0.040	-0.009	0.403	1.000

Figure 1: Distributions of the main variables

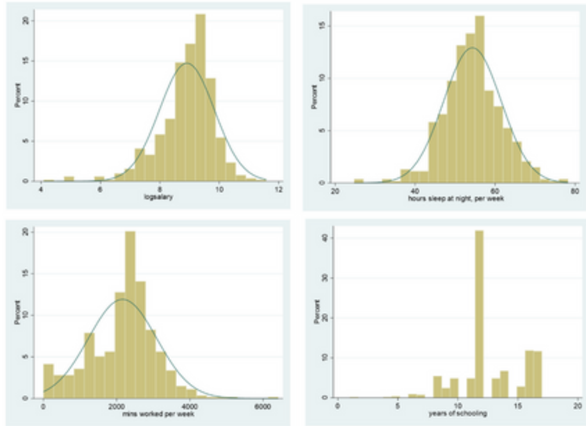
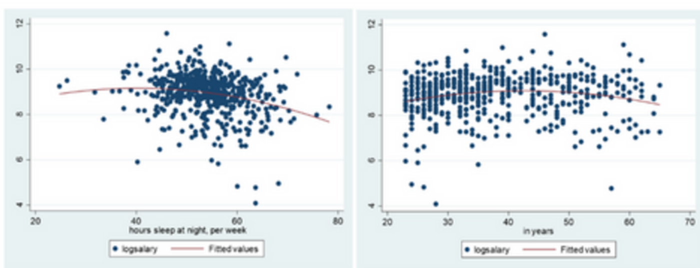


Figure 1 presents the histograms of four variables: *logsalary, totwrk, sleep,* and *education*. The distributions of *logsalary* and *sleep* are approximately normal, while the distribution of *totwrk* is skewed with a high peak, indicating that most individuals work between 2,000 and 2,500 minutes per week. The distribution of *education* reveals that approximately 42% of respondents have 12 years of schooling, representing a large proportion of individuals who entered the workforce with a high school diploma.

According to labor economists, more sleep reduces working hours and, consequently, salary. Table 2 reports the correlation coefficients between the variables, and the results align with this inference: sleep is negatively correlated with salary (-0.187) and totwrk (-0.324). However, this does not contradict medical research suggesting a positive effect of sleep on productivity, as correlation coefficients cannot adequately capture nonlinear relationships, and the relationship between sleep and salary may be nonlinear. Figure 2 below presents scatter plots with quadratic curves illustrating the relationships between sleep and logsalary, as well as age and logsalary, suggesting potential non-linear patterns. Additionally, correlation does not imply causation, reinforcing the necessity of regression analysis.

Figure 2: Non-linear Correlations



Sleeep and Logsalary Age and Logsalary

Table 3 summarizes the results of my regression models. Model 1 is a simple regression that examines the relationship between salary and sleep duration, using the equation:

$$\log(salary_i) = B_0 + B_1 sleep_i + u_i$$

Regression and results

Table 3 : **Regression Results Summary**

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
sleep	-0.027***	-0.019***	0.001	0.087***
	(0.006)	(0.005)	(0.004)	(0.033)
sleepsq				-0.001***
				(0.000)
age		0.087***	0.071***	0.069***
		(0.024)	(0.019)	(0.019)
agesq		-0.001***	-0.001***	-0.001***
		(0.000)	(0.000)	(0.000)
educ		0.060***	0.075***	0.072***
		(0.013)	(0.010)	(0.010)
male		0.944***	0.537***	0.532***
		(0.067)	(0.058)	(0.058)
totwrk			0.001***	0.001***
			(0.000)	(0.000)
Constant	10.386***	6.839***	4.718***	2.530***
	(0.307)	(0.579)	(0.478)	(0.948)
Observations	513	513	513	513
Adjusted R-squared	0.042	0.350	0.587	0.592

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This is a semi-log model that estimates the percentage change in salary associated with a one-unit change in sleep duration. The null and alternative hypotheses are formulated as follows:

$$H_0: B_1 = 0 \text{ and } H_1: B_1 \neq 0$$

The regression result showed that the sleep duration variable had a coefficient of 0.027, which means that for every additional hour of sleep per week, salary was associated with a decrease of 2.7 percent on average. This coefficient estimate was statistically significant at the 1% level ($p < 0.01$), providing strong evidence to reject the null hypothesis. This result supported the labor economists' view of a negative link between sleep duration and salary. However, this simple regression did not control for the effects of other variables, which might cause omitted variable bias, potentially leading to overestimated or underestimated effects of sleep duration on salary.

As shown in Table 2, *male* and *educ* had positive correlations with *salary* and negative correlations with *sleep*, suggesting that omitting these variables in our regression analysis can cause on overestimated $B1$. Possible explanations include: 1) males and females might have different physiological tendencies regarding sleep, and their average salaries differ; or/and 2) education might influence people's average salaries and consequently affect their sleep habits. It is also plausible to assume that age has a non-linear relationship with both salary and sleep duration. Therefore, I added these variables to Model 2 as control variables and formulated the following analysis:

$$\log(salary_i) = B_0 + B_1 sleep_i + B_2 age_i + B_3 agesq_i + B_4 educ_i + B_5 male_i + u_i$$

The *agesqi* variable was used to capture and control for the non-linear effect of age on salary (as shown in Figure 2). My null and alternative hypotheses are the same as before.

The regression result showed that the coefficient of the sleep duration variable was -0.019, indicating that for every additional hour of sleep per week, salary decreased by an average of 1.9%, holding all other variables constant. This result was 0.8 percentage points lower than that from the simple regression model. The change was likely due to omitted variable bias in Model 1, and the positive estimated coefficients for *educ* and male confirmed their positive correlations with salary, consistent with our previous inferences. This regression model had an adjusted R-squared value of 0.35, indicating that it accounted for 35% of the variation in log(salary) observed in the data, an improvement over the simple regression model. As the estimation remained significant at the 1% level ($p < 0.01$), the conclusion about the negative link between sleep duration and salary still holds.

On the other hand, while labor economists argued that increas-ed sleep duration reduces available time for work and, consequently, wages, the extent to which reduced working hours contribute to lowered wages is not clear. Additionally, although medical research suggested a positive correlation between sleep duration and productivity (or work performance), this conclusion is better tested and would be more convincing if the number of working hours is controlled. Therefore, I included totwrk as a control variable in Model 3:

$$\log(salary_i) = B_0 + B_1 sleep_i + B_2 age_i + B_3 agesq_i + B_4 educ_i + B_5 male_i + B_6 totwrk_i + u_i$$

The regression result in Table 3 showed that the estimated value of $B1$ is 0.001. Moreover, this estimate was not statistically significant at any conventional level (p=0.818), suggesting no evidence of a linear relationship between totwrk and log(*salary*). However, the high correlation between totwrk, sleep, and salary may cause multicollinearity issues, potentially inflating standard errors and reducing the reliability of the estimates.

This is also potentially reflected by the high adjusted R-squared of 0.587 of this model. To address this, I checked the variance inflation factors (VIFs) of the independent variables and found that multicollinearity was not a serious problem. Therefore, the results indicated that the effect of working hours was crucial, and controlling for it can almost eliminate the negative correlation between sleeping hours and wages. However, this regression did not provide a confident conclusion to support the view of medical research either. Additionally, after controlling for working hours, the estimated coefficient for male dropped from 0.944 to 0.537, which interestingly suggests that part of the reason for gender income inequality could be that men on average work longer hours.

As shown in Figure 2, a non-linear relationship between sleep duration and salary can be plausible. This is potentially because there is a similar threshold of healthy sleeping time for most people, and deviating from this range could adversely affect our health, energy, and cognitive abilities, consequently leading to a decline in productivity at work. To capture this non-linear effect, I added sleepsq to Model 4:

$$\log(salary_i) = B_0 + B_1 sleep_i + B_2 sleepsq_i + B_3 age_i + B_4 agesq_i + B_5 educ_i + B_6 male_i + B_7 totwrk_i + u_i$$

The result of this regression analysis showed that sleepsq had a coefficient of -0.0008, which was statistically significant at the 1% level. This suggests that there is strong evidence supporting a non-linear relationship between sleep duration and salary. The distribution tests for normality and homoscedasticity of this regression are presented in Figure 3. The residuals exhibit an approximately normal distribution but show unequal variability (scatter) across different values, indicating some degree of heteroscedasticity. This could introduce bias in the standard errors of our regression model, potentially affecting the validity of our inferences based on previous regression results. Nevertheless, the marginal effect of sleep can be calculated as follows:

$$\frac{\partial(\log(salary_i))}{\partial \text{sleep}_i} = B_1 + 2B_2 \text{sleep}_i$$

The regression estimate for the marginal effect was given by 0.087 − 0.0016*sleepi*, indicating that the effect of an additional hour of sleep per week on log(*salaryi*) decreases as the level of sleeping hours increases. Assuming all other variables are constant, the marginal effect of sleeep*i* on log($salary_i$) is illustrated in Figure 4 below. It shows that an extra hour of weekly sleep positively impacts income levels up to 54.38 hours, after which it has a negative effect. This implies that holding other variables constant, sleeping 54.38 hours a week, or approximately 7.8 hours a day, is optimal for productivity (measured by wages). Thus, these regression results partially support the medical perspective: sleep enhances productivity up to a certain point, beyond which it reduces productivity.

Discussion and Conclusion

In this paper, I conducted 4 regression analysis to examine the relationship between salary and sleep duration. The simple regression model suggests that an additional hour of weekly sleep is associated with a 2.7% decrease in salary on average. This negative correlation remained significant after controlling for age, education, and gender, even though the value of the coefficient decreased from 0.027 to 0.019. However, this linear correlation disappeared after controlling for working hours, suggesting that the effect of sleep on available hours for work is a key factor in determining salary variations.

Additionally, a significant quadratic relationship between sleep hours and productivity can be observed, with total working hours held constant. This finding suggests that increasing sleep hours enhances productivity within the optimal sleep range (7.8 hours per night), while reducing productivity beyond this range. Therefore, our overall results are consistent with the economic perspective that more sleep lowers wages by decreasing working hours; when working hours are kept constant, our findings partially support the medical perspective claiming that more sleep boosts productivity.

This study has several limitations. First, potential endogeneity—where one or more independent variables may be correlated with the error term—is not thoroughly addressed. As a result, our estimates may be inconsistent, particularly as the sample size increases. Second, there are concerns regarding reverse causality, whereby income levels may influence individuals' sleep patterns, introducing bias and reducing the reliability of our estimates. Third, additional robustness checks could have been conducted to strengthen the credibility of the findings.

Despite these limitations, the study makes a meaningful contribution to the discourse on work-life balance and offers practical insights for individuals in managing their daily schedules, as well as for policymakers in developing effective workplace policies.

Figure 3:: Test of Normality Test of Homoscedasticity

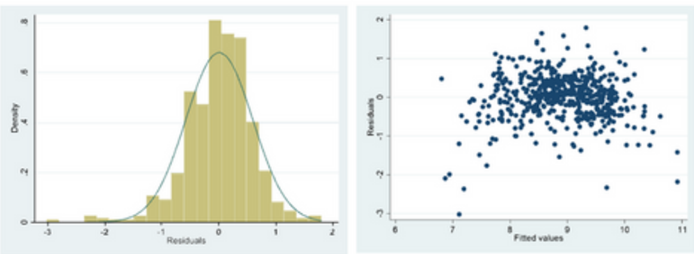
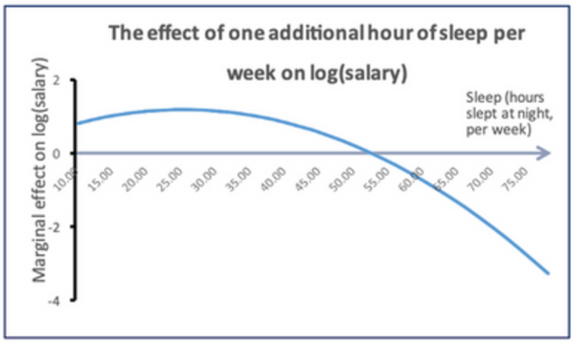
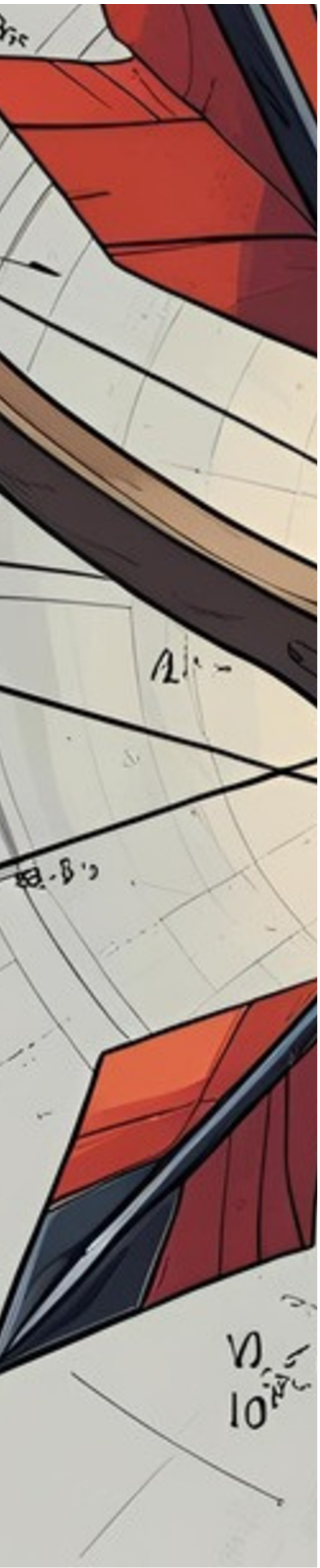


Figure 4:



Meet the Author.

Xingrong Li is a graduate of the University of Bristol and an incoming MPhil student at the University of Cambridge. Her academic interests lie at the intersection of economics, public policy, and human well-being. She is particularly interested in how empirical research can inform individual decision-making and guide policy design. In this paper, she explores the relationship between sleep duration and income, drawing on both economic theory and medical insights to assess how sleep patterns influence labour market outcomes. Through this work, she hopes to contribute to broader conversations on productivity, work-life balance, and quality of life.



Subject Engineering, Mathematics & Technology

Subject's Foreword

The BILT Student Research Journal is delighted to introduce the subject of Engineering, Mathematics, and Technology (EMT) for the first time. These fields—grounded in numerical reasoning, scientific inquiry, and practical innovation—are central to shaping the modern world. From artificial intelligence and robotics to clean energy and electric vehicles, their impact is far-reaching and transformative.

The journal invites students to see themselves as researchers—active participants in discovery and innovation. Every advancement begins with a question, a calculation, or a single written thought. Through study and exploration, today's students become tomorrow's engineers, scientists, and problem-solvers.

We commend the exceptional quality of this year's submissions and express sincere thanks to all contributing authors. Appreciation is also extended to the editorial team, including the Deputy Subject Editor Hou Hin Ip (Izaac Ip), the previous Subject Editor, and the previous Deputy Subject Editor, and all Peer Reviewers for their dedication and support.

Finally, we extend a heartfelt thanks to Jay for the opportunity to contribute to this exciting new chapter in the journal's development.

Blu Parsons, Subject Editor (EMT)
Hou Hin Ip (Izaac Ip), Deputy Subject Editor (EMT)

Meet Blu Parsons

Blu Parsons is a final-year, part-time master's degree student studying MSc Data Science at the University of Bristol. Blu works full-time as a Senior Data Analyst for Lloyds Banking Group. As a mature student, Blu is an advocate of returning to studies; he also mentors students to develop their social skills, explore career options and offer an insight into higher education. Blu's academic interests include NLP, LLMs, topic modelling, event detection in text, and text summarisation, amongst others!

Meet Hou Hin Ip (Izaac Ip)

Izaac Ip is an undergraduate student pursuing a BSc in Data Science at the University of Bristol. His academic interests include artificial intelligence, machine learning, and statistical data analysis, with a particular emphasis on the development and application of computational methods to real-world challenges. Beyond his academic pursuits, Izaac has engaged in consulting projects and educational support roles, reflecting a strong commitment to collaborative problem-solving and evidence-based decision-making. He is particularly interested in the practical translation of emerging technologies into functional products, and has experience in app and game development as part of this interest in applied innovation.

Modelling Arrow Dynamics for Optimised Recurve Archery Arrow Selection

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Programme: MEng Mechanical Engineering

Abstract

This study develops a methodology to improve arrow selection methods for competitive recurve archers, using dynamic spine modelling to enhance accuracy. Existing arrow selection methods do not consider sufficient parameters of the bow, arrow or archer. An arrow must be well-matched to a given bow in order for the arrow to flex correctly upon exiting the bow. A comprehensive existing model of lateral-plane arrow dynamics was found in the literature and replicated, with the equations of motion solved using a finite difference approximation. An algorithm to solve the system of equations is presented here, as none were found in existing literature. The model developed in this study was validated against another for identical input parameters and results found to be qualitatively consistent. Two improved arrow selection methods are proposed. The first replicates the existing arrow selection tables but at a greater resolution, using first principles modelling instead of empirical relationships. The second describes an accelerated method for the optimisation of a specific archer's equipment. The new arrow selection tables were found to be generally consistent with those provided by the arrow manufacturer, but with notable trends present for extremes of draw weight and arrow length. Further validations of both the model and selection methods are required.

Keywords: Archery, Recurve Bow, Arrow, Arrow Selection, Dynamic Spine

1. Introduction

In the Olympic sport of recurve archery archers compete to score the most points on a diameter target divided into ten scoring rings, shot from away. Competition success is a function of consistency, which is achieved through skill, proper tuning and arrows correctly matched to the bow. The stiffness of an arrow is crucial for consistent flight due to the Archer's Paradox — a phenomenon where a properly matched arrow flexes around the bow's riser. This behaviour, shown in Figure 1a, ensures the arrow flies straight despite appearing to 'snake' around the riser (handle). This phenomenon is well documented[1,2] and can be observed with high frame-rate photography.

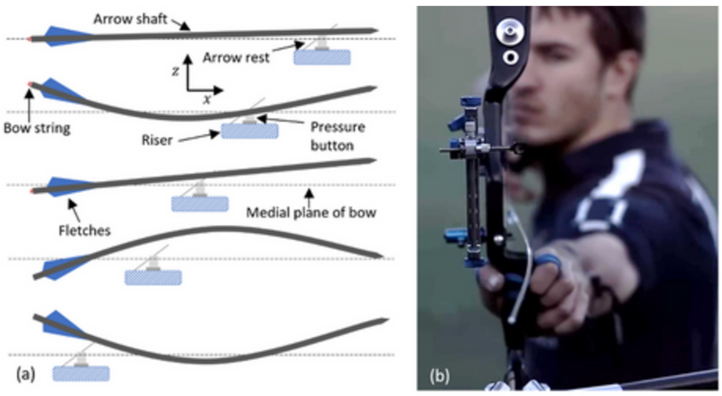


Figure 1: The Archer's Paradox. (a) Schematic showing the movement of an arrow through a recurve bow from a top view. (b) Experimental observation by Logan[3].

The selection of arrows for a given bow is currently done using two parameters: draw weight and arrow length. Draw weight refers to the force on the fingers of the draw-hand of an archer when the bow is fully drawn, typically measured in pound-force [lbf]. Elite archers usually have a draw weight of 40 – 50 lbf (178 – 222 N)[3]. Arrow length, conventionally measured in inches ["], varies with the build of an archer but is typically between 25 " (635 mm) and 32 " (813 mm). An archer can use a range of arrow lengths, but typically uses arrows a few centimetres longer than their draw length. The draw length of an archer refers to the distance from the arrow nock to the pressure button when the bow is fully drawn.

Arrow manufacturers, such as Easton Technical Products[4], provide arrow selection charts[5], which archers can use to select the best size arrow for their draw weight and arrow length. These charts are primarily based on the static spine of an arrow, a measure of stiffness from a three point bending test. The static spine is the deflection in 1000 ths of an inch for a specified test arrow[6]. The higher the static spine the more flexible (commonly referred to as weaker) an arrow is and hence more suitable for archers using shorter arrows or lower draw weight. The accuracy of these selection charts is variable, with the extremities of both draw weight and arrow lengths often being inaccurate. The inaccuracies of the selection charts can lead to archers being misled to buy the wrong size arrows. Park noted that for any given bow there is typically no more than one size of arrow that will match that bow well[7]. A further inaccuracy is for arrows which are not parallel along their length, such as the Easton X10 typically used in Olympic archery[4]. Their dynamic behaviour is hard to capture through a static spine test as their mass and stiffness profiles differ along their length.

Applications such as Archers Advantage[8] and Software for Archers Xpert[9] are an alternative to selection charts with the added benefit of using a wider range of parameters, however they work as black boxes with no information available about their accuracy.

The dynamic spine of an arrow refers to the vibrational behaviour of an arrow when shot from a given bow. This is a function of many variables, some specific to an individual archer. The dynamic spine of an arrow generally correlates well with the static spine of parallel arrows, however this relationship breaks down for non-parallel arrows. At present, archers tune the dynamic spine of their arrows using a number of parameters to minimise phenomena known as fishtailing and porpoising. The bareshaft tuning method[10] is a common way of achieving this.

In this study, a model is developed to gauge the suitability of a given recurve bow-arrow combination. This analysis was based on modelling the dynamics response of arrows during and after the power stroke of the bow. Section 3 discusses the modelling methodology, presenting the equations of motion and an algorithm to solve a finite difference form of these. In Section 4 the model is validated and improved arrow selection methods are proposed.

2. Literature Review

The archer's paradox was first observed experimentally for wooden arrows shot from an English longbow in 1933 by Klopsteg[2]. Static spine was first defined in 1937 and a mathematical method of arrow selection for varying draw weight proposed[11].

Kooi modelled the statics and dynamics of a recurve bow[12] in his 1983 PhD thesis. This was the first model of a modern recurve bow of the type used in competition today. A complex system of partial differential equations (PDE) to describe the motion of the limbs of the bow during the power stroke were derived and solved using a finite difference approximation. The first model of the vibrations of an arrow leaving a bow was constructed and validated via high speed photography by Pekalski in 1990[13]. This model was improved on in 1997 when Kooi and Sparenberg refined the motion of the arrow during the release and included a pressure button[1].

Non-parallel arrows had to wait until the early 2010's for their first appearance in research by Park. During this time the dynamics of arrows during the power stroke of a recurve bow[7] and in free flight[14] were studied, and the boundary condition on the arrow nock was refined. The model was further validated by high frame-rate videography[3].

3. Methodology

The numerical results presented in this study use the model presented by Park[7] to analyse the dynamics of an arrow leaving a recurve bow. A finite difference approximation of the equations of motion is used, and solved in Python 3.11[15].The resulting motion of the arrow is analysed and used to select an arrow to create a well-matched bow-arrow system. The dynamics of an arrow in the vertical plane are not considered, as for any approximately matched bow-arrow combination porpoising can be eliminated by a simple bareshaft test[10].

A well-tuned (and hence well-matched) bow-arrow combination can be defined as when the arrow has zero angular rotation rate in the lateral plane about the centre of mass (CoM) after leaving the bow[7]. That is, the arrow is not rotating in the horizontal plane and hence not fishtailing. There may be a small residual angle of attack, however this will be corrected by aerodynamic forces on the arrow.

3.1 Arrow Model

Two typical competition standard arrows were considered in this study. The Easton X10 is a non-parallel arrow constructed from carbon fibre reinforced plastic (CFRP) bonded to an internal hollow aluminium tube, while the Easton X7 is solely made from a hollow aluminium tube. For parallel aluminium arrows the Young's modulus E can be found from the static spine of an arrow[6], δ_{sp} is given by Equation 1 with P_{sp} =8.63 N and L_{sp}=28" . The cross-sectional area and second moment of area can be found from Equations 1 and 2 respectively, with d as the diameter of the arrow and g the wall thickness. For non-parallel arrows the mass and stiffness distributions generated by Park's model[16] were used, as data was not available for the geometry of all sizes of arrows in this study. Park's model uses the method described by Rieckmann[17] to calculate mass and stiffness profiles.

$$E = \frac{P_{sp} L_{sp}^3}{48 \cdot \delta_{sp}} \quad (1) \qquad C = \frac{\pi}{4(d^2 - (d-2g)^2)} \quad (2) \qquad I = \frac{\pi}{64(d^4 - (d-2g)^4)} \quad (3)$$

3.2 Bow Model

Figure 2a shows an annotated diagram of a right-handed recurve bow. The static draw force curve of a recurve bow can easily be found by recording the draw weight at varying draw lengths, however the dynamic force is more complex and accounts for accelerating the inertia of the bowstring, limbs and arrow during the power stroke[12]. These are shown by F and E in Figure 2b respectively.

As the dynamics of the bow were not the primary concern of this study, a high order polynomial was fitted to the dynamic draw force produces by Kooi's model and scaled for varying draw weights and lengths. Arrow mass (which influences the dynamic draw force) is omitted, which introduces an error to the model. The arrow is supported in the lateral plane by the pressure button, a pre-tensioned spring. This spring exerts a force on the arrow during the power stroke, helping to damp the initial oscillation. The stabiliser system (as shown in Figure 2a) used on Olympic recurve bows causes, by design, significant inertial resistance to the movement of the bow while shooting. Consequently, the lateral movement and rotation of the bow are assumed to be zero for all analysis in this study.

3.3 Phases of Motion

As an arrow is shot it goes through several phases of motions with varying boundary conditions. During $0 < t < t_r$, the bowstring is in contact with the fingers of the draw hand of the archer. For $0 < t < t_l$ the arrow nock remains attached to the bowstring – t_l is determined by when x = H. While $0 < t < t_g$ the arrow may be in contact with the pressure button. For $t_g < t < T$ the arrow is free-free boundary conditions.

3.4 Equation of Motion

The arrow is placed in a local moving coordinate system in the lateral plane with axes ξ and ζ. The global coordinate system x and z is fixed and used to calculate the forward motion of the arrow. The origin of the moving coordinate system is located such that $\xi = 0$ occurs at $x = b(t)$, with $b(t)$ the position of the nock of the arrow with time. The ζ axis is parallel to the z axis and the deflection of the arrow as a function of position along the arrow and time, $\zeta(\xi,t)$ is found.

Equation 4 relates the density and cross-sectional area $\rho C(\xi)$, acceleration, bending moments $M(\xi,t)$ and longitudinal force $H(\xi,t)$ in the arrow. Equation 5 is the Euler-Bernoulli Beam equation with $EI(\xi)$,

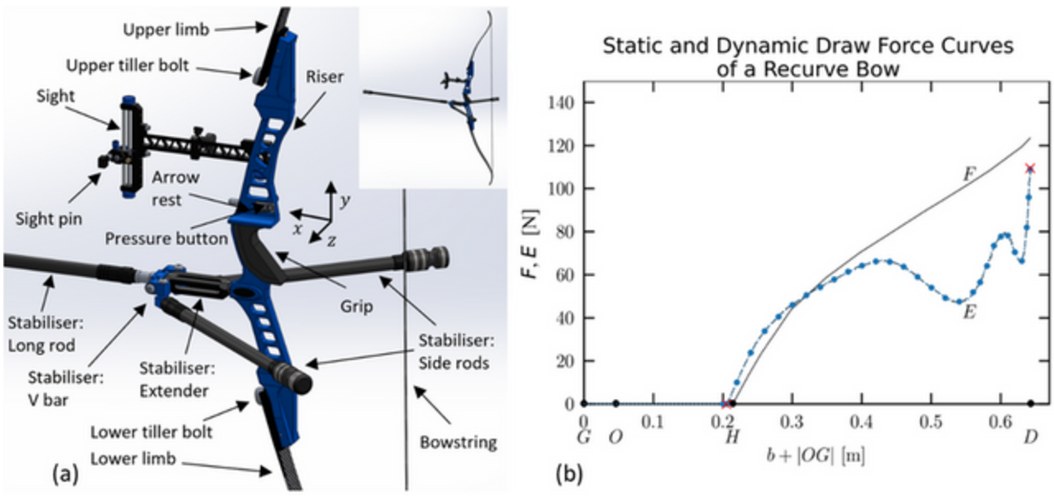


Figure 2: (a) Annotated diagram of right-handed recurve bow. The medial plane is the x-y plane on the midline of the bow. The lateral plane is the near horizontal plane the arrow initially rests in, perpendicular to the medial plane. (b) Static, F, and dynamic, E, draw force curves of a Greenhorn Comet TD 350 from Kooi and Sparenberg[1], calculated using Kooi's bow model[12]. Shown also is the fitted polynomial used by this model. O is the location of the origin of the fixed coordinate system and G the location of the pressure point. H is the brace height where the bowstring rests when the bow is not drawn. and D the full draw position, at which $t = 0$.

the flexural stiffness, which varies along the length of the arrow. Equation 6 is the longitudinal force in the ξ direction down the arrow, which becomes zero when the arrow leaves the bowstring. $\ddot{b}(t)$ is the acceleration of the arrow in the x direction.

$$\frac{\rho C(\xi)(\partial^2\zeta(\xi,t))}{\partial t^2} = -\frac{\partial^2 M(\xi,t)}{\partial \xi^2} - \frac{\partial H(\xi,t)}{\partial \xi}\frac{\partial \zeta(\xi,t)}{\partial \xi} - \frac{H(\xi,t)(\partial^2\zeta(\xi,t))}{\partial \xi^2} \qquad (4)$$

$$M(\xi,t) = \frac{EI(\xi)(\partial^2\zeta(\xi,t))}{\partial \xi^2} \qquad (5) \qquad H(\xi,t) = \begin{cases} \ddot{b}(t)\int_{\xi}^{l_a} \rho C(\xi')\,d\xi' & \text{if } t \le t_l \\ 0 & \text{if } t > t_l \end{cases} \qquad (6)$$

3.5 Boundary and Initial Conditions

It is assumed that the nock of the arrow provides no resistance to the rotation of the arrow. Under this assumption, the bending moment at the nock must be zero for all time. In addition, the arrow tip has no support and hence is also free to rotate with no opposing moment. These are defined by Equation 7.

$$M(0,t) = M(l_a,t) = 0 \quad \text{for all} \quad t \ge 0 \qquad (7)$$

Modelling the true motion of the nock of the arrow through the release would require consideration of the forces exerted on the bowstring by the fingers of an individual archer. To avoid this complexity, previous models assumed the nock follows a diagonal path until the bowstring leaves the fingers of the archer[1,7]. Two parameters describe this motion: h_x as the forward motion of the arrow in the ξ direction during the release and h_z, the maximum lateral displacement of the nock in the ζ direction during the release. The motion of the nock is hence given by Equation 8.

$$\zeta(0,t) = \frac{h_z}{h_x} b(t) \quad \text{for} \quad 0 \le t \le t_r \qquad (8)$$

$$V(0,t) = -\frac{H(0,t)\cos(\alpha_s(t))}{l_{st}}\zeta(0,t) \qquad (9)$$

While the arrow nock is clipped onto the bowstring, the bowstring exerts a lateral restoring force towards the medial plane of the bow as given by Equation 9. $\alpha_s(t)$ is the angle between the bowstring and the x axis. This can be calculated from Kooi's bow model[12] however is assumed here to vary linearly with position of the nock between α_{sFD} =65 ° at full draw $x=D$, and α_{sFD} =90 ° at brace height $x=H$[7].

While the pressure button is fixed in the global coordinate system, it is moving in the (ξ,ζ) coordinate system in which the equations of motion are constructed. Consequently, the position of the pressure button, $(\xi_\gamma(t),\zeta_\gamma(t))$, must be calculated for each time step. ξ_γ is found from Equation 10, while $\zeta_\gamma(t)$ is found using the method described by Figure 4 in Appendix 1. For non-parallel arrows the variable radius of the arrow, $r(\xi)$ must also be considered.

$$\xi_\gamma(t) = b(t) + OG \qquad (10)$$

In Equation 10 expression OG is the distance from the origin of the fixed coordinate system to the pressure point. While Park's model considered non-parallel arrows, the equations presented did not include this[7]. Equation 11 has been adapted to account for non-parallel arrows and gives the force exerted on the arrow by the pressure button, R.

$$R(\zeta_\gamma(t)) = \begin{cases} 0 & \text{if} \quad \zeta_\gamma(t) - r(\xi_\gamma(t)) > h_g - r(GD) \\ -\left(\zeta_\gamma(t) - r(\xi_\gamma(t)) - h_g + r(GD)\right)k_{gs} & \text{if} \quad h_{gs} - r(GD) < \zeta_\gamma(t) - r(\xi_\gamma(t)) \le h_g - r(GD) \\ R_{min} - \left(\zeta_\gamma(t) - r(\xi_\gamma(t)) - h_{gs} + r(GD)\right)k_g & \text{if} \quad h_{gss} - r(GD) < \zeta_\gamma(t) - r(\xi_\gamma(t)) \le h_{gs} - r(GD) \\ R_{max} - \left(\zeta_\gamma(t) - r(\xi_\gamma(t)) - h_{gss} + r(GD)\right)k_{gs} & \text{if} \quad \zeta_\gamma(t) - r(\xi_\gamma(t)) \le h_{gss} - r(GD) \end{cases} \qquad (11)$$

Here k_g is the spring constant of the spring within the pressure button, R_{min} the minimum force that the arrow must exert on the pressure button to cause it to displace and GD the draw length. h_{gs} and h_{gss} are the positions of the pressure button for $R = R_{min}$ and $R = R_{max}$ respectively, found from Equation 12 and 13. ϵ is the maximum deflection of the pressure button and the maximum force exerted by the pressure button R_{max} is found from Equation 14. k_{gs} is a larger spring constant used to avoid computational difficulties due to the sudden jump in force when the arrow comes in contact with the pressure button.

$$h_{gs} = h_g - R_{min}/k_{gs} \qquad (12) \qquad h_{gss} = h_g - \epsilon \qquad (13)$$

$$R_{max} = R_{min} + k_g\epsilon \qquad (14) \qquad M(\xi,0) = 0 \qquad (15)$$

As the arrow is initially undeformed, there is no bending moment at any position along the arrow, as given by Equation 15. When $t = 0$, the arrow is at rest and in contact with the pressure button. Under the assumption that the nock of the arrow is in the medial plane of the bow, the initial position of the arrow is given by Equation 16 with h_g the distance in the ζ direction that the axis of the arrow is offset at the pressure button. Equation 16 has been adapted from Park to account for non-parallel arrows[7].

$$\zeta(\xi,0) = \zeta(\xi,-\Delta t) = \frac{h_g + r(GD) - r(0)}{GD}\xi + r(0) - r(\xi) \qquad (16)$$

3.6 Finite Difference Discretisation

The system of PDEs was solved using an explicit finite difference scheme. The arrow was discretised with equally placed space steps as shown in Figure

3 (as seen below). The space step $\Delta\xi$ and time step Δt are defined by Equation 17. In order to apply the initial conditions, a time step for t = -Δt was included. Similarly, fictitious nodes outside the arrow for $\xi = -\Delta\xi$ and $\xi = (n+1)\Delta\xi$ were considered for application of the boundary conditions.

$$\Delta\xi = \frac{l_a}{n} \quad \text{and} \quad \Delta t = \frac{T}{m} \tag{17}$$

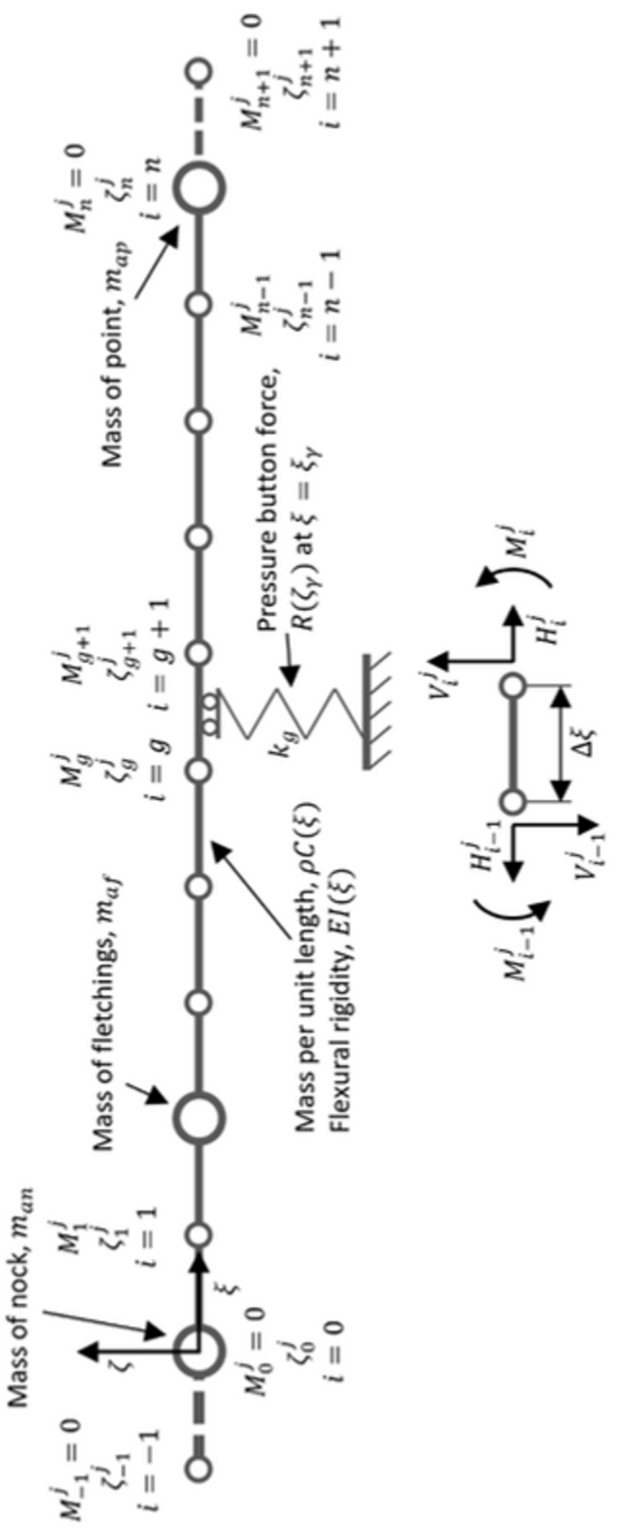


Figure 3: Discretisation of arrow using space step Δξ, replicated from Kooi and Sparenberg[1].

Equations 4 - 9, 15 and 16 are discretised to Equations 18 - 26. The discretisation notation used is such that $\zeta(\xi,t)=\zeta(i\Delta\xi,j\Delta t)=\zeta_i^j$. Here m_{shaft_i} is the mass concentrated at each node and R_g^j, R_{g+1}^j are the forces from the pressure button at nodes i = g and i = g+1 respectively, found from Equation 21.

$$\frac{m_{\text{shaft}_i}}{\Delta\xi}\frac{\zeta_i^{j+1} - 2\zeta_i^j + \zeta_i^{j-1}}{(\Delta t)^2} = -\frac{M_{i+1}^j - 2M_i^j + M_{i-1}^j}{(\Delta\xi)^2} + \frac{H_{i+1}^j - H_{i-1}^j}{2\Delta\xi}\frac{\zeta_{i+1}^j - \zeta_{i-1}^j}{2\Delta\xi} + H_i^j \frac{M_i^j}{EI(i\Delta\xi)} + \frac{V_i^j}{\Delta\xi} \tag{18}$$

$$R\big(\zeta_\gamma(t)\big) = \begin{cases} 0 & \text{if} \quad \zeta_\gamma^j - r(\xi_\gamma^j) > h_g - r(GD) \\ -(\zeta_\gamma^j - r(\xi_\gamma^j) - h_g + r(GD))k_{gs} & \text{if} \quad h_{gs} - r(GD) < \zeta_\gamma^j - r(\xi_\gamma^j) \le h_g - r(GD) \\ R_{min} - (\zeta_\gamma^j - r(\xi_\gamma^j) - h_{gs} + r(GD))k_g & \text{if} \quad h_{gss} - r(GD) < \zeta_\gamma^j - r(\xi_\gamma^j) \le h_{gs} - r(GD) \\ R_{max} - (\zeta_\gamma^j - r(\xi_\gamma^j) - h_{gss} + r(GD)k_{gs} & \text{if} \quad \zeta_\gamma^j - r(\xi_\gamma^j) \le h_{gss} - r(GD) \end{cases} \tag{19}$$

$$V_i^j = \begin{cases} -H_0^j \dfrac{\cos(\alpha_s(j\Delta t))}{l_{st}}\zeta_0^j & \text{if} \quad i = 0 \\ R_g^j & \text{if} \quad i = g \\ R_{g+1}^j & \text{if} \quad i = g+1 \\ 0 & \text{if} \quad \text{Otherwise} \end{cases} \tag{20}$$

$$R_g^j = R(\zeta_\gamma^j)\frac{\xi_{g+1} - \xi_\gamma^j}{\Delta\xi} \quad \text{and} \quad R_{g+1}^j = R(\zeta_\gamma^j)\frac{\xi_\gamma^j - \xi_g}{\Delta\xi} \tag{21}$$

$$M_i^j = EI(i\Delta\xi)\frac{\zeta_{i+1}^j - 2\zeta_i^j + \zeta_{i-1}^j}{(\Delta\xi)^2} \tag{22}$$

$$V_0^{j+1} = -H((j+1)\Delta t)\frac{\cos(\alpha_s((j+1)\Delta t))}{l_{st}}\zeta_0^j + 1 \tag{23}$$

$$\zeta_0^{j+1} = \frac{h_z}{h_x} b((j+1)\Delta t) \tag{24}$$

$$\zeta_i^0 = \zeta_i^{-1} = \frac{h_g + r(GD) - r(0)}{GD} i\Delta\xi + r(0) - r(i\Delta\xi) \tag{25}$$

$$M_0^j = M_n^j = 0 \tag{26}$$

$$M_i^0 = M_i^{-1} = 0 \tag{27}$$

3.7 Solving Method

The system of finite difference equations was solved in Python 3.11 using the Numpy[18,19] and Scipy[19] modules. Under the assumption of inextensibility, the forward motion of the arrow $b(t)$ is a simple initial value ordinary differential equation with acceleration as a function of position, as given by Equation 28. $E(b(t))$ is given by the dynamic draw force curve shown in Figure 2b. Here $2m_a$ is the mass of the arrow and m_s the mass of the bowstring. One third of m_s has been added as an assumption of Kooi's model was that m_s was concentrated at each of the top limb, arrow nock and bottom limb[12].

$$\ddot{b}(b(t)) = \frac{E(b(t))}{2m_a + m_s/3} \tag{28}$$

All time dependent finite difference equations were rearranged for ζ_i^{j+1} or equivalent term at $t=(j+1)\Delta t$ and defined as functions. No algorithm was presented in any existing literature for solving this system of equations, so the algorithm shown in Appendix 1 was developed.

After solving for all ζ_i^j the angle of attack in the lateral plane, α was calculated to assess the suitability of a given bow-arrow combination. The method defined by Park is used, considering the alignment of the nodes of the first mode of vibration[7]. The mode-shapes of the arrow under free-free boundary conditions were found using finite element analysis, with ξ_{nf} and ξ_{nr} the locations of the front and rear nodes of the first mode of vibration. For each time step Equation 28 was used to find the angle of attack α^j. ξ_{nf}^j and ξ_{nr}^j are the positions of ξ_{nf} and ξ_{nr}, respectively at $t=j\Delta t$. α_{CoM} is the angle along which the CoM moves when the arrow is in free flight, $t > t_g$. The angular rotation rate used for further analysis was found by fitting a first-order polynomial to α for $t > t_g$. The gradient of this polynomial gives the free flight average rotation rate, $\bar{\dot{\alpha}}$.

$$\alpha^j = arctan\left(\frac{\zeta_{n_f}^j - \zeta_{n_r}^j}{\xi_{n_f} - \xi_{n_r}}\right) - \alpha_{CoM} \tag{29}$$

4. Results and Discussion

The model was found to be numerically unstable for $\Delta t \geq 20\ \mu s$ with $n = 32$. Computational time was found to increase significantly with smaller space and time steps, so $n = 32$ and $\Delta t = 14\ \mu s$ were used over a simulation period of $T = 35$ ms for all further analysis.

4.1 Model Validation

This model should be validated against real world data, typically found from analysis of high frame-rate photography. Park used this method to validate his model against the motion of arrows shot by elite archers in 2011 and observed a good match[3]. To gather this data, a complex experimental setup is required and this was outside the practical scope of this study. The model developed here has instead been validated against Park's model using identical input parameters.The results of this can be seen in the animation (via the QR code), comparing Park's model (green arrow) with the model developed in this study (black arrow). Results are qualitatively consistent between this model and Park's. The sources of inconsistency are limited modelling of the bow dynamics and a discrepancy in the boundary condition of the arrow nock. This is likely as the parameters lst and αsFD are estimated for this model and hence not identical to those used by Park.

Crucially the lateral plane rotation rate was found to be similar between both models, as this is the primary parameter used for arrow selection. This validation confirms that the model developed here can be used to improve arrow selection methods. To improve the results, the full dynamics of the bow should be included and the nock boundary condition should be re-examined.

4.2 Improved Arrow Selection Methods

The model developed allows for the dynamics of any bow-arrow combination to be analysed. The Easton arrow selection chart[5] has increments of draw weight varying between 4 lbf and 6 lbf, while arrow length is provided in increments of 1". The resolution of both parameters has been improved here, using steps of 4 lbf and 0.5 " (12.7 mm). Due to the international limb fitting used almost exclusively by modern recurve bows, all bows can be adjusted by ±2 lbf draw weight, and often more.

An arrow selection function was defined in the model to select the best size arrow of a specific type for a given draw length and draw weight by minimising $\bar{\dot{\alpha}}$. This modelling was done iteratively for all sizes of Easton X7 and X10 arrows. Arrow parameters were defined according to the recommended components given by Easton[4]. Typical values were used for all other bow parameters, and the parameters describing the release were set to the average values found by Park and Logan[3]. The draw length was assumed to be 1.5" less than the arrow length. It was assumed any variation from these parameters could be corrected using small changes in draw weight or fine-tuning of the pressure button.

The result of this modelling is the improved arrow selection chart shown in Tables 1a and 1b for Easton X7 and X10 arrows respectively. The colour code used to compare the recommended arrow sizes to the Easton arrow selection table is given by Table 1c (refer to the next page). The new arrow selection tables should be validated, which was beyond the scope of this study.

Distinct trends appear in both tables. In Table 1a, for longer arrow lengths, Easton recommends an arrow that is too stiff and this is exacerbated by extremes of draw weight. Table 1b also shows that for lower draw weights Easton recommends too stiff an arrow. Both Tables 1a and 1b clearly show that the improved resolution of arrow length steps of 0.5 " is necessary, as recommended arrows differ for this small change in arrow length. For both tables the majority of recommended arrows have rotation rates of $\bar{\dot{\alpha}} < 20°/s$. This is acceptable as further small

Table 1a: New arrow selection table for Easton X7 arrows.

Draw Weight [lbf]	Arrow Length [″]														
	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32
20	1514	1514	1514	1614	1614	1614	1614	1714	1714	1714	1714	1714	1714	1814	1814
24	1614	1614	1614	1714	1714	1714	1714	1714	1814	1814	1814	1814	1814	1914	1914
28	1714	1714	1714	1714	1814	1814	1814	1814	1814	1914	1914	1914	1914	2014	2014
32	1714	1714	1814	1814	1814	1814	1914	1914	1914	1914	2014	2014	2014	2014	2114
36	1814	1814	1814	1914	1914	1914	1914	2014	2014	2014	2014	2014	2114	2114	2212
40	1814	1914	1914	1914	1914	2014	2014	2014	2014	2114	2114	2212	2212	2213	2214
44	1914	1914	1914	2014	2014	2014	2014	2114	2114	2212	2213	2213	2214	2214	2312
48	1914	1914	2014	2014	2014	2114	2114	2212	2212	2213	2214	2312	2312	2314	2314
52	2014	2014	2014	2014	2114	2114	2212	2213	2214	2214	2312	2314	2314	2315	2315

Table 1b: New arrow selection table for Easton X10 arrows.

Draw Weight [lbf]	Arrow Length [″]														
	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32
20	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	900	830	830
24	1000	1000	1000	1000	1000	1000	1000	1000	900	830	830	830	750	750	750
28	1000	1000	1000	1000	1000	900	900	830	830	750	750	700	650	650	600
32	1000	1000	900	900	830	830	750	750	700	700	650	600	600	550	550
36	900	830	830	750	750	700	700	650	650	600	600	550	500	500	450
40	830	750	750	700	700	650	600	600	550	550	500	500	450	450	410
44	750	700	650	650	600	600	550	550	500	500	450	450	450	410	2312
48	700	650	600	600	550	550	500	500	450	450	410	410	410	380	350
52	650	600	550	550	500	500	500	450	450	410	380	380	380	350	325

Table 1c: Colour codes for comparison of arrows recommended by new selection tables compared to existing tables[5].

Four sizes weaker	Three sizes weaker	Two sizes weaker	One size weaker	Same size	One size stiffer

adjustments to draw weight and pressure button parameters will reduce this to near zero.

An advanced method for optimising arrow selection for a specific archer would use high-frame rate photography to determine h_x and h_z for an individual archer. The process of arrow selection could be automated by giving bounds on specific parameters, while defining objectives to optimise the performance of a bow-arrow system. The implementation of this would be challenging, however it presents an interesting area for further work.

5. Conclusion

The dynamics of an arrow leaving a recurve bow have been modelled using that presented by Park. The equations of motion have been solved using a finite difference approximation, and the resulting motion analysed to assess the suitability of a bow-arrow combination. An acceptable match with Park's model was observed, which in turn has been shown to match experimental data well.

This study aimed to model the dynamic spine of arrows and apply this to arrow selection methods. Modelling of non-parallel arrows has shown that the dynamic spine of a statically stiff arrow may be weaker than that of a statically weak arrow, highlighting the importance of considering dynamic spine. This study has produced the first arrow selection table based on first principles modelling, by simulating the dynamics of many bow-arrow combinations. The framework developed in this study can be extended to simulate other arrow types and generate corresponding selection tables. The modelling completed in this study is of direct benefit to competitive archers, allowing them to select their arrows with confidence and avoid restricting their potential performance through poor equipment choice. Additional validation of both this model and framework are required, however this study represents a step forward for research into the Olympic sport of archery.

Meet the Author

Alex Williams has been a keen archer for over eight years and currently competes at a national level. Fascinated by the technical aspects of the sport, Alex chose to combine their interests in archery and engineering for their third-year individual research project, focusing on a practical issue they had personally encountered: how to choose the correct arrows for a bow. The project sparked a deep interest in the existing literature and ongoing research in this area. In September 2025, Alex will begin a Ph.D. in Data Driven Engineering and Science at the School of Engineering Mathematics, University of Bristol, where they hope to continue exploring the intersection of engineering and archery.

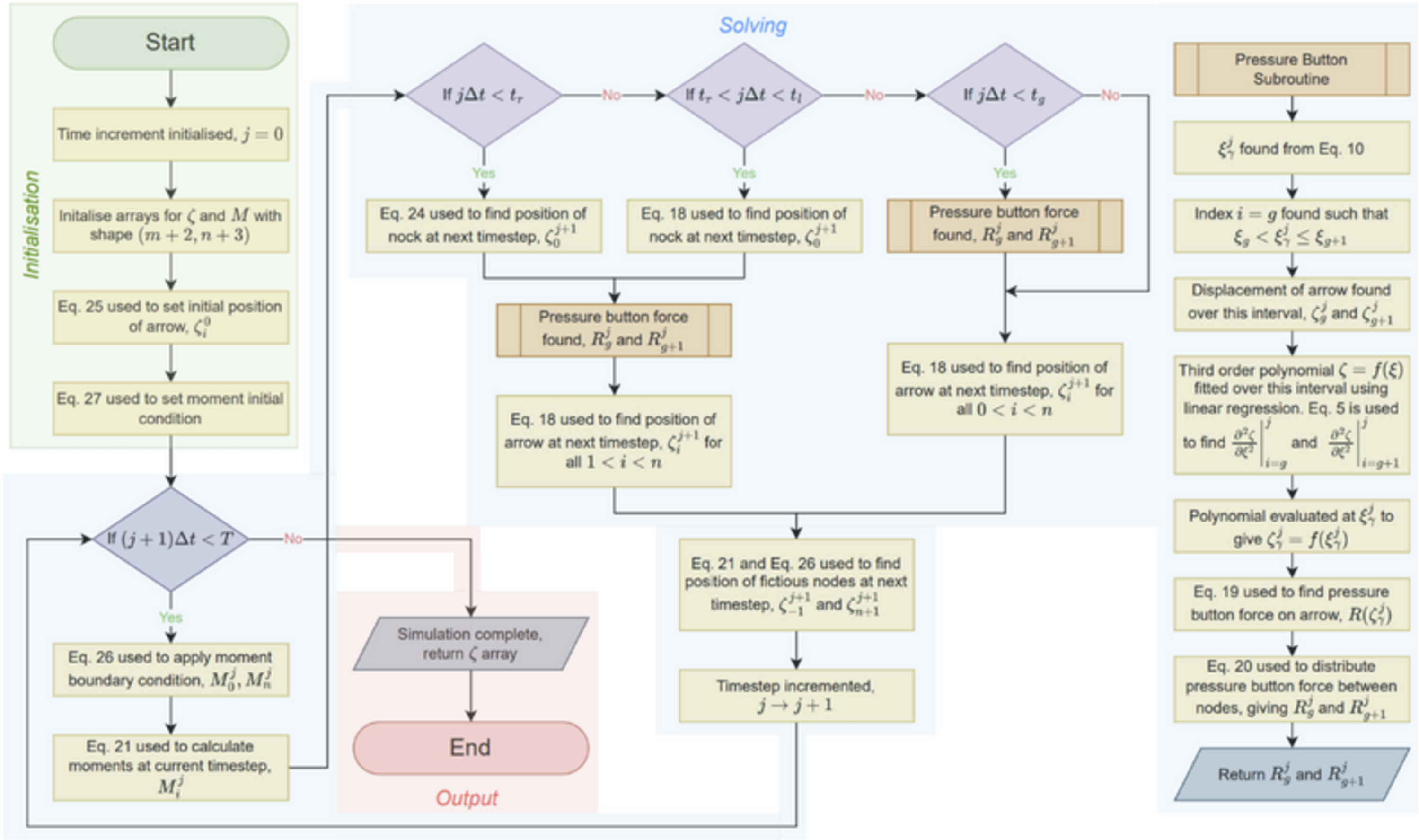
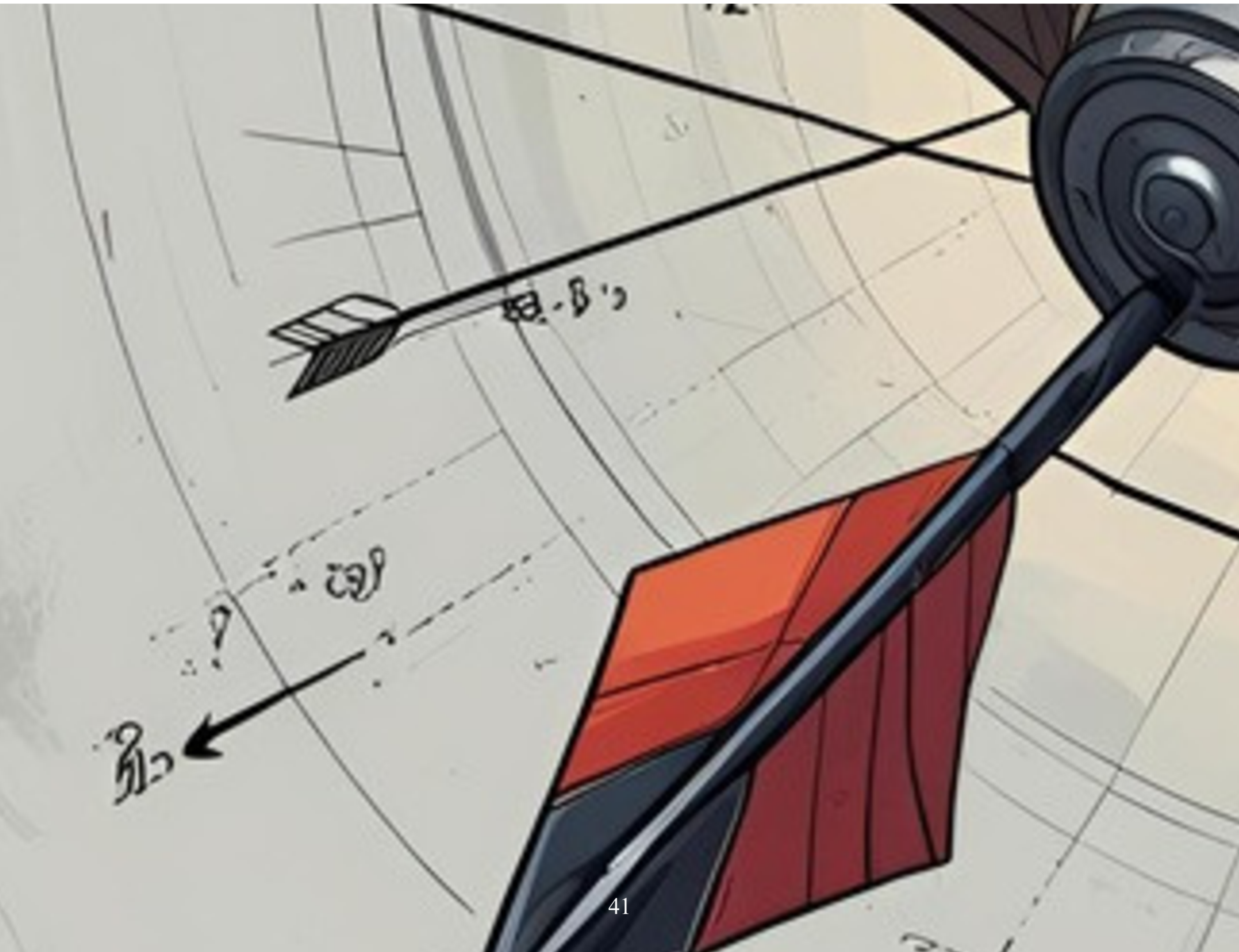


Figure 4: Flowchart of algorithm used to solve system of equations.



Subject History & Humanities

Subject's Foreword

It has been a delightful experience reading and offering feedback on diverse interdisciplinary investigations, which will be budding dissertations with development, and reflecting the passionate independent learning of taught students. Our entries revolve around the Francophone world with studies covering French literature and maritime culture; we are encouraged to reflect on our reading experiences and consider the ideologies underpinning fractions of literature and historical society. This was not an imposed theme by the journal, but each entry embraced Francophone landscapes and offered engaging discussions from the eighteenth century and beyond.

We are delighted to introduce 'the best student submission' written by Nel Roden, English Literature (MA), who has produced a cross-cultural analysis of Albert Camus' The Outsider and Samuel Beckett's The Unnamable considering generative agnosticism and allusions. The editorial board and Peer Reviewers congratulate Nel Roden for their well-written exploration in Literature with special commendation for its effective communication structure.

Alice Denton, Subject Editor (History & Humanities)
Bintu Danso, Deputy Subject Editor (History & Humanities)

Meet Alice Denton

Alice Denton has greatly enjoyed serving as the Subject Editor and guiding the process from abstract selection through to the final stages. With a strong academic interest in the Middle Ages—particularly English and Old French cultures—she was especially pleased to read and engage with submissions spanning not only her primary area of focus but also later periods of French and English literature. She found it rewarding to offer constructive writing feedback to help authors strengthen their work. Alice extends her sincere thanks to all the Peer Reviewers and Editors for their valuable contributions throughout the process.

Meet Bintu Danso

Bintu Danso began their involvement as a peer reviewer before stepping into the role of Deputy Editor—a transition that proved to be a truly rewarding experience. Although their research is rooted in political theory and philosophy, with a focus on race, colonialism, liberal universality, and Afro-Caribbean intellectual traditions, Bintu found it both enjoyable and intellectually enriching to read and provide feedback on a wide range of topics. Supporting and assisting authors who submitted thoughtful and compelling pieces has deepened their appreciation for the value and impact of editorial work.

Facilitating Generative Agnosticism: Challenging Christian dogma in the absurdist literature of Albert Camus and Samuel Beckett

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Abstract
Despite the wealth of academic literature on the respective religious themes and allusions in The Outsider (1942) and The Unnamable (1953), analyses of the functional role these works play in demystifying the purchase of religious dogma are seldom explored at length or with sufficient emphasis on the reader. This study considers the ways in which these texts challenge Christian dogma by way of questions and questioning. Taking this into account, I then utilise Roland Barthes' theoretical insights on rejecting definitive meanings in literary works to contend that the novels' sceptical interrogations of Christian dogma do not merely condemn its principles but might instead be understood as facilitating a generative agnosticism. In doing so, this study presents a broader argument regarding the functional potential of literature as a catalyst for facilitating the development of the reader's critical consciousness and in fostering a worldview that is cognisant of that which exists beyond the confines of religious dogmatism. I conclude that The Outsider and The Unnamable are neither irreligious nor anti-Christian but instead belong to a post-Christian canon of literature.

Keywords: Samuel Beckett, Albert Camus, Christianity, Dogma, Generative Agnosticism

Simon Blackburn puts forth that dogma is broadly considered to be 'a belief held unquestioningly and with undefended certainty'.[1] In the context of Christianity, Blackburn writes of it as 'a belief communicated by divine revelation […] defined by the Church'.[2] Blackburn delineates dogma as a set of doctrines that 'selects some set of propositions and insists, apparently arbitrarily, that they be not doubted' – this sentiment of unwavering credence to an authority that centralises and, in turn, unifies its followers being a central factor.[3] Another crucial aspect of dogma is its characterisation as a concept that pertains solely to Christianity as an institution. While the genesis of all dogma is found in Biblical scripture, such teachings have been historically codified by organised religion through institutions such as the Church. As such, dogmas are the Biblical teachings that are interpreted, upheld and enforced exclusively by people. It is precisely this institutionalised aspect of dogma – its claim to unquestioned authority – that is challenged in Albert Camus' The Outsider (1942) and Samuel Beckett's The Unnamable (1953).[4] While scholarship on the religious themes and allusions in TO and TU is extensive, analyses of the functional role these works play in demystifying the purchase of religious dogma are seldom explored at length or with sufficient emphasis on the reader. As such, thesis considers how Camus and Beckett's absurdist works challenge the absolutist rhetoric of Christian dogma through their respective uses of questions.

In TO, questions function as something far greater than speech acts that precipitate dialogue. Moreover, the questions put forth by Camus' characters rarely accomplish what the reader expects of them.

On the general function of questions, John Seale posits that 'asking questions is really a special case of requesting […] requesting information […] or requesting that the hearer display knowledge'.[5] In TO, questions form the cornerstone of Camus' interrogation of Christian dogma, with their repeated refusal to satisfy requests for information having a distinctly destabilising effect on both the peripheral characters and the reader. Questions become particularly integral to Camus' critique of Christian dogma in the latter half of the novel, where, after murdering the Arab in a sun-induced frenzy, Meursault is interrogated by a judge. While the judge's inquiries probing into the motive behind Meursault's actions serve as the entry point for their discourse on Christianity, it is the unanswered questions that frustrate this passage.

At the beginning of his interrogation, the judge declares, 'There are certain things about what you [Meursault] did that I can't comprehend […] I'm sure you'll help me to understand'.6 From the outset, his aim is clear: to uncover why Meursault killed the Arab and, in doing so, impose meaning on an otherwise inexplicable act of violence. Their exchange holds a discernible tension, which might be read as the result of Meursault's pointed rejection of the existence of God and the threat this poses to the judge's Christian beliefs. Meursault observes that if the judge ever had cause to doubt his own religiosity, 'his life would no longer have any meaning'.7 This is then emphatically reiterated by the judge himself: 'Do you want my life to have no meaning?'8 When faced with Meursault's rejection of God, the judge's instinctive response is to internalise the prospect of this uncertainty, thereby actualising the threat of Meursault's atheism. It is through this that Meursault obscures the fundamental ideals on which the judge's life balances, destabilising the primary mechanism through which he understands the world: the unquestionable principles of dogma. In doing so, Meursault uncovers the fragility of Christian beliefs when confronted with the Absurdist understanding of the world as inherently devoid of any sanctimonious explanation. The interaction is therefore exemplar of the fallible human impulse to attribute significance to life itself.

In The Myth of Sisyphus (1942), Camus identifies religion as a type of 'forced hope', and argues that those who seek solace from the Absurd through faith merely 'deify what crushes them'.9 Camus terms this concept Philosophical Suicide – the idea that turning to religion for answers about the meaning of life is ultimately inadequate. answers about the meaning of life is ultimately inadequate. Seeking to make sense of an action or event does not negate its intrinsic inexplicability, and thus cannot resolve the existential dilemma posed by life's inherent absurdity. In light of Myth's influence on TO, one might read the judge as emblematic of Camus' is not seeking what is desirable' portrays religious beliefs as mere impositions of meaning comforting illusions that substantiate one's existence.[10] Meursault's unwillingness to elucidate the motive behind his crime renders the judge unable to configure any semblance of divine explanation – or, as Camus puts it, to 'deify' that which he cannot comprehend – thereby denying him the consolation he seeks in the face of the absurd.

Indeed, having a murder be the inciting incident that exposes the judge to the cognitions of the absurd sensibility is, in and of itself, absurd. Camus' philosophy refracts against the backdrop of the murder, distorting both the judge's and the reader's understanding of reality. In turn, it rescinds any promise of clarification. In an attempt to mitigate the anguish wrought by Meursault's unbelief, the judge proffers the figure of Christ on the cross and demands to know: 'How can you [Meursault] not believe that He suffered for you?'[11] When faced with the figure of Christ – the 'symbol of suffering' – Meursault is apathetic.[12] Unlike with previous criminals, who we are told to have 'always cried' when presented with the image of Christ, the symbol proves ineffective as the judge's final expedient for eliciting a response.[13] The effect of Meursault's unwavering demeanour once again underscores the palpable threat of his unbelief, where he renders the judge's revered Christian iconography fatuous, undermines all it represents to a believing Christian and, ultimately, reveals Camus' concept of 'forced hope' within religious ideology.

When at the beginning of the passage the judge posits his objectives for the interrogation, an expectation is established. The reader anticipates the information they believe they will be granted access to, a curiosity that is left wholly unsatisfied. Camus' subversion of the interrogative framework underscores the destabilising undercurrent of the passage as a whole, where the elucidatory potential of questions is rejected entirely. Questions are, in this instance, false promises, functioning as integral tools for dismantling the illusion of dogma. The passage ultimately serves as an exploration of the instability of religious dogma, its pointed use of questions inviting the reader to engage alongside Meursault in a critical reassessment of the boundaries between truth and illusion.

Although questions in TU materialise differently from those in TO, they nonetheless play a fundamental role in Beckett's literature, both as a distinct characteristic of his post-war writing and as an integral aspect of his critique of Christian dogma. Rhetorical questions, in particular, serve as vehicles for the narrator's existential deliberations. They can be read as manifestations of what Martha Nussbaum suggests Beckett's characters aim to achieve throughout the trilogy to which TU belongs: '[F]reedom from Christian teachings that train them to spurn a fallen world and a corrupt human body'.[14] Questions, then, are indicative of the narrator's refusal to relinquish their obligation to speak, becoming a mechanism of perseverance and thereby signifying a simultaneous refusal to turn away from a world that is devoid of religion and its doctrines – 'I shall never be silent. Never'.[15]

TU aptly opens with a series of questions – 'Where now? Who now? When now?' – deftly establishing a sense of narratorial uncertainty and unknowing from the outset.[16] The opening triptych addresses the realms of place, person, and time, with the repetitive use of 'now' firmly anchoring the narrative in the present moment for both the narrator and the reader. In this sense, Beckett's opening rhetorical questions possess a similar metafictionality to Camus' interrogatives; the unnamable articulates the questions the reader has as they begin reading the novel, questions that – to draw on Seale's phrasing – 'request' answers but never obtain them. The narrator proceeds to characterise their initial utterances not merely as questions but as 'hypotheses'.[17] This frames the opening questions as a starting point for further investigation, suggesting the novel itself will perhaps be an examination of the where, who, and when – an inquiry into the unsettling, Godless world of the text. As such, within the opening lines alone, the narrator's radical determination to persist, even in the absence of any religious underpinning, becomes unmistakably evident. The opening questions are echoed later in the passage as the Unnamable asks, 'What am I to do, what shall I do, what should I do, in my situation, how proceed?'[18] Theodor Adorno, as noted in Shane Weller's collation of his marginalia on TU, proposed that Beckett's narratives 'present the reduction of life to basic human relationships, that minimum of existence that subsists in extremis'.[19] Similarly to Nussbaum's conjecture, Adorno's idea that Beckett distils the lives he depicts to their most corporeal essence can be discerned in the narrator's rhetorical questions. Through these pleas, the essentiality of questioning – the fundamental desire to know and, in turn, apprehend resonates. It gestures to the relationship between asking questions and the instinctual human drive to persevere, whether through utter confusion or through communication now rendered void. These unanswerable pleas also signify a refusal of conclusive responses. The Unnamable's assertion that these absolutes 'will come back to me as I go along', but that they will 'like a bird, shit on them all without exception', suggests that the human condition in extremis transcends definitive answers.[20] The 'reduction of life' Adorno discerns in Beckett's prose is therefore, paradoxically, both a reduction and an expansion.

Reading questions and questioning as central to this paradox, one might view them as a means through which Beckett interrogates the place of Christian dogma in, as Nussbaum coins it, a 'fallen world'. Beckett's use of hypophora – a form of rhetorical questioning where the speaker poses a question only to answer it themselves – allows his narrator to engage in an active dialogue with the self. It is in these moments of introspective self-deliberation that Beckett's narrator begins to work through the problematics of Christian dogma:

'Can it be innate knowledge? Like that of good and evil. […] They also gave me the low-down on God. They told me I depended on him, in the last analysis. They had it on the reliable authority of his agents at Bally I forget what […] where the inestimable gift of life had been rammed down my gullet'.[21]

Here, the Unnamable's questioning of the innate conception of 'good and evil' and mandated dependence on God calls into question the ethics of imposed religion. The visceral image of occluded speech highlights Beckett's primary objective: to enable his narrator's speech to expand outward rather than, as the 'agents' have done, suppress it inward. Indeed, the passage might be read as a critique of Catechesis – the education of converts or children on the teachings of Christianity. Reading this passage as such, the dogmatic inscription of truth as proffered by Christian institutions is thereby rendered open to critical examination. Through the Unnamable's introspections, Beckett challenges the unquestioned acceptance of religious truths and the authoritative sources that propagate them. By employing hypophora, he facilitates an internal dialogue that actively interrogates these conventional beliefs. Furthermore, the bodily imagery of having 'the inestimable gift of life' rammed down one's gullet speaks to the forceful imposition of dogma. This image is comparable to the judge's evocation in TO, where a life without God or religion is deemed a life devoid of meaning. Once again, we return to the paradox of bodily reduction and the expansion of one's consciousness. While the Unnamable physically resembles a non- or sub-human being, their consciousness – spurred on by questions and a dialogue with the self – perseveres in its endeavour to resist Christian dogma.

It is through the narrator's self-deliberating back-and-forth of that the logic of conventional thought and the authority of religious teachings are temporarily suspended. Like Camus, Beckett subverts the function of questions, drawing upon them not as a means to supply answers, but rather to create a textual space in which the boundaries of certainty are transgressed. Tom Driver observes that '[o]ne cannot say, "Beckett has said so and so," for Beckett has said, "Perhaps"'.[22] It is the 'perhaps' that lies at the heart of these passages, weaving a thread of uncertainty for the reader and in turn acting as a catalyst for something far more threatening than atheism: unremitting agnosticism. By diverging from absolute adherence to the polarising, monolithic voice of Christian doctrine, TU serves as an incisive exploration of the landscape of religious doubt, where, by foregrounding these destabilising questions, Beckett renounces the imperatives and instead favours interrogatives.

While Camus and Beckett's critiques of the intolerant and oppressive nature of dogma might ostensibly be read as abject condemnation, a closer analysis of how their respective narratives critically engage with, rather than criticise, such doctrines suggests a shift towards a more constructive mode of critique. Their approach can be understood as delineating a productive way in which we can begin to look beyond dogmatic constructs, as opposed to merely disparaging them. In Myth, Camus poignantly writes that '[b]eginning to think is beginning to be undermined', which, though perhaps unintentionally, captures the process through which both he and Beckett construct their narratives. If beginning to think is the beginning of being undermined, then being undermined can be understood as the transition from homogenised thought to a view of the human experience independent of rigid doctrinal constraints.[23]

A framework for considering the texts' deviations from dogma is outlined in Roland Barthes' The Death of the Author. While the crux of Barthes' theory – that in order to derive meaning from a text, one must discard the author's biographical meaning from a text, to 'reach that point where only language acts' – may not directly apply here, several aspects of his conceptual thinking are helpful.[24] One key aspect of Barthes' theoretical framework is the duality that, by metaphorically killing the author, one allows for the birth of the reader. In this sense, it signifies a 'freeing [of] the reading process from the constraints of fidelity to an origin' – which in turn opens the space for critical engagement with seemingly immutable religious beliefs.[25] Barthes' theory therefore offers an advantageous framework for understanding how Beckett and Camus create literary landscapes that extend beyond the supposed certainties of dogma.

Barthes asserts that a literary work should not be read as the sole '"message" of the Author-God', but rather as a 'multi-dimensional space in which a variety of writings […] blend and clash'.[26] What is alluded to here is not only the insufficiency of interpreting a text through a monolithic framework – of viewing writing as the product of one pen or mind – but also the idea that literary works are heterogeneous and, in turn, irreligious. Ultimately, Barthes' theory gestures to the necessity of reading texts as artefacts that defy a singular author, meaning and essence, wherein the reader becomes, as outlined in his work, S/Z (1970), 'no longer a consumer, but a producer of the text'.[27]

To apply Barthes' theory to TO and TU, it is perhaps fitting to turn our attention to the novels' closing passages. In the final lines of TO, Meursault contemplates the inevitability of his impending death, directing his thoughts towards his mother: '[s]o close to death, Mama must have felt set free, ready to live once more'.[28] Now, he too 'felt ready to start life all over again'.[29] Meursault's touching sentiment of embracing rebirth and regeneration emerges in the wake of his confrontation with the prison chaplain.

Now said to be feeling 'purged [...] of evil' after renouncing religion and embracing the absurd – an incisive appropriation of Christian rhetoric – Meursault repudiates any authority of an 'Author-God' over his own existence.[30]

When finally he looks to his execution, Meursault articulates his hopes that the spectators will greet him 'with cries of hatred'.[31] The ambiguity of this final remark leaves the task of constructing its meaning to the reader. Its significance is twofold: on one level, it alludes to Barthes' notion of the multiplicity of meaning in a text, while simultaneously serving as the culmination point of Meursault's defiance against Christian doctrine. It symbolises the apex of the narrative's resistance to the monologic impositions of dogma, for few actions are more diametrically opposed to the principle of 'love thy neighbour' than the expression of 'cries of hatred'. On writing TO, Camus articulated his intention for the novel to serve as an "exercise in objectivity".[32] By writing it as such, TO becomes 'writerly'. Its ambiguity and, in turn, the expansiveness of its meaning foster a collaborative dynamic, eschewing any singular interpretation and enabling the text to reach what Barthes calls 'the true place of the writing, which is reading'.[33]

The conclusion of TU closes on a similar note of expansiveness. The narrator's characteristic repetition of 'perhaps' amplifies its inconclusiveness and, in turn, invites multiple interpretations.[34] The final passage, then, is presented as the apotheosis of the apprehensions the Unnamable is tormented by throughout the narrative – namely, the dilemma of persevering. In TU's final exposition, its narrator's frenetic self-deliberating reaches its apex. As they incessantly echo the refrain, 'you must go on, I can't go on, you must go on, I'll go on', we understand them to be struggling against the inertia of life's meaninglessness, grappling with the inexplicability of their own existence.[35] Here, the narrator stands on the precipice of indecision, and the narrative is suspended beyond any 'exterior or interior reality'. Like TO, TU's conclusion also renders a lucid image and regeneration as the narrator ponders, 'perhaps they have carried me to the threshold of my story, before the door that opens on my story'.[36] This sense of cyclicality underscores the narrative's perpetual oscillation between despondency and hope, where the narrator's verbal struggle becomes the ultimate affirmation of their existence. For when the Unnamable remarks that if the door opens, 'it will be I', we return once again to Barthes' idea of denying the 'Author-God'.[37] Beyond what we might here assume is death is not the omnipotent divine, but rather the self. Beckett's 'I' is ultimately transferable partake in the production of the text. Such a conception of production is, however, crucially non-forceful.

As Christian dogma seeks to enact the fundamentals of belief upon its subjects, and in turn serve as a sole constructor of the narrative, the consumer of the writerly text merely participates in a continuous process of construction. As Barthes notes, the reader frees themselves and the text from the 'constraints of fidelity to an origin'. It is through the evasion of such constraints, paired with the liberation of their conclusions, that both Beckett's and Camus' narratives look beyond Christian dogma rather than simply criticising it. We can read the novels' respective refusals to conform to any one definitive conclusion as synonymous with revolting against the very essence of dogma and, in turn, against God. Through the authors' respective construction of textual spaces in which inquiry, scepticism, and doubt are embraced as propitious over fixed doctrinal adherence, both TO and TU can be read as novels that foster a generative agnosticism. In these texts, embracing an absurd contentment in uncertainty eclipses the security of what is known or thought to be understood. Ultimately, this facilitates the reader in looking beyond dogmatic constraints.

As part of his aforementioned definition of dogma, Blackburn also posits that '[d]ogmatism is one possible reaction to scepticism'.38 In light of the analyses conducted in this thesis, there is indeed an argument to be made for the inverse: scepticism is one possible reaction to dogmatism. It is scepticism that drives Camus and Beckett's impulse to question, although importantly does not render their works merely pessimistic. Rather, by engaging in a process of interrogation, both authors leverage scepticism and doubt as generative mechanisms that enable them to broaden and, ultimately, transcend the monolithic voice of Christian dogma.

Both TO and TU appear as works that are neither irreligious nor anti-Christian. Instead, they can be situated within a post-Christian literary canon where, by critiquing dogma in a way that fundamentally opposes its principles, they offer a radical reassessment of Christianity's purported truths. In turn, such a challenge to these entrenched belief systems functions to foster the constructive development of the reader's critical consciousness, illuminating the fallibility of dogmatism and guiding them away from its confines towards independent inquiry and exploration. Both texts encourage the reader to contemplate the spiritual obedience Christianity mandates, yet refrain from advocating for the rejection of faith or religious practice. Instead, they extend an invitation, opening the door to the prospect of re-evaluating one's religious beliefs, while leaving the reader alone at the threshold with the freedom to decide whether to cross it.

Meet the Author

Nel Roden is currently pursuing an MA in English at the University of Bristol, having previously completed a BA in English Literature. Her academic interests include modernism, experimental literature, twentieth-century American fiction, and the works of Samuel Beckett. Nel extends sincere thanks to the subject editors and peer reviewers for their thoughtful comments and valuable feedback.

Subject Law

Subject's Foreword

It has been a privilege to serve as the Subject Editor for Law and to engage with some of the exceptional work being produced at Bristol. This section features a wide range of topics—from medical and mental health law to international law and criminal justice—all contributing to a deeper understanding of law's role in society and its evolution in a changing world.

Thank you to everyone who made this possible. To those who submitted abstracts: your courage and quality of work made the selection process both rewarding and challenging. To the authors of accepted pieces: your engagement with feedback and commitment to refining your work were invaluable. To our deputy editor and peer reviewers: your thoughtful contributions and detailed feedback strengthened each piece. And to the journal's editorial team: thank you for your constant support and for assembling such a dedicated team.

It is a pleasure to present the outstanding work showcased in the Law section of this year's Student Research Journal.

Stuart Hurst, Subject Editor (Law)
Hui Ling Tay, Deputy Subject Editor (Law)

Meet Stuart Hurst

Stuart Hurst served as the Subject Editor for the Law section of the sixth edition of the Student Research Journal at the University of Bristol. Currently in the first year of a PhD in Law, Stuart previously completed an LL.M. at Bristol. His research focuses on psychosocial risk and disability in the workplace, with broader academic interests in employment and labour law, contract law, and equality law.

Meet Hui Ling Tay

Hui Ling is a second-year law student and currently serves as the Deputy Subject Editor for the Law section of the journal. She is particularly interested in how law intersects with real people and systems, finding areas such as medical law compelling for the complex, deeply human questions it raises around autonomy, consent, and care. Hui also has a strong interest in comparative law, appreciating the diversity in how different legal systems approach similar challenges. In public international law, she is drawn to the tension between state interests and global responsibility, especially in relation to human rights and environmental issues.

Un(trans)formed: How does the law surrounding gender recognition following AP Garcon and Nicot v France still manifest as reproductive injustice?

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Abstract

At present, the subject of transgender rights – particularly where they concern the safeguarding of transgender reproduction – has represented a fiercely fought political battleground. The inflammatory debates have inevitably bled into the legal landscape, and trepidation regarding transgender procreation has influenced the way European jurisdictions legally recognise gender. Through *AP, Garcon and Nicot v France*, the ECtHR has undoubtedly made a watershed ruling in declaring that compulsory sterilisation requirements infringed Article 8 Convention Rights. The Courts ultimately ruled on the side of the reproductive rights of trans persons.

However, we must remain vigilant of prematurely celebrating its decision. In doing away with sterilisation requirements, the Court effectively ensured that legal gender recognition remained firmly within the remit of trans-medicalism, placing significant power in the hands of medical providers as gatekeepers to gender recognition.

This article critiques the decision of *AP Garcon and Nicot*. It utilises the theoretical framework of Reproductive Justice to scrutinise the enduring pathologisation of trans bodies, and its effect on the ability for trans individuals to reproduce and parent freely. This article ultimately argues that despite the merits of the case, the long sought-after state of reproductive justice is yet to be served.

Keywords: Legal Gender Identity, Reproductive Justice, Transgender, Pathologisation, Reproductive Rights

Introduction

At present, the subject of transgender rights has represented a 'fiercely-fought battleground'[1,] and within the past decade has been placed at the forefront of socio-political debate. The subject of trans reproduction has historically aroused much controversy, perhaps reflecting an oft propagated contradiction rooted in hetero-normative conceptions of reproduction; that trans reproduction represents a transgression of pregnancy as being inherently female, and a trans man carrying a child presents to be a controversial 'U-turn' in their transition.[2]

The inflammatory debates surrounding transgender rights have inevitably bled into the legal landscape, and the trepidation regarding transgender procreation has had 'a profound impact on the way European jurisdictions legally recognise gender'.[3] The requirements for legal gender recognition prior to AP, Garcon and Nicot v France[4] have reflected these anxieties, with 22 countries within the Council of Europe maintaining a mandate on sterility as a qualification for gender recognition. Such a context drives home the legal significance of AP Garcon and Nicot; in finding that sterilisation requirements for gender recognition violated fundamental Convention rights, the Court ultimately made a highly consequential ruling on the side of the reproductive rights of trans persons.

Whilst *AP Garcon and Nicot* is certainly a hard-won victory, it is however prudent to be wary of prematurely celebrating its decision. In doing away with sterilisation requirements, the Court effectively ensured that legal gender recognition remained firmly within the remit of trans-medicalism, placing significant power in the hands of medical providers as gatekeepers to gender recognition. The reaffirmation of pathologising pathways to gender recognition has thus created tangible disadvantages for Europe's transgender population; one may now be a trans parent, so long as they accept the designation of being a 'mentally-ill' parent.[5]

This article critiques the decision of *AP Garcon and Nicot*, whilst engaging with its implications on reproductive trans bodies. It utilises the theoretical framework of reproductive justice to scrutinise the enduring pathologisation of trans bodies, and its effect on the ability for trans individuals to reproduce and parent freely. This article ultimately argues that despite the merits of the case, the long sought-after state of reproductive justice is yet to be served. Unless judges and the courts are willing to accept a model for legal gender recognition based on self-determination, trans bodies are condemned to the marginality and vulnerability emanating from reproductive *injustice*.

This article proceeds in four chapters. Chapter I discusses the need to focus on trans reproductive rights specifically, and the erasure of trans reproductive bodies both in advocacy and scholarship. Chapter II engages with justifications of the reproductive justice framework and its nexus with issues of trans reproductive rights. Subsequently, Chapter III and Chapter IV will engage in academic criticisms of *AP Garcon and Nicot* through a lens of the reproductive justice framework, ultimately arguing that the Courts have yet to provide all-encompassing protection for the reproductive capacities of transgender individuals.

Part I: Why focus on trans reproductive rights?

1.1 Transgender identities and the significance of legal gender recognition

At the advent of 20th century queer and feminist theory, conceptualisations of sex and gender that were traditionally used interchangeably and synonymously, began to diverge into fundamentally distinct categories. The once intertwined concepts of sex and gender have been disentangled to encapsulate two discrete definitions, with sex typically referring to the biological taxonomy between the male and the female, and gender as a purely social classification.[6] It is thus a category that is *superimposed* on a biologically sexed body. Whilst gender identity and presentation are typically congruent with the sex assigned at birth, there exists an oft silenced community whose gender identity deviates from that of their pre-assigned sex.[7] This gender incongruence[8] - where affirmed gender does not coincide with societal expectation – is encapsulated in the umbrella term 'transgender' (hereafter 'trans').

The provision of gender affirming care – including pathways for both medical and social means of transitioning – is crucial to the mental health and overall well-being of transgender individuals.[9] The legal dimension encompassed in the process of transitioning is the ability for transgender and gender-diverse people to alter their gender designation and names on official identity documents. Such documents manifest as a 'ubiquitous and essential currency of contemporary life'. [10]

1.2 Trans-reproductive bodies: Dysphoric bodies of the law

What is particularly noteworthy is that engagement with the intersection of trans reproductive justice is curiously lacking within the sister spheres of transgender rights advocacy and reproductive rights advocacy.[11] For example, advocates within the reproductive rights movement have on one hand demonstrated their anxieties or even hostility towards trans people claiming space within the movement. Journalist Elinor Burkett, for example, described that the push towards framing the reproductive discussion from being a 'woman's issue' to a 'uterus owner's issue' has the potential of 'erasing' or 'undermining' cis-gender women in particular. [12] The glaring irony of this argument becomes apparent considering the ontological goal of feminist theorists to denaturalise the categorisation of (cis) women as mothers and society's reproducers.[13]

In determining who is, or should be, a legitimate reproducer, Burkett and trans-exclusionary feminists have, in essence, reinscribed the very repro-normative norms the movement has attempted to oppose. By the same token, advocates for transgender rights are similarly not blameless in the disregard and exclusion of trans reproductive bodies. Mainstream trans activism has predominantly fixated on issues pertaining to legal rights such as bathroom access, whereas broader concepts of reproductive and sexual health (including access to contraception, abortion, and assisted reproductive technology) have arguably been marginalised.14

Strangio examines this mutual erasure of trans reproductive bodies, arguing that this lacuna – or rather the apparent erasure of trans reproductive bodies – is not without reason 15. Trans people are consistently told that '[their] bodies are not meant to reproduce, and that [they] cannot and should not parent the kids [they] make the kids [they] raise'.16 The deep-rooted cultural framework that reifies pre-existing rules of 'repro-normativity'17 bolsters the misconception of trans individuals as a 'sterile population' who voluntarily relinquish the ability to reproduce.18 Sweeping assumptions of this nature are not only nonsensical but have the effect of essentialising the multiplicity of trans experiences, entirely disregarding what Yeung describes to be the 'powerful and aching longing' for a child that is commonly present within LGBTQ+ communities.19 Trans bodies are not merely 'vehicles crossing from one side of a coherently sexed gender binary to the other', but rather have the desire to exist with 'child-bearing, sperm-producing and menstruating capacities'.20

Where the notion of transness and the ability to reproduce is seen as mutually exclusive, trans individuals are stripped of their citizenship as sexual or reproductive subjects and are, in essence, written into non-existence and fallaciously presumed to be illegitimate reproducers or parents. This has fostered what Radi calls a 'eugenic social atmosphere'[21]; an atmosphere that appears to justify policies such as the aforementioned sterilisation requirements that were deeply embedded in the legal procedures to change gender markers.

Thus, unless we are willing to unseat such cultural or societal assumptions, we continue to contribute to the eugenic undertones that are instrumental to negative (reproductive) health outcomes for trans people. The subsequent section will argue that the reproductive justice framework provides the much-needed mechanism through which trans individuals may be recognised as reproductive bodies.

Part II: The Reproductive Justice Approach

As we turn to consider precisely why issues of transgender reproduction ought to be situated within the theoretical paradigm of reproductive justice, we must firstly examine the ways in which the mainstream discourse surrounding reproductive rights has failed to provide sufficient mechanisms to critique the present legal framework.

Here, the mainstream reproductive rights movement refers specifically to one which has historically been realised within the arena of an abortion-centric framework, as characterised through a 'pro-choice' or 'pro-life' debate.[22] What is the subject of intense criticism here is precisely this rhetoric of choice. Roberts argues that the language of choice has only privileged white middle-class women who have the capacity and facilities to choose from reproductive options. In such a case, the mainstream movement for reproductive rights effectively casts aside those who sit at the intersection of oppressions.[23] The empowerment to make choices is thus rendered largely redundant in the absence of sufficient resources or secure conditions that allow for people to maintain control over their bodies and lives.

Moreover, the idea that reproductive rights ought not to be focus-ed solely on choice is rooted in the argument that reproduction is not simply a biological process.[24] Inherent in reproduction are entities including the state, the interests of political parties and the interests of religious groups. As such, the question of who should reproduce (and those who should not) is not solely a matter individual choice. What ought to be an 'intensely private' act of reproduction is instead thrusted into the centre of public concern and obsession.[25]

The intersectional approach of reproductive justice is consequently one which repositions the reproductive rights discourse within its political context, accounting for race, gender, and class oppressions.[26] The framework extends beyond the idea of choice as the linchpin of reproductive freedom, and instead focuses on three crucial tenets: (i) the right not to have a child (ii) the right to have a child and (iii) the right to parent children in safe and healthy environments.[27] At its core is the claim that 'all fertile persons and persons who reproduce and become parents require a safe and dignified context' in making reproductive choices.[28] The ideal state of reproductive justice can therefore only exist when 'all people have the economic, social power, and resources to make healthy decisions about [their] gender, bodies and sexuality' (Emphasis added).[29]

How, then, does reproductive justice stand as a natural theoretical home for issues at the intersection of reproductive rights and gender identity? The 'queering' of reproductive justice is by no means novel, with Yeung arguing that the LGBT movement and the reproductive justice movement are similarly underscored by homogenous moral and legal considerations.[30] In shifting the reproductive rights discourse to one which advocates for the access of resources, the framework champions for the rights of minoritised groups – including non-normative reproductive subjects– to have children and raise them with dignity. In doing so, reproductive justice explodes conventional and normative assumptions that the 'legitimate' reproducer solely exists within the confines of a white middle-class nuclear-family[31], and thus is able to bring forward trans individuals within the scope of reproductive discussion.

It is of note that the reproductive justice framework has traditionally focused on motherhood, but that is not to preclude an extrapolation of its analysis to encompass parenthood. This is particularly tenable where reproductive justice is understood to be an 'open-source code' or a mutable framework lending us the mechanisms to critique power and powerlessness within the vast realm of reproduction[32] from Article 8. That is, every individual is entitled to the right to respect for their private and family life, and that the State may not interfere unless it should be deemed necessary in a democratic society.[33]

3.2 Out with sterilisation, in with pathologisation

When faced with the question of whether the requirement for 'an irreversible change in appearance' infringed Article 8, the Court affirmed the judgement of Y.Y v Turkey, in which the precondition of 'permanent sterility' was deemed to amount to de facto 'forced sterilisation'.[34] Extrapolating from its precedent, the Court found that the right of trans individuals to physical and moral security was indeed guaranteed by Article 8.[35] Its judgement was founded on the acknowledgement that the requirement of mandatory infertility of trans individuals created an 'insoluble dilemma'[36]: trans individuals seeking legal gender recognition either submitted to sterilising medical treatments – in spite of their reproductive wishes – thereby jeopardising their right to respect for physical integrity; or they relinquished their right to the recognition of their gender identity, and accepted the socio-legal consequences of a discordant civil status. In such a case, the Court found that France only enjoyed a narrow margin of appreciation[37] and that any imposed requirement for sterilisation or infertility was a violation of the applicants' Article 8 rights. What is abundantly clear is that AP Garcon and Nicot demonstrated the Courts drawing a hard line against any 'involuntary compromise of procreative abilities'.[38]

The Courts, however, adopted a more latent approach towards the requirement to prove a medical diagnosis for 'gender identity disorder'. Controversially, the Court stated that unlike the sterility condition, a requirement for psychiatric diagnosis 'does not directly affect individuals' physical integrity'.[39] State actors as such withheld a wide margin of appreciation when legislating on the diagnostic requirement. Hence, it was found that there was no violation of Article 8 on account of France's requirement to demonstrate the existence of a gender identity disorder.

The implication of AP Garcon and Nicot is as follows: State parties cannot, under ECHR law, impose mandatory infertility; they may still, however, refuse the legal recognition of trans individuals who lack a diagnosis of gender identity disorder.[40] Such a jurisprudential shift in the test used to determine gender transitions is by no means novel; there has, indeed, been preceding developments in the criterion through which the Courts have defined sex and gender.[41] In light of this, the case may, prima facie, be regarded as another consequential development in the jurisprudence of transgender rights by overcoming what Sharpe describes to be the 'genito-centrism' of the law.[42] Nonetheless, whilst the case signifies the apparent 'end of an imposed causal link between anatomy and gender'[43] by means of an explicit departure from sterilisation, the Courts understandings of gender identity remain steadfastly situated within a medical model. It appears that despite the leaps made by the Court in ousting sterility, the spectre of the psychiatric framework of gender determination continues to haunt the legal landscape of transgender jurisprudence. This is arguably the so-called 'insoluble dilemma' repackaged: trans individuals must choose the legal recognition of their gender with the addendum of being deemed mentally ill by the law, or else renounce legal recognition entirely.

The subsequent section will discuss the implications of this on trans reproduction and parentage.

Part VI: Justice yet to be served: Enduring reproductive injustice

4.1 Parenting with dignity in a culture of stigmatisation

It bears repeating that within the ideal state of reproductive justice is the enshrined human right to parent and raise children in safe and healthy environments, and to do so in a dignified manner.[44] What is paramount – as argued by Ross and Solinger – is the (re)construction of societies where reproductive capacities, including the ability to parent, are not pre-determined, controlled or enforced by law and policy.[45] In other words, we must dare to dismantle and unseat the very structures that perpetuate reproductive inequalities and make fallacious decisions on behalf of individuals and communities. Considering the reaffirmation of psychiatric diagnoses as the legal threshold for gender identity, the pressing question is thus as follows: whilst trans individuals now withhold the means of reproducing and procreating, are they able to do so with dignity?

Indeed, examination of the Court's judgement demonstrates that recourse to a psychodiagnostics test is justified as a safeguard against those who may not be 'really transgender' from 'embarking unadvisedly in the process of legally changing their identity'.[46] This view is arguably unduly paternalistic and superfluous. Gonzalez-Salzberg substantiates this view stating that to insist that all trans individuals be deemed mentally ill for the protection of others is 'unnecessary', creating a 'tiered system of mental stability'.[47] This reinforces a binarised and hierarchised vision of reproductive bodies; it reiterates the notion of cisgender populations as 'mentally sound' and thereby normative, whilst trans individuals are labelled 'mentally ill', non-normative and anomalous bodies of the law. Notwithstanding the continued endorsement of the stigmatisation and pathologisation of trans bodies, it further reinforces the narrative of trans individuals as 'bad parents' who are ill-fitted for the role of parentage.[48] The legal requirement for a diagnosis of gender dysphoria undoubtedly feeds into persisting and misconceived assumptions that trans parentage is detrimental to children, often founded on heteronormative societal expectations of what a 'real' family ought to be.[49] In fact, those who typically oppose trans procreation rely on the portrayal of trans identities as 'inherently pathological', thereby delegitimising trans individuals as well-suited parents.[50] The consequence of AP Garcon and Nicot is such that trans individuals may try in vain to attest that they experience no mental distress, emotional instability or so called 'disordered confusion'[51], this unfortunately is ultimately of no consequence to the legitimation of their parental and procreative capacities. The mere fact that they are trans will always inevitably mean that they are, by law, symptomatic of pathology.

The Courts have, ergo, named an undeniably high price to ob-tain legal gender recognition, and it is a price that is inexplicably paradoxical. It is fundamentally contradictory to demand a psychiatric diagnosis from trans individuals, then use this as a pathologised basis to undermine their family rights and the right to parent.[52] Recalling the core tenets of reproductive justice, it is indeed questionable as to how trans individuals may parent with dignity, if they are consistently dogged with the stigmatisations teamed with pathologisation.

AP Garcon and Nicot, in essence, stands as a reinforcement of state regulations dictating 'legitimate' parenthood – of who can reproduce and who cannot, and of who can raise and parent children and who should not. This persistent exercise of power is not justice as envisaged by the reproductive justice framework; it remains still, reproductive injustice.

4.2 Towards Reproductive Justice: Embracing Self-Determination

If reproductive justice is located as the site through which 'all people have the economic, social power and resources'[53] to make their own decisions about their bodies, how ought the ECtHR and subsequently State Parties within Europe bring legal gender recognition in line with this conception of justice?

The answer may perhaps lie in the removal of the diagnostic requirement, and in its place, the embracing of a self-determination model. The self-determination model is such that legal gender recognition procedures ought to be founded on the self-declared gender identity of the individual, thereby abrogating the need for a judge, psychiatrist, or medical provider to stand as gatekeepers to gender identity. The adoption of such a model would, in effect, do away with any psychiatric diagnosis that actively fortifies the implicit link between trans identities and pathology. In doing so, this would represent a significant shift towards depathologising trans identities. Legal recognition of gender would no longer be founded on or associated with a mandatory mental health diagnosis that perilously views trans identities through a lens of psychiatric and psychological illness.

What is ultimately undeniable is that embracing self-determination is crucial to achieving the conception of reproductive and bodily autonomy that is so fiercely advocated by the reproductive justice framework. Only then are trans individuals able to procreate, parent, and raise children in dignified, healthy, and safe environments that are divorced from the stigmas of pathology. In this sense, justice is only served where individuals and communities are able to make decisions for themselves and their bodies beyond the undue influence of the state or other authorities.

Conclusion

Whilst *AP Garcon and Nicot* must be accredited for successfully ousting sterilisation requirements that directly infringe the bodily integrity of trans persons, the ECtHR has, however, yet to dispense of mental health diagnoses as a threshold for legal gender recognition. It is clear that *AP Garcon and Nicot* is not, therefore, a panacea to the reproductive injustices they face. In concretising the pathologisation of trans individuals, this leaves them vulnerable to disparate parental rights, reinforcing societal norms that non-normative families are inherently lesser than hetero-normative families. In other words, we must dare to question how the law remains complicit in obstructing reproductive justice. This entails the acknowledgement of the powerful and aching longing'[54] for a child and the re-centring of trans reproductive bodies that have traditionally been silenced and rendered invisible. At present, it is evident that the law surrounding trans reproductive rights remains, for the most part, untransformed.Trans individuals continue to be 'discriminated against, pathologised, and victimised'[55], and complete reproductive emancipation is yet to be achieved. Justice, is yet to be served. In the long, hard journey of transgender (reproductive) rights, the light is yet to be seen from the end of this arduous tunnel. There remains still, a long way to go.

Meet the Author

Abbie Chen is a feminist scholar currently completing a master's degree in Gender and International Relations (MSc) at the University of Bristol. With a background in legal research, having earned an undergraduate degree in law (LLB), Abbi's early academic focus centered on the intersection of law and contemporary socio-political issues. Her current research is grounded in feminist and decolonial theories, incorporating queer, gender, and sexuality studies. Taking an interdisciplinary approach, Abbie explores themes related to conflict-affected societies, post-conflict transitions to peace and justice, civil-military relations, and migration. Informed by intersectional frameworks, her work interrogates how colonialism, capitalism, gender, and race have historically been employed to justify, legitimate, or sustain conflict and the policing of borders. These critical perspectives shape her ongoing research into the politics of death and mourning, particularly in relation to normative conceptions of sexuality within the context of Israel's occupation of Palestinian territories.

Subject Philosophy & Theology

Subject Foreword

This year's Philosophy and Theology submissions have been exceptional, showcasing impressive depth, originality, and engagement from both writers and reviewers. The papers highlight the ongoing relevance of these disciplines and aim to inspire further exploration.

Topics range from death as deprivation harm and cognition in typing to thought-writing in poetry and abstract creationism in music. Theological pieces explore Orthodox Jewish women and reproductive tech in Israel, Zen in Japan, and Catholicism's role in Polish nationalism.

Sincere thanks to the authors for making these insights accessible, and to peer reviewers Alex, Anastasia, Ayaan, Harvey, and Yifei for their dedication. Special appreciation goes to Deputy Editor Ujjwala for her outstanding support. We hope readers enjoy and reflect on this rich collection as much as we have.

Georgina Moverley, Subject Editor (Philosophy & Theology)
Ujjwala Chandra, Deputy Subject Editor (Philosophy & Theology)

Meet Georgina Moverley

Now in her second year with the journal, Georgina Moverley has had the honour of serving as the Subject Editor for Philosophy and Theology. Currently in the second year of her undergraduate degree in Liberal Arts, with a pathway in Theology, she feels she has grown alongside the journal and hopes readers will appreciate its value as much as she does. In addition to this role, Georgina also serves as an editor for other publications, including Aurora, the Liberal Arts journal. She believes the papers featured are strong representations of the discipline and sees the journal as an essential platform for making this important work accessible.

Meet Ujjwala Chandra

Ujjwala Chandra is currently pursuing a Master's degree in International Relations at the University of Bristol and serves as the Deputy Subject Editor for Philosophy and Theology. With a background in Philosophy from the University of Delhi, India, their academic interests lie in both foreign and domestic policy, particularly in exploring how data influences decision-making. They are especially focused on connecting theoretical frameworks with social scientific data to inform effective policy. Outside of their academic work, they enjoy reading and painting.

Ties that Bind and Break: Catholicism's Historic Role in Polish Nationalism

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Abstract

Poland stands tall, proud of its deep cultural ties with religion; one of the unofficial slogans of the Republic is "Bóg, Honor, Ojczyzna" or God, Honor, Fatherland. This article explores the way in which the Church stood as a unifying force in times of oppression in Poland, and how the concept of Poland as the "Christ of Nations" emerged thanks to the works of Adam Mickiewicz. This narrative became fundamental to Polish cultural resistance in both the Partitions and the later Communist period. Yet, I will examine how the Catholic Church as this binding force slowly begins the break in the 21st Century, as Politics and Media begin to become involved with the Polish Catholic Church, and vice versa, how the Catholic Church becomes intertwined with Politics. How did this institution of hope and bastion of Polish culture, language and identity slowly start to become perceived as a controlling force. I will examine this change, the secularisation of youth in Poland, what the next steps are for Poland, the weaponization of religious rhetoric by the far-right in modern politics and how this rhetoric actually portrays the ideas presented by Christ in the Bible.

Keywords: Polish Messianism, Political Theology in Poland, Polish Identity and Catholicism, Polish Romanticism and Identity, Messianic Nationalism

The Emergence of Jesus in Polish Identity:

Poland's Catholic Identity can be traced back to Mieszko I's conversion to Catholicism in 966. However, I will be examining the time period of the 19th century and how Catholicism truly emerged as part of the Polish Identity and as a consequence its presence in modern nationalist identity. Poland was partitioned between Prussia, Russia and Austria-Hungary – ceasing to be a nation for 123 years, disappearing off the map. Yet the Polish identity didn't capitulate to foreign influence, it remained. Romantic literature emerged during this era of a"Poland Exiled" where numerous authors wrote of ideas of martyrdom and suffering. Historians such as Monica Gardner argue that these poets were the sustenance of Polish identity, bringing their hidden heritage to light – allowing the conquered to claim back their selfhood (Gardner 325). One of the most famous Polish-Romantic Poets was Adam Mickiewicz, whose words have continuous effect on the ideas of Polish identity of today; some of the most famous being "Forefather's Eve[1]" and "the Book of the Polish Nation and Polish Pilgrimage[2]" which were published in the 1830s, both carrying themes of the nationality of Poland in exile. In the latter, Mickiewicz personifies Poland into an individual with Christlike tendencies:

"And the Polish nation was martyred and laid in a grave, and the kings exclaimed: We killed and buried Freedom […] because [the] Polish nation is not dead, its body lies in the grave, and its soul descended from the earth[…] And on the third day the soul will return to the body, and the nation will the body, and the nation will rise again, and will free all the peoples of Europe from slavery." (Mickiewicz 11) [3]

There are messianic parallels between Poland and Jesus in the Bible; as Mickiewicz deliberately uses the words of "Martyred and laid in a grave" to draw a connection with Christ's burial after his crucifixion: "So Joseph bought some linen cloth, took down the

[1] Dziady
[2] Księgi Narodu Polskiego i Pielgrzymstwa Polskiego
[3] "I umęczono naród polski, i złożono w grobie, a królowie wykrzyknęli: Zabiliśmy i pochowaliśmy Wolność. [...] Bo naród polski nie umarł, ciało jego leży w grobie, a dusza jego zstąpiła z ziemi, [...] A trzeciego dnia dusza wróci do ciała, i naród zmartwychwstanie, i uwolni wszystkie ludy Europy z niewoli."

body, wrapped it in the linen, and placed it in a tomb cut out of rock." (Mark 15:42-47). The next line draws quite a literal comparison as it states the Polish nation will rise on the third day to free Europe from slavery. This is a clear similarity to Christ's own death and resurrection after 3 days, as it too freed humanity from the slavery of sin. It is imperative in the study of Catholicism in Poland to acknowledge the historical context of the past that led into the emergence of literature such as this, which paves a way for national identity. To understand Polish Catholicism and how it ties into nationalism we need to learn how and why it emerged in the first place. In 1867, Alexander II introduced the doctrine of Russification in Poland, banning the language from government. By the following year, the ban reached schools where all subjects were to be taught in Russian – except for Polish Language and Religious education. By 1885, only Religion could be taught in Polish; the language itself was banned from classrooms and school grounds (Porter 146).

Mickiewicz's Poland: A Nation Martyred

Andrzej Walicki, a Polish historian writes about the implications of Mickiewicz's work and how it influences the "non-existent" Polish people; he elaborates on the parallels of Poland and Christ. The nations that partitioned Poland are like the Roman Empire, pagan. But not to pantheons of gods but rather in their idolization and worship of European Ideals such as commerce and expansionism (Walicki 248). Poland's death is framed to have purpose, just like Jesus' death. Walicki argues, it serves to draw parallels, to show the resemblance of the two rather than the equivalence. The narrative creates comfort to the people of the nation, serving as reminder that they will rise again as a people. Poland and its' exiles were meant to be a shining example for Europe upon its return, akin to Christ's Disciples in the Acts of the Apostles. Moreover, Walicki also argues that Mickiewicz has some xenophobic undertones in his writings as he warns the Polish people of being a "flock amongst wolves" whilst also calling them "apostles amongst idolaters" (Walicki, 250). What this does, according to Walicki, is create the notion that those who are not Polish in the eyes of the Polish people are the enemy, whilst the Polish are "Knights of Universal Freedom" (ibid). It creates a sense of national pride and duty to be upholders of Christianity and to be wary of those who are not 'us'. We can observe the beginnings of a Catholic nationalistic identity, where the Polish identity is bound with the ideas of being chosen to lead and represent the ideas of God.

Xenophobia is definitely an issue within modern Polish politics, as we can see in the former governance of the Law-and-Order[4] party which acted towards groups such as migrants with prejudice. We can examine this with how Polish Politicians demonize refugees, in this case regarding the crisis on the Eastern Border. Journalists present the prejudice, quoting party leader such as Jarosław Kaczynski stating that refugees "won't abide by Polish Law", ministers saying refugees are "horny bulls", even the President Andrzej Duda saying that refugees create potential for "epidemics" (Mazzini). Cleary, there is a problem of xenophobia with politicians, which cycles back towards those ideas presented by Mickiewicz – those not of the same nation or creed, those who are not 'us', those are the people Poland must be wary of.

The Church as Poland's Beacon

The Polish Catholic Church wasn't a constant force of negative nationalism. Rather, in times when Poland didn't govern itself, it was a source of hope and resilience for the Polish population. Anna Królikowska argues that literature was so intertwined with Catholicism because of the fact that it conveyed a lot of similar ideas. For example, the devotion to Mary as Queen is central to Mickiewicz but also to Polish Culture. Therefore, as Królikowska states they "blended deeply into an ideational layer of culture" (Królikowska 445). People would congregate at churches, as it allowed for people to speak their own language - here it kept the heart of Polish culture beating (Hruby 318). As Królikowska had stated, we can observe the blend of Polish-Catholic literature as

[4] Prawo i Sprawiedliwość (PiS)

one, in Adam Mickiewicz's most famous work – "Forefathers Eve". He writes:

"Poland has been the scene of such […] cruelty at the hands of the tyrants who oppress Her […] The history of martyred Poland" (Mickiewicz 141).

Again, Biblical parallels are made; capitalising 'Her' to personify Poland is suggestive of the argument Królikowska had made of Mary and her role of Protectorate of Poland. If Poland has been under cruelty, then it is not an attack on just itself but on all of Christendom. Mickiewicz continuously alludes to the fact the 'death' of Poland – its martyrdom – isn't in vain. Its destruction is at the time vital for Europe's later salvation. Ideas of Polish Messianism are so ingrained in its own cultural literary work as both the Church and text itself blended together, aiding one another. These texts are used within Polish curriculum to this day as we can see through an announcement via an educational news page titled: "Forefather's Eve Part III. by Adam Mickiewicz is a mandatory exam for the 2025 Matura Exam[5]" (Konczal). It can certainly be argued that the presence of these Romantic Poets is felt in all corners of life. It is unsurprising that the spirit of nationalism and idea of Poland's position of saviour can be felt in today's Polish society. Evidently this text is important, as we can see during the student strikes of 1968. Poland at the time was a country under the USSR, once again experiencing censorship and rule by a foreign entity. Marcin Zaremba writes regarding these events and states that the stage performance of the play was – by the Communist backed government – deemed 'Anti-Russian' (Zaremba 771). This in turn led to students protesting against censorship of a culturally important anti-imperialist text. The fact these protests emerged goes to show how important the text was within the Polish population; already by the 1960s it became a staple of Polish culture. Having it censored led to the continuous idea that this text was a part of the inherent bastion of what it means to be Polish – it cannot be taken away.

Nonetheless, not all nationalism in this period was positive; around the time in 1968 there Nonetheless, not all nationalism in this period was positive; around the time in 1968 there was anti-Jewish Pogrom led by the Polish-Communist government. Piotr Żuk explains that although the Six-Day War occurred in 1967, it was not until the student protests of 1968 that the Polish communist regime invoked it as a pretext to launch a Pogrom to divert attention from the student protests of the same year. (Żuk 74, 76). Nationalistic ideas were used in order to push blame off the government and onto the Jewish minority group in Poland (ibid). Just as in the previous chapter, nationalism is used as a tool to strike at minority groups. Nationalism can be used as in order to fuel personal gain of governments in the pretence of following culture. Żuk discusses how in 2018 the former PiS government celebrated the 100th Anniversary of Polish Independence yet, no acknowledgment of the events of the 1968. This can be explained by an earlier argument presented by Żuk, citing Zaremba, who claims that there is an ongoing battle for national identity. Those in power need to present the national identity in a positive way in order to keep a nationalist agenda, meaning that as a result they will ignore historic events that could undermine nationalism (ibid 74). A force of nationalism emerged out of the protests. The texts that inspired the protests are themselves based on national identity with ideas of self-determination with a religious will driving it. A Catholic banner that challenges the atheistic dogma of the USSR. However, this tool of unity ultimately used to marginalise minority groups.

John Paul II: Catholic Resistance Leader

Thus far we have seen the influence of the Church on Poland, and how Mickiewicz's texts became an idealisation of Polish Nationalism. I will now be examining indisputably the most influential figure in modern Polish history, Karol Józef Wojtyła or as he is better known, Pope John Paul II. Suzanne Hruby writes regarding the impact the Pope had upon the Polish community with his visit in 1979 after his election to the Holy See. It is important to note the year of the text I am citing was published in 1982 which is 7 years before the transition to democracy in

[5] "Dziady" cz. III Adama Mickiewicza to lektura obowiązkowa na maturze 2025"

Poland in 1989, it allows us already to see how the Papacy allows for a road to democracy to be constructed within Poland. Regarding the Papal Visit, it is clear that having someone of the same nationality at the head of such institution would be a morale boost for the Polish Solidarity Movement. Lech Wałęsa, the leader of it, stated that the Church served as upholding national interest (Hruby 325). Yet again, the idea of the Church as a bastion of Polish ideals emerges, evidently a bastion for the Solidarity movement since the institution is pivotal for the retention of ideas and resistance against occupation. Other Church members were also important for the stand against the USSR such as Father Jerzy Popiełuszko, a priest who supported the Solidarity movement, murdered by secret service members. A Time's article from 1984 even gives us a glimpse at his importance; his funeral attended by around 400,000 people with even a speech by Wałęsa (Kohan).

In 1979 on the 2nd of June, John Paul II famously says, "the pilgrimage that we Poles are making down through the history of the Church not only along the ways of our motherland but also along those of Europe and the world" (John Paul II 1979). It is no mere coincidence that the Pontif alludes to the title of Mickiewicz's title of "the book of the Polish People and Polish Pilgrimage, it is a precise move on his part. It becomes evidently clear as, the following day in Gniezno, in his speech he directly quotes Mickiewicz as he says, "a civilization truly worthy of man must be a Christian civilization" (John Paul II 1979). John Paul II is aware of the messianic Nationalistic ideas embedded within Polish literature, spurting the ideas of a shared national identity in faith, yet we can see how it is a continuation of the xenophobia of one singular religious identity of a nation.

On June 2nd in Waraw he states, "Without Christ it is impossible to understand the history of Poland […] In him (Jesus) it becomes the history of salvation." (John Paul II 1979). John Paull II was pivotal in the reignition of Polish Catholic Nationalism against the Communist regime, evident by the fact that priests such as Father Popiełuszko and the institution itself served to preserve national Identity. The Church also allowed for the Solidarity group to function and for ideas to be shared that would go against what the state mandated. A multi-generational impact can be felt due to those who would risk their lives in order to speak out and allow for Poland to have solidarity in its own identity. The Pope echoed a message that has been with Poland from the partitions to its emergence to its continuous struggle for democratic self-identity, a message heard in its anthem: that Poland is not yet lost.

The Church as Poland's Burden

Examining the political landscape helps us understand the changes of Poland and the Church. In this section, I will continue to examine the attitude towards refugees by the former government as they lost the elections due to a coalition whilst still retaining a majority of the popular vote. The Law-and-Order party prides itself on its Catholic identity and the President himself has stated that "Christian values form the deep history of Poland […] I would say a conservative Catholicism" (Holdren). The head of the President's own cabinet has stated "A good Christian is someone who helps, not necessarily by accepting refugees" (Cienski). Let us turn to examine the fundamental Catholic teachings on if we are to determine the accuracy of the testimony of these proclaimed Catholics. Pope Francis is outspoken on refugees, it's illustrated in his message to the lay people as he's said: "During the flight into Egypt, the child Jesus experienced with his parents the tragic fate of the displaced and refugees […] In each of these people, forced to flee to safety, Jesus is present" (Francis). Whilst similarly John Paul II, the Polish Pope, has said "We see greater ethnic, cultural and religious tensions, which severely affect migrants and refugees, who are especially vulnerable to the prejudice and injustice which often accompany these tensions" (John Paul II). Catholic teaching therefore is consistent in its message about refugees, the teaching is love and compassion for these people; rather than see them as a statistic Catholics are called to see the image of God in them and aid them as if they were aiding Jesus himself. In Kasia Narkowicz's research she explores the relationship of the Church and Government as to why such anti-refugee stance exists; she highlights how PiS representatives would reject Francis' message on refugees. (Narkowicz 364). Ultimately these religious teachings are ignored even by a party that is so committed to upholding Catholic values. As Francis states, Jesus was a refugee, who advocates love for our neighbour. For example, in the Parable of the Sheep and the Goats Jesus says, "I was a stranger, and you invited me in" (Matthew 25:35). Jesus' message wants us to care for people who aren't "us", yet we live in times where we are viewing migrants and refugees as not people but rather data on the news. The Polish Church also doesn't draw itself from negative connections; Jacek Międlar during his time as a Priest organised a sermon on the Right-Wing Nationalist Party's Anniversary (the ONR). There was a march with Islamophobic and antisemitic rhetoric and consequently the Church apologised and distanced itself from him (Narkowicz 364). Narkowicz brings us some strong points regarding how the Church in Poland stays silent to such individuals. It isn't an isolated case as she presents how one priest calls the ONR a patriotic loving party. There is a clear indication that there is a problem with the Church since it appeals too much to both political and nationalistic sentiments, whilst not condemning those who manipulate faith for their own gain. Nor does it help promote the true message of love that Jesus displays in the Bible.

A New Era for Poland?

Poland though, is secularising as a country. Robert Carlton writes regarding the decrease of mass attendance in Poland in 2015. He states that self-labelling Roman-Catholics have decreased by 6.4% and how there has been an increase of individuals not associating with religion. (Carlton 2015 34). Carlton's research comes from 2015, and we should compare this with more recent research. I will use a report by the Catholic Intelligence Agency[6] (eKAI) - which is an association that is linked with the Polish Catholic Church. They state that from 2023 fewer people are trusting the Catholic Church in Poland: "public trust, is also weakening - in the last decade it weakening - in the last decade it has decreased from approximately 65% down to 48%[7]" (Przeciszewski). Carlton even examines how Polish people didn't like having their lives controlled by a government during the communist regime, but some consider it hypocritical as the Church seems that they take sides within political issues as well as dictating how someone should live in their own private life (Carlton 37). People clearly want to live their own lives, without the constant scrutiny of the Church. Supporting evidence comes from the Centre for Public Opinion Research[8] (CBOS), which regularly inquiries into the opinion of the population concerning numerous topics. This report comes from 2021 and shows that "the proportion of regular practitioners in the youngest age group (18-24) fell from 69% in 1992 to 23% in 2021. The percentage of non-practicing increased from 8% to 36% during this period" (CBOS). We have two statistical bureaus: one that comes from a Catholic perspective and one that is an analytical unbiased institution. Both show that the Church is in fact in decline because there is no vital need to keep culture and identity alive in a time when there is no oppression in Poland. As a self-determining country the young people of today's Polish society are not in need of reassurance of their own historical culture and identity, as there is no foreign entity that is trying to dismiss this.

What is next for Poland.

To conclude, the Catholic Identity emerged as a necessity of preserving Polish Culture and Identity in a period when both were systematically supressed. It can be a force for good, as evident by Pope John Paul II and Jerzy Popiełuszko, but now nationalism has become a dangerous force that goes against Jesus' own message. People do not want to be told what political party to support. They do not want restrictions and control over their identities. In an ironic twist of fate, it would seem that the Polish Church has become the entity that, at the time of the Partitions and USSR control, it was fighting. During this period these

[6] Katolicka Agencja Informacyjna
[7] Zaufania publicznego – w ostatnim dziesięcioleciu jest to spadek z ok. 65 proc. do 48 proc (Przeciszewski 2023)
[8] Centrum Badania Opinii Społecznej

occupying institutions told the Polish people what moral ideas to subscribe to and what to believe whilst silencing independent thought. But now evidently by the Church meddling with politics and politics meddling with the Church, people have lost faith in the Church as an institution. It no longer is beacon of hope of individualism and expression but rather an oppressive power telling people what to think. I believe that Poland will continue to secularise, people will form their identities away from the Church, but as the Church is so ingrained in the identity of the country people will still look to it for guidance and community. The Church will not lose its place in Poland but rather it will take a step back from the active force that it holds. Political decisions will not be made on what the Church promotes but rather they will form on what is right for the greater success of the people and the country itself.

Meet the Author

David Ostrowski is an MPhil student in the Department of Religion and Theology within the School of Humanities at the University of Bristol. His research focuses on Female Mysticism in the Medieval Period, with particular interest in understanding the significance of the words and actions of mystics in their historical context and their impact on contemporary understandings of faith. Originally from Poland, having moved to England in 2005, David has long been passionate about Polish history and culture. Through his MPhil research and journal articles, he aims to shed greater light on Poland's rich heritage. He extends his gratitude to everyone at BILT—Jay, Lilian, Georgina, and Ujjwala—for the opportunity to present his research ideas and to grow academically.

Subject Politics & Sociology

Subject Foreword

At a time when the loudest voices in politics are so often marked by pessimism and division, this year's contributions to the research journal offer a refreshing alternative. Not only do these authors engage with complex global challenges, but they also ask difficult questions and point us towards meaningful change. Whether it's understanding the motivations of female terrorists or exploring decolonial approaches to transitional justice, all the papers featured here demonstrate a nuanced and thoughtful contribution to issues that dominate public debate. Together, they remind us why forward-looking research, and a commitment to critical, curious thinking, matter more than ever.

A huge thank you to the authors for their inspiring work, and to our peer reviewers, Radhika, Harry, Marley, Wisdom, Joseph, and Nicole, whose feedback helped shape the final pieces. We're also very grateful to our Deputy Editor-in-Chief, Lilian Sudi, for her tireless support and guidance throughout this process.

It has been an honour to contribute to this year's journal, and we hope you find all the research in it as insightful as we have.

Alex Kabia, Subject Editor (Politics and Sociology)
Perdie Hibbins, Deputy Subject Editor (Politics and Sociology)

Meet Alex Kabia

Alex Kabia is a Distinguished Chevening Scholar pursuing a PhD in Politics at the University of Bristol (UoB). At the UoB, Kabia teaches Theories of International Relations. He also serves as Politics and Sociology Subject Editor for the Bristol Institute for Learning and Teaching (BILT) Student Research Journal. At BILT, Kabia owes many thanks to Perdie Hibbins, whose intellectual self-sufficiency significantly assisted during the journal review process. He had previously served as Adjunct Faculty for various universities in Kenya. Kabia has served as a board member of the Global Centre for Policy and Strategy (GLOCEPS). He received the British Foreign and Commonwealth Chevening Scholarship Award for 2017/18. Kabia was a lead researcher and analyst in the Office of the Auditor General (AoG) during the audit of the 2010 Constitution of Kenya. He has also consulted as a policy analyst and strategist for various institutions in the Horn of Africa and beyond.

Meet Perdie Hibbins

Perdie Hibbins is a final year undergraduate studying Philosophy and Politics at Bristol. She is particularly interested in immigration politics and volunteers regularly with organisations that assist refugees and migrants in Bristol. This is her first editorial position beyond working for her student magazine in sixth form. She hopes to build on these experiences when she leaves university, pursuing work in journalism and research.

How can a Feminist Approach to Understanding the Motives of Terrorists be used to Improve Counterterrorism?

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Abstract

Both conceptually and in practice, counterterrorism efforts have been continuously stunted due to an androcentric understanding of terrorism. As a subject of security, 'the terrorist' has become sexed and deemed male, catalysing gendered assumptions of motivation that have constructed misdirected and flawed counterterrorism policies. The purpose of this paper is to de-centre such androcentric understandings that erroneously sustain counterterrorism efforts. Such essential de-sexing of the terrorist subject and its motivations may be precipitated by a feminist standpoint that equips a gender framework, which will constitute as the methodology for this paper. The first section of this paper explores how understandings of terrorist motivations may become diversified through considering the presence of women within terrorist currents in gendered and thus meaningful ways. The second section of this paper interrogates how forms of gendered insecurity function as valid motivators for women to participate within terror. To ensure the conceptual risk of reinforcing the homogenised image of the female terrorist as a helpless victim is inhibited, the final section of this paper explores how women become motivated to engage with terror as a form of autonomised political participation, so that a multidimensional understanding of motivations may be acquired and better inform counterterrorism strategies.

Keywords: Feminism, Gender, Counterterrorism, Terrorism, Security

Introduction

In its current state, counterterrorism as an academic field and political practice suffers from a deeply circulated homogenisation of androcentrism. Counterterrorism strategists and policymakers have provided the often-invisible entity of terrorism with a concretised body that is persistently male, becoming the authoritative model from which energies of prevention are directed. The reluctance to engage with the female terrorist as a valid, growing and diversifying subject of security has been described as one of counterterrorism's 'greatest challenges', contributing to a climate of deficiency that poses a wider, feminist concern (Gasztold, 2020: 85). This paper will argue that the implementation of a gender framework can elucidate the continuous evolution of women's motivations for participating in terror, ensuring that their presence is acknowledged and counterterrorism enriched with operational efficacy.

The following argument will explore a dual approach to interrogate and understand women's motivations for engaging in terror. The first section of the paper 'Adopting Gender […]' outlines the importance of equipping gender as a framework to understand the complexities that facilitate women's presence within terror cells. Empirical examples of media reports that rely on gendered assumptions and stereotypes concerning female terrorists are deconstructed. This deconstruction reveals how such a deterministic language contributes towards a normative understanding of female terrorists as devoid of agency, an assumption that inhibits counterterrorism efforts. The second section of the paper, 'Insecurity as a form of Motivation', continues the use of a gender analysis in its application to how women's identity, sexual and physical insecurities contribute to motivation and consequent radicalisation. The final section, 'Political Participation […]', affords a feminist critical insight into how terror activity can function as an expression of agency for female terrorists. As the approach will be informed by a feminist agenda that seeks to resituate female terrorists as autonomous and multidimensional individuals throughout, it is asserted that this position does not function as a defence of female-attributed terror activity, but as a provision of nuanced insights into motivation that can better inform counterterrorism measures to ensure effective mitigation.

Adopting Gender in Contrast to 'Adding Women':

The most recent statistics released by the Home Office (UK) in their 'Operation of police powers […]' report demonstrate that 248 arrests were made for terror-related activity throughout the year of 2024 (Home Office, 2025). In instances where the sex was known, 19% of the perpetrators arrested were female, forming an increase of 27.1% in female-attributed terror acts in comparison with the previous year (Home Office, 2025). These statistics reveal that, at least domestically, the radicalisation and activity of female terrorists is unarguably increasing. However, unanalysed statistics produced post-arrest that ignore the complexities of gendered factors, in adoption for providing sex with a foundational and deterministic status, are oversimplified and insufficient if pre-emptive counterterrorism practices are to be enhanced. If counterterrorism researchers do accept the existence of women within terrorist organisations, conceptual barriers to a comprehensive and diversified understanding of their motives persist that require deconstruction. Such conceptual barriers enact influence as stereotypes that are explicitly gendered (Gasztold: 115, 134, 139, Cunningham: 119, Jacques and Taylor: 504, 511). One of the dominant representations of women terrorists is that they are anomalous; a rarity and a deviation from the norm (Campion: 1, Gasztold: 95). Another representation that persists, is the notion that female terrorists are apolitical and that their behaviour is a product of personal feeling and thus 'irrational' (Gasztold, 2020: 134). This paper acknowledges that there exists a wider academic argument of all and non-gender specific terrorism as essentially 'irrational' (Abrahms, 2008: 82). Whilst this argument cannot be substantially considered within the scope of this paper, I argue that such casting of women terrorists as irrational is particularly gendered and poses operational limitations to counterterrorism strategies in the underdeveloped understanding of their motivations. Thirdly, this paper asserts that women terrorists are stereotyped as beings of passivity, whose motivation is explicated by extrinsic influences and not agentic desire which is disregarded (Jacques and Taylor, 2009: 504). Such gendered representations are sustained through their promulgation by mass media (Gasztold: 103, 134, Jacques and Taylor: 505, Delahunty: 45, Hulsse and Spencer: 576).

An example of this is evident in The New York Times' coverage of an attempted assassination by the White Knights of the Klu Klux Klan. Despite Kathy Ainsworth's involvement in the assassination, documented membership to the terrorist group and observed connection to a series of previous white supremacist attacks, she was described as 'a woman companion [… who] was killed' (Campion: 149, The New York Times, 1970). The New York Times reaffirmed this exclusionary position on women terrorists in its report of an anti-Semitic attack, in which three people were shot and killed by Francine Graham and David Anderson in Jersey City (Knoll, 2019). The article informs readers of Graham's recent occupation as a 'nurse' and retells the action within a polarised framework of gendered agency and passivity, as her partner 'Mr. Anderson sprang out […] quickly raised a rifle […] firing without hesitation while striding across the road. […] Ms. Graham […] held a shotgun, […] less confident, [...] scurried after Mr. Anderson' (Knoll, 2019). Anderson's ideological affiliation was also detailed in the article, whilst no religious or political beliefs were included regarding Graham (Knoll, 2019).

Most recently, Vice published an article entitled 'She was a Teacher and Mother. She Became a Suicide Bomber' when reporting the Baloch Liberation Army's attack in Karachi University, Pakistan (Farrukh, 2022). A gendered rendering of Shari Baloch's identity as a 'doting mother of two' is highlighted when explaining how four people were killed during an explosion she detonated in a 'shocking' and 'surreal' event (Farrukh, 2022). These empirical examples of media reports that detail acts of violence committed by women terrorists reinforce the notion that such individuals are continuously portrayed in a manner that denies agency and subscribes unto them gendered attributes of passivity, abnormality and emotionality. Ultimately, such gendered representations ensure that women terrorists are understood as products of coercion, and this poses severe limitations to how counterterrorism strategies may consider their motivations.

When theorizing on gender and counterterrorism, there exists a cognitive dissonance between the two. Herschinger criticises research on terrorism as essentially 'gender [blind]' (2014: 48). This avoidance of gender is reflected in counterterrorism policy, evident within the Home Office's (UK) CONTEST paper which assures that 'gender sensitivity is implemented and monitored' but provides no empirical or policy examples (Home Office, 2023). However, when one applies a thorough gender framework, the notion of gender as inextricable to terrorism arises; to understand gender is equated to understanding 'the process of becoming a terrorist' (Gasztold, 2020: 71). This urgency to theorize counterterrorism with a gender framework becomes more pertinent when considering evidence that terrorist organisations themselves equip gender biases when orchestrating attacks (Gasztold: 73, Cunningham: 117, Blee: 425, Herschinger: 57). In the US, the Klu Klux Klan incorporated women within their racial terrorism plots to enhance political '[respectability]' (Blee, 2005: 425). Terrorist organisations also have acquired an understanding that Muslim women possess 'tactical advantages that their male counterparts do not' (Cunningham, 2007: 118). Advantages include the ability to gain a proximity to targets, move through borders and security without raising suspicion and use clothing to conceal weapons and for camouflage (Gasztold, 2020: 111). An example of this is evident within the 2004 hijacking and crashing of two Russian aircrafts by the Black Widows, a Chechen female terrorist group who passed through security checks unnoticed and whose existence officials dismissed as a 'fiction' (Cunningham, 2007: 118-119). Terrorist organisations actively and continuously recruit female suicide bombers due to their persistent success as 'the perfect terrorist', namely in their ability to catalyse outrage, fear, empathy and thus garner enhanced media attention (Gasztold, 2020: 73, Krause: 290). This paper contends that an effective counterterrorism approach must overcome any influence that such stereotypes posit, so as not to be rendered 'predictable' and futile (Cunningham, 2007: 113). Women's motivations must be understood in multifaceted and diverse ways, which can only be facilitated through adoption of a gender framework, which will ensure that motivations are precisely identified and curtailed from developing into acts of rebel violence.

Insecurity as a form of Motivation:

This paper argues that a gendered understanding of women's insecurity can improve the efficacy of counterterrorism strategies. This paper concurs with the contention that women are motivated to commit acts of terror to achieve 'emancipation' (Gasztold, 2020: 59). However, it is this notion of emancipation that this paper will interrogate further, recontextualising and resituating it away from its monolithic conceptualisation. Following the constructivist understanding of agency as 'always both active and constrained', this paper asserts that emancipation from a woman's gendered insecurity functions as a valid form of motivation (Delahunty, 2021: 47). Whilst a feminist mantle seeks to reinstate women as agent individuals, a gendered approach must recognise specific contexts in which motivation is not always synonymous to (or an indicator of) autonomy. Primarily, this paper contends that the acquisition of identity security functions as a form of motivation. In his essay 'What Terrorists Really Want […]', Abrahms argues that 'terrorist organisations appeal disproportionately to […] the socially alienated' (2008: 97). When applying a gendered approach to this argument, a myriad of ways in which women become alienated materialises. For example, disruption to a woman's private sphere in the loss of a father or husband can place a family unit into economic and physical insecurity (Gasztold: 87, Herschinger: 59). In an interview conducted by the BBC, a female and former member of terrorist group Boko Haram expressed that '[her husband] used to look after [her …]. But, when [he] died, the other men would no longer bring [her] food [...]. It was better to do a suicide bomb' (Gidda, 2019). Even though it is imperative that women are not relegated to the private sphere within academic research, it seems that 'personal issues such as depression [and] monetary problems' should not be discarded either when exploring women's motivations to enact terror (Jacques and Taylor, 2009: 506).

Another form of gendered insecurity that motivates women to enrol within terrorist currents is her sexuality (Gasztold, 2020: 59, 77, 86). There exists a cultural belief that the death of a female martyr can provide her with a revirginization and sexual '[purification]' (Gasztold, 2020: 86). This narrative is equipped by terrorist organisations to exploit widows, infertile and sexually violated women in the promise of 'rewards connected to the forgiveness of her sins [and] an eternal husband' (Gasztold, 2020: 86). This is a particular recruitment strategy that is operationalised by the Islamist Jihadist group Boko Haram, who have used women as suicide bombers in over half of its attacks from 2011 to 2017 (Sampson, 2024). An academic expert on terrorism, Professor Bloom explicates how many women are enticed by the false idea of security that a husband can provide, only to discover that 'they have a better chance of survival as a bomber than [marriage with] a Boko fighter' (Sampson, 2024). If counterterrorism systems are to improve, an awareness of the role that sexuality can enact in recruitment processes can aid such endeavours, such as in the use of sexual violence databases. A gendered approach to counterterrorism affords one with the knowledge that to protect women, is also to minimise the cultivation of motivations that allow terrorist currents to grow in operational strength. It is a largely corroborated claim that women are disproportionately affected during outbreaks of conflict (Kangas et al, 2015, Henry: 63). This argument that a 'conflictive context' can function as a mobiliser for a woman's motivation to join a terrorist organisation can positively inform counterterrorism strategies; namely, in the decision to apply a soft or hard-line approach (Gasztold, 2020: 55). As established, a woman's physical safety during conflict is a particularly gendered insecurity and may manifest in homelessness, unsafe shelter, displacement, sexual violence and a lack of food or resources necessary for survival (Gasztold: 92, Jacques and Taylor: 506). Therefore, women may join terrorist organisations as a means of preserving their physical security, due to the alluring resources that terrorist organisations can provide; in particular, it was found that 'better living conditions [functioned as] one of the main motivations' for women to engage in terror activity (Jacques and Taylor, 2009: 506). An identified deficit of counterterrorism research is the 'absence of worked out strategies and analyses of women's environment' (Gasztold, 2020: 132). Therefore, a consideration of conflict zones, not simply as public spaces of official warfare but as a private site where female recruitment into terror may be routinely facilitated, will enhance the pre-emptive power of counterterrorism strategies.

When theorizing counterterrorism and conflict from a feminist standpoint, it is essential to recognise instances of campaigns that have catalysed a counterintuitive effect in creating fertile grounds for female radicalisation. Herschinger contends that counterterrorism strategies tend to be conducted without an awareness of protecting women's rights, providing 'female family member interrogation [… and] drone strikes' as examples (2014: 55). This contention is built upon through Gasztold's exploration of the intersection between counterterrorism and conflict, where it is argued that strategies which resort to hard-line approaches of militarisation, violence and breach of international law create such insecure environments for women that only increase rates of recruitment (2020: 137). This antithetical approach to counterterrorism has been publicly criticised by the United Nation's Special Rapporteur on Human Rights and

Counterterrorism (OHCHR, 2024). Ben Saul expressed indignation at the fact that military violence is rarely recognised as a 'root cause' of terrorism and commanded that 'human rights [must be placed] at the heart of all counterterrorism measures' (OHCHR, 2024). If future radicalisation and recruitment of female terrorists is to be mitigated, counterterrorism strategies should reorient their hard-line approaches and adopt soft and humanitarian responsibilities that also preserve women's rights.

Political Participation as a form of Motivation:

Having recognised how a woman's motivation to enrol in terror activity may originate in the emancipation from gendered insecurities felt within the private sphere, this paper will now consider how women's political ideologies function as another form of motivation. The application of a gender framework to women's terrorist activity reveals that their acts of violence are rarely conceived as forms of political expression or emancipation (Gasztold: 78, 108, 138, Delahunty: 46, 60, Herschinger: 58). However, it is imperative that counterterrorism strategists conceive both male and female terrorists alike with the same consideration of political agency, or the risk of equipping theories grounded in biological determinism manifest in 'giving the sex of a terrorist a foundational status' (Herschinger, 2014: 61). In providing political expression as a secondary form of motivation, this paper seeks to demonstrate that one does not posit dominance over the other (Jacques and Taylor, 2009: 507). In keeping with the feminist mantle that 'the personal is political', it is imperative that counterterrorism strategists develop an understanding that these two forms of motivation in the emancipation from gendered insecurity and political repression are in constant interaction (Hanisch, 2006, Delahunty: 59). It is crucial that the application of a gender framework does not catalyse the construction of further categorical hierarchies within the subject of female terrorist, but that women who suffer from gendered insecurity and consequently resist via terror are simultaneously viewed as political beings.

As this paper is sustained by a feminist approach to understanding female terrorists' motivations, it is necessary to highlight how women can be mobilised by their own 'political victimization and grievance' (Gasztold, 2020: 90). Understandably, gender equality is desirable to many women who are not in possession of it. Therefore, rebel activity is situated as a platform through which gender equality may be acquired (Jacques and Taylor: 508, Gasztold: 73). Predominantly occupied by men, the role of violent actor holds attraction for women as terrorist organisations recruit '[a large] number of women who see themselves as empowered through the enactment of physical violence' (Blee, 2005: 429-430). This knowledge should inform counterterrorism strategies with a sensitivity to changing sociopolitical environments regarding gender equality, as a possible environment for female, violent radicalisation. However, it is important that counterterrorism strategists do not only focus on communities of women seeking to balance social and gender relations but should also factor in women attempting to keep such relations disparate. Within counterterrorism research, there exists an assumption that far-right, conservative and extremist groups are a hostile and misogynistic environment for women and that their recruitment is thus mitigated as a result (Campion, 2020: 2). However, research has shown that, despite the gender-oppressive views of many terrorist networks, 'there are nonetheless women who are active, not passive contributors' (Campion, 2020: 14). Demographic data on membership to the World Church of The Creator and Klu Klux Klan depicts that women are occupying an increased number of leadership roles and consist of a quarter of all members (Campion, 2020: 4). Another empirical example of the gendered dynamics of membership is evident within the Christian, antiabortion, terrorist organisation the Army of God; of which, five out of the eighteen members were women (Cunningham: 114-115, Campion: 4). One member in particular, Shelly Shannon, was incarcerated for attempted murder of an abortion provider, two acid attacks in women's reproductive clinics and multiple incidences of arson and bombings (Cunningham, 2007: 115). Shannon should function as a stark reminder to counterterrorism research to not underestimate or ignore the danger that individual women can enact outside of the organisational structure of a terrorist community (Gasztold: 59, 88, Campion: 2).

When considering women as comprehensively political beings, one must err on the side of caution in constructing an idea of women's politics as solely concerned with gender relationships, feminism and reproductive rights. Not only is this approach non-feminist, but it is incongruent with empirical reality as women have been increasingly motivated to engage with terror due to political ideals of nationalistic liberation (Gasztold: 100, Jacques and Taylor: 505). When a terrorist organisation's ideology is left-wing, secular and nationalistic, there is a higher tendency for women to occupy combatant roles (Gasztold, 2020: 92). This is evident within the terrorist organisation the Liberation Tigers of Tamil Eelam, where women were present in large numbers and received a treatment of gender equality that was lacking in Sri Lankan civilian society (Cunningham, 2007: 123). For this knowledge to aid counterterrorism operations, it is imperative that strategists conceive women terrorists as legitimate, political actors to avoid affording them with the advantage of underestimation. It is evident that women are present and agent in multiple and varied political spheres, thus it should be a priority of counterterrorism efforts to acknowledge women terrorists as political actors so that their legitimate forms of violence may receive legitimate responses of prevention in turn.

Conclusion

Both accepting and understanding the presence of women within terrorist organisations has, thus far, materialised as an underdeveloped endeavour. With her motives diminished, overshadowed and scrutinised, the absence of an adequate understanding of the female terrorist within counterterrorism projects has damaged their efficacy. However, this damage is not beyond rectification. With the inclusion of a gender framework that considers the multiplicity and variation of women's motivations, counterterrorism strategies can be better informed to effectively prevent the upward trend of female radicalisation. Through this papers' consideration of how gender insecurities and the desire to exert political autonomy interact and co-exist, it is vital that counterterrorism strategies not only incorporate female terrorists into its agenda but analyse their recruitment and presence in diverse ways.

This paper has asserted that the importance of a gender framework that demystifies the presence of female terrorists whilst effectively considering how insecurity and political autonomy catalyse powerful motivation, cannot go unnoticed. This paper has also outlined the benefit of a counterterrorism approach that reinstates the lost value of soft and humanitarian methods, where women's rights remain a present and enduring factor. Ultimately, the implementation of a gender framework that can facilitate these adaptations to approach and policy would result in improved counterterrorism systems where the initial intention remains constant: to reduce the loss of life catalysed by terror.

Meet the Author

Isobel Edwards is a student on the MSc programme in Gender and International Relations. Her research is grounded in the feminist principle that "the personal is political," and seeks to challenge harmful assumptions by reframing women as agentic, powerful, and multidimensional actors in global politics. Her academic work engages with feminist security studies, with a particular focus on conflict-related sexual violence. She is especially interested in how social constructivist theory can help explain the ways in which violence against women is framed, and how those framings influence public understanding and policy responses. Isobel extends sincere thanks to the peer reviewers for their thoughtful feedback, and to the editorial team for including her work. She is also deeply grateful to Professor Eric Herring, whose inspiring teaching and encouragement played a vital role in the development of this paper.

Subject Psychology

Subject's Foreword

We're excited to introduce Psychology as a new subject category in the BILT Student Research Journal. This marks a significant step in recognizing the role of psychological research in understanding human thought and behavior. For this inaugural edition, we've selected a diverse range of papers across psychological subfields, laying a strong foundation for future contributions. We thank all the authors for their dedication and look forward to seeing Psychology continue to grow within BILT. We hope this edition sparks meaningful discussion and inspires future research.

Rashmi Mallya, Subject Editor (Psychology)
Will Wheatley, Deputy Subject Editor (Psychology)

Meet Rashmi Mallya

Rashmi Mallya is currently pursuing an MSc in Neuropsychology, building on her academic foundation in Psychology from her undergraduate studies. She holds a strong interest in creating research-based psychoeducational content, which inspired her to initiate and lead mental health awareness workshops in schools across India—particularly in rural and under-resourced areas. Her current academic focus includes adult ADHD and LGBTQ+ mental health, both of which she believes require greater visibility and robust, evidence-informed support systems. Serving as the Subject Editor for Psychology in this journal has been an enriching experience, allowing her to apply her academic knowledge while engaging in meaningful collaboration with the wider editorial team.

Meet Will Wheatley

Will Wheatley is a second-year neuroscience PhD student in the School of Physiology, Pharmacology, and Neuroscience at the University of Bristol. His research focuses on torpor in mice, specifically investigating how thermoregulation and behaviour change during this sleep-like state. Within his lab, he explores the neural circuits underlying torpor, aiming to identify aspects that may be translatable to interventions in human health. Will holds a BA in Experimental Psychology from the University of Oxford and an MSc in Neuroscience from the University of Southampton. He is particularly interested in how cellular and circuit-level brain activity contributes to behaviour and cognition. His previous research includes studying the updating of mental images during working memory tasks, the cognitive effects of disrupted sleep, and computational modelling of pharmacological data to investigate NMDA receptor membrane distribution. As Deputy Subject Editor for Psychology, he brings both scientific rigour and a passion for interdisciplinary insight to the journal.

A Narrative Review: The Role that Ketamine may play in the Treatment of Depression and the underlying Mechanisms of its Effect

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Abstract

The novel antidepressant ketamine has been shown to achieve what most classic antidepressants, such as Selective Serotonin Reuptake Inhibitors, have not been able to. A rapid onset of symptomatic improvement across multiple domains; mood, anhedonia, and suicidal ideation. The exact neuropsychopharmacological mechanisms of this unique phenomenon are still unknown, although many theories are emerging from human and animal studies using neuroimaging and placebo-controlled, cross-over randomised control trials. This review discusses current state-of-the-art theories of action, focussing on neurotransmitter systems, effects of ketamine at the synapse, and functional connectivity in the form of brain networks. These theories are discussed in the context of dysfunctionality in depression, concluding that a major mechanism contributing to ketamine's antidepressant effects is the reversal of chronic stress pathology present in depression. Possible limitations of evidence presented are discussed.

Keywords: Ketamine, Antidepressant, Depression, Mechanisms of Action

Glossary of Abbreviations

AMPAR: α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid receptor
BDNF: Brain-derived Neurotropic Factor
BGN: Basal Ganglia Network
BOLD: blood oxygen level dependent
CEN: Central Executive Network
CNS: Central Nervous System
DMN: Default-Mode Network
GABA: gamma-aminobutyric acid
HPA-axis: Hypothalamic-pituitary-adrenal-axis
LTP: Long Term Potentiation
MADRS: Montgomery and Asberg Depression Rating Scale
MDD: Major Depressive Disorder
NMDAR: N-methyl-aspartate receptor
PFC: Prefrontal Cortex
RCT: Randomised Control Trial
rs-fMRI: resting-state functional Magnetic Resonance Imaging
sgACC: subgenual anterior cingulate cortex
SN: Salience Network
TRD: Treatment Resistant Depression

Introduction

Major depressive disorder (MDD) is the most prevalent mental health condition worldwide with continuously rising cases, making it a global public health priority (World Health Organization, 2012). It is predicted to be the number one cause of burden of disease, i.e., the impact of a health burden on the population, worldwide by 2030, emphasising the need for effective interventions (Liu et al., 2020; Proudman et al., 2021). The condition, characterised by cognitive and behavioural symptoms like low mood and anhedonia (Beck & Alford, 2014), is commonly treated using pharmacological or psychotherapeutic interventions (Malhi & Mann, 2018). However, symptoms only improve in a third of patients after their first pharmacological treatment, and another third show no improvement even after four rounds of treatment, defined as treatment-resistant depression (TRD; Rush et al., 2006). In the past decade, the dissociative anaesthetic substance ketamine has been rediscovered as a novel antidepressant treatment, being described as "the most important discovery in half a century" (Duman & Aghajanian, 2012, p.68; Wolff & Winstock, 2006).

Ketamine is a racemic mixture of its two enantiomers, (R)- and (S)-ketamine, meaning that both mirror image molecules exist in Ketamine in equal parts (Jelen et al., 2021; Johnston et al., 2023). At a subanaesthetic dose, antidepressant effects occur within as little as 15 minutes (Yavi et al., 2022). Side effects include addiction, dissociation, conceptual disorganisation, emotional withdrawal and motor retardation (Vlisides et al., 2018). Ketamine is a N-methyl-aspartate receptor (NMDAR) antagonist, acting as a non-competitive open-channel blocker. The NMDAR is a glutamate receptor with predominately CA2+ ion channels, and its blockade causes a surge in glutamate & Brain-derived Neurotropic Factor (BDNF) release, which is thought to result in the dissociative and antidepressant effects of ketamine (Sanacora & Schatzberg, 2015; Shaffer et al., 2014; Zanos et al., 2018).

This review aims to examine ketamine's mechanisms of action, focusing on its effects on neurotransmitter systems, synaptic plasticity, and functional brain connectivity.

Glutamate & GABA

Historically, the role of glutamate receptors and gamma-aminobutyric acid (GABA) for the utilisation in antidepressant treatments has been under-appreciated. Glutamate is the primary excitatory neurotransmitter in the central nervous system (CNS), with about 90 percent of neurons containing glutamate receptors (Gasiorowska et al., 2021). Both increased and decreased levels of glutamate have been shown to be problematic: Phasic stress can elevate levels of glutamate, whereas chronic stress can lead to glutamate dysregulation, reduced clearance of glutamate and reduced glutamate neurotransmission. Increased levels of glutamate in the hippocampus and decreased levels in the prefrontal cortex (PFC) and amygdala as a result of stress can lead to impaired long term potentiation (LTP) and reduced dendric spine complexity, subsequently contributing to the presentation of MDD (Pal, 2021). In depression, the release of BDNF is significantly reduced due to inhibited glutamate activity, leading to a limited ability for neuroplasticity. These effects of chronic stress seem to be diminished with ketamine administration. Evidence from both animal and human studies has found ketamine to enhance glutamatergic activity by blocking NMDAR on GABA interneurons. This altered glutamate activity subsequently stimulates BDNF release and AMPAR(α-amino-3-hydroxy-5-methyl-4-soxazolepro-pionic acid receptor), resulting in increased synaptic protein synthesis (Abdallah et al., 2018; Duman et al., 2019). This is also known as the NMDAR inhibition hypothesis. Detailed effects at the synapse are shown in Figure 1.

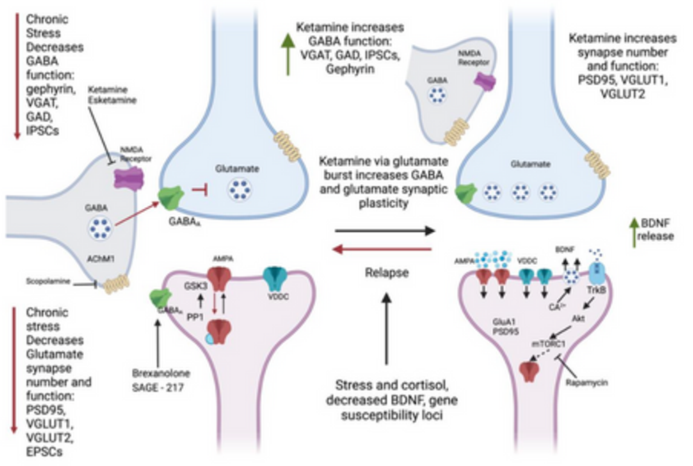

Figure 1: Chronic Stress and Depression Decrease (left; red arrows) and Ketamine Increases (right; green arrows) Glutamate and GABA Function (Reproduced from Duman et al., 2019).

The aforesaid stress-reversing effects of ketamine in MDD align with one of the major theories of depression, Hypothalamic-pituitary-adrenal-axis (HPA-axis) hyperactivity (Pariante & Lightman, 2008). Stress and consequently the activation of the HPA-axis can lead to reductions in synaptic plasticity and hippocampal dysfunction, contributing to depressive symptomology (Geerlings & Gerritsen, 2017; Kim et al., 2015). This might manifest as low mood, anhedonia, suicidality, and changes in appetite, libido, or sleep (Beck & Alford, 2014). The impact of ketamine's effects on post synaptic sensitivity and increased synaptic plasticity are a crucial part of its rapid antidepressant actions (Gerhard et al., 2016). Rodent studies support this claim; Moda-Sava and colleagues induced rodents with chronic stress for 21 days, which led to the elimination of a significant portion of dendric spines, as found using photon imaging. On day 22, the rodents were given a single intravenous dose of ketamine, subsequently restoring dendric spines (Moda-Sava et al., 2019). Although the longitudinal maintenance of this effect is still to be investigated, its onset within minutes of administration is remarkable and unique compared to other antidepressant drugs (Dwyer & Duman, 2013;

Lepack et al., 2015; Moskal et al., 2017).

Ketamine has also been linked to influence GABA uptake and GABA receptors. Findings of various rodent and guinea pig studies have indicated that ketamine potentiates $GABA_A$ receptors and GABAergic inhibitory postsynaptic currents on neurons in the hippocampus and olfactory cortex (Gage & Robertson, 1985; Jacob et al., 2008; Scholfield, 1980). However, the ketamine concentration needed to activate these processes is much higher than that needed for antidepressant effects in humans (Wood & Hertz, 1980). Hence, the antidepressant effects of ketamine cannot be fully attributed to increased GABA uptake. Nonetheless, there is evidence for subanaesthetic dose ketamine to indirectly affect the $GABA_A$ receptor activity both as an agonist and antagonist in mice (Rosa et al., 2016). It has been suggested that the psychological effects of ketamine are a result of NMDAR blockage on GABAergic inhibitory interneurons, disinhibiting GABA release, and consequently reduced activation of $GABA_A$ receptors in glutamatergic synapses, as found in both human and animal studies (Hare et al., 2017; Wohleb et al., 2017). Nonetheless, it is not always clear whether extracellular levels or actual neurotransmission are measured in the aforementioned papers, leading to confusion and misinterpretation of findings, especially as glutamate-based interventions are said to action based on intracellular mechanisms (Harmer et al., 2017; Murrough et al., 2017).

As previously illustrated, both enhanced and reduced glutamate activity can be neurotoxic, meaning that these neurotransmitter levels result in changes at the level of the synapse, and major depressive disorder can impact the glutamate level equilibrium in both ways. Vasilescu and colleagues treated depressed participants with either ketamine, or the NMDAR agonist rapastinel (Vasilescu et al., 2017). Their findings suggest that depending on the individual's glutamate imbalance, either a NMDAR antagonist or agonist is favourable as an antidepressant treatment. This may explain the proportion of non-responding patients in ketamine trials (McInnes et al., 2022). Nonetheless, the NMDAR inhibition hypothesis of antidepressant action of ketamine has been challenged. (S)-ketamine has been found to have a potency 4 times higher than (R)-ketamine, and 2 times that of the racemic mix at the NMDAR binding site (Temme et al., 2018). However, multiple experimental investigations have found no difference in brain exposure between the enantiomers (Fukumoto et al., 2017; Zanos et al., 2016), thus challenging the idea that the antidepressant effects of ketamine are solely mediated by NMDAR inhibition (Fukumoto et al., 2017; Zanos et al., 2016). This is further emphasised by alternative NMDAR antagonists, such as memantine or lanicemine, that do not show antidepressant effects similar to ketamine (Newport et al., 2015). Contrarily, the non-selective NMDAR antagonist lanicemine induced similar rapid antidepressant effects to ketamine in a randomised control trial. Further, both substances showed increased blood oxygen level dependent (BOLD) signal in the subgenual anterior cingulate cortex (sgACC), suggesting similar mechanisms of action (Downey et al., 2016). Future studies ought to investigate the functionality of NMDAR inhibition on ketamine's antidepressant effects to discern the exact mechanisms of action.

Serotonin

Ketamine's antidepressant actions have also been linked to serotonergic activity. Evidence form non-human primate studies suggests that when pre-treated with an AMPAR antagonist, ketamine's accumbal and ventral pallidum 5-HT1B receptor binding was diminished, as well as behavioural antidepressant effects. Without the pre-treatment, ketamine acts as an agonist at AMPAR, and shows increased binding at serotonin receptors in PET studies (Yamanaka et al., 2014; Yang et al., 2015; Zanos & Gould, 2018). Similar effects have been found in rodent studies. Pre-treatments with compounds that reduce serotonin levels diminished ketamine's antidepressant effects, measured using the forced-swim test and novelty-suppressed feeding test (Du Jardin et al., 2016; Fukumoto et al., 2014; Pham et al., 2017). This suggests that the effect of ketamine in increasing serotonin levels is necessary for its antidepressant effects. Nonetheless, these correlational findings should be interpreted with caution, as ketamine concentrations higher than clinically significant were used, meaning that the antidepressant effects of ketamine occur even at lower doses in humans (Can et al., 2016).

Functional Networks

Aside from its molecular effects, ketamine has also been shown to influence large-scale brain networks in MDD. Menon proposed the triple network model as an explanation for affective dysfunction in neuropsychiatric conditions based on dysfunctional neural networks (Menon, 2011). The three networks, default-mode network (DMN), central executive network (CEN), and salience network (SN), are responsible for self-referential processes, cognitively demanding tasks, and information integration, respectively (Menon, 2011). The CEN is comprised of the dorsolateral PFC and posterior parietal cortex, and is activated during processes like decision making or goal-directed behaviour. The SN is comprised of the fronto-insular cortex and dorsal anterior cingulate cortex, and integrates and filters emotional and interoceptive information (Menon, 2011).

The DMN, comprised of the medial prefrontal cortex and posterior cingulate cortex, is responsible for emotions such as anger and sadness, and is active during internalised cognition and shows abnormal activity in MDD patients most consistently out of the three networks, and is henceforth proposed to be the most impactful in MDD (Buckner et al., 2008; Doucet et al., 2020; Satpute & Lindquist, 2019). Its dysfunction in MDD heightens focus on internal thoughts, leading to rumination and extreme forms of internalised cognition, as DMN hyper- and hypo-activity are associated with increased rumination and pessimism (Chai et al., 2023; Fischer et al., 2016; Zhou et al., 2020).

Various resting-state functional magnetic resonance imaging (rs-fMRI) studies have compared the functional connectivity in participants with MDD and healthy controls after ketamine treatment. One suggested that the connectivity between the posterior DMN and insula is normalised following ketamine infusion. This connectivity change predicted scores on the Montgomery and Asberg Depression Rating Scale (MADRS) 10 days post-infusion in in participants diagnosed with MDD (Evans et al., 2018). A similar study examining the relationship between internal and external focus, ketamine and DMN connectivity came to the same conclusions, suggesting the antidepressant effects of ketamine result from an increased ability to process external stimuli due to DMN connectivity changes in a sample of healthy participants (Lehmann et al., 2016). In another study, Li and colleagues compared pre- and post-ketamine connectivity in treatment resistant depressed and non-depressed participants using rs-fMRI. The posterior and anterior DM subnetworks showed increased functional connectivity in treatment resistant depression. The posterior DMN appeared similar to healthy controls after treatment, whereas the abnormal anterior DMN activity persisted (B. Li et al., 2013). A recent randomised control trial comparing rs-fMRI activity two days post ketamine or placebo in TRD and health, highlighted the role of reward circuity in ketamine's antidepressant effects. Ketamine infusion resulted in increased fronto-striatal functional connectivity in TRD participants, matching the levels of controls. This effect on circuits related to motivation may result in improvements in motivation-related symptoms in TRD (Mkrtchian et al., 2021).

Furthermore, hyperactivity in the PFC and amygdala has been suggested to be associated with TRD. Region of interest (ROI) analysis found depressive symptoms to improve after ketamine infusion in line with the facilitation of glutamatergic neurotransmission in the PFC and amygdala, emphasising the role of changes to glutamate neurotransmission in ketamine's rapid antidepressant effects (C. Li et al., 2016). An rs-fMRI study comparing the functional connectivity of MDD participants with and without previous suicide attempt to healthy controls found DMN activity to relate to suicidal ideation (Malhi et al., 2020). Specifically, they found the 79 depressed participants to have greater posterior DMN activity compared to controls, as well as reduced activity in the basal ganglia network (BGN) and dorso-medial DMN, which was associated with lifelong suicidal ideation. Further, the pattern of BGN and DMN activity differed significantly between participants who had attempted suicide and those who had not, suggesting a possible explanation for the anti-suicidal effects of ketamine. The repeated administration of ketamine has also been shown effective for symptoms of suicidal ideation (Zheng et al., 2020). This suggests impaired self-referential thought processing and altered cognitive flexibility as the basis of suicidal thoughts.

Numerous randomised control trials suggest the efficacy of ketamine: One study indicates that even a single 40-minute infusion results in rapid antidepressant effects within two hours (Singh et al., 2016). These effects are also shown when repeatedly administered (Daly et al., 2018). Ketamine's antidepressant effects can disappear as fast as they appeared if they are not supplemented with additional longer-term pharmacological therapy, psychotherapy, or both (Henter et al., 2018). Reports have shown that to sustain the immediate antidepressant effects of ketamine, e.g., a reduction in low mood, one to two infusions per week are required (Segmiller et al., 2013; Szymkowicz et al., 2013). Hu and colleagues conducted a 4-week RCT comparing antidepressant treatment with escitalopram in conjunction with either a single infusion of ketamine or placebo. Their results suggest that ketamine and SSRIs are safe and effective to combine (Hu et al., 2016). Interestingly, a study comparing ketamine monotherapy to adjunctive therapy with SSRIs in 220 participants with TRD found the conjunctive therapy to be worse for measures of suicidality (Di Vincenzo et al., 2021). Both conjunctive ketamine therapy with behavioural training, and psychotherapy has been shown to sustainably reduce depressive symptoms in RCTs (Price et al., 2022; Wilkinson et al., 2021). This may contribute to the real-world efficacy and application of ketamine as an antidepressant.

Conclusion

This review highlights that the mechanisms of ketamine's antidepressant effects are multifaceted and cannot be explained by a single process. Based on its molecular mechanisms and effects on functional connectivity in combination with the chronic stress pathology commonly found in individuals with major depressive disorder, the antidepressant effects are most likely partially explained by the reversal of said pathology. As discussed, ketamine has been shown to produce remarkable and unique antidepressant effects, and achieves these faster than classical antidepressants, even in patients with treatment resistant depression. Its unique effects on suicidality and mood make ketamine an attractive and effective novel antidepressant. Nonetheless, there is a trajectory towards the development of new pharmacological therapies that work similarly to ketamine but avoid undesired side effects, which should be explored further in future research (Zanos et al., 2018).

Meet the Author

Sophie Höfels graduated from the University of Bristol with an MSc Applied Neuropsychology in 2024 and has since started her PhD in Psychology at the University of Leeds, researching Childhood Trauma, Stress Reactivity, and Suicide Risk. She is a Durham University alumna with a BSc (Hons) Psychology. I would like to thank the two anonymous reviewers for their kind and helpful comments and feedback.

Subject Special Section

Subject's Foreword

We are pleased to present this year's Special Section on Interdisciplinary Research, showcasing compelling work at the crossroads of society, ecology, technology, and culture. This section underscores the value of cross-disciplinary approaches in tackling today's most complex challenges. Highlights include "Indigenous food systems heal the socio-ecological wounds of colonialism", which explores the role of diverse knowledge systems, and "'Seen L.A? What about South Wales?'", which examines the 2019–2020 New South Wales bushfires through an interdisciplinary lens. These contributions exemplify how interdisciplinary research bridges worlds, amplifies diverse voices, and inspires change. We thank all authors, reviewers, and collaborators who made this section possible.

Zhengzhe Peng , Subject Editor (Special Section)
Segun Bamidele, Deputy Subject Editor (Special Section)
Asha Bewtra, Deputy Subject Editor (Special Section)

Meet Zhengzhe Peng

Zhengzhe is a PhD candidate at the Business School, focusing on the intersection of management science, AI, and supply chain research. Their work examines how technologies like deep learning impact decision-making and operations. With a background in management science (BSc) and computer science (MSc), Zhengzhe blends qualitative insights with advanced analytics. As a Data Science Research Advocate at JGI, they support PGRs in developing data science skills. Passionate about interdisciplinary collaboration, Zhengzhe aims to bridge theory and practice in applying AI to business

Meet Segun Bamidele

Segun Bamidele is an MSc student in Climate Change Science and Policy at the University of Bristol. He is actively involved in university initiatives, including roles with BILT, the BSU Future Research Leader Programme, and the Academic Quality and Policy Unit. His research focuses on quantifying climate risks, correcting biases using machine learning and statistics, and downscaling climate models to better understand regional climate variability.

Meet Asha Bewtra

Asha is a final-year undergraduate in Geography, specializing in human geography. Her research examines how tools of oppression are repurposed for resistance, focusing on the discursive shift in gothic literature from colonial to postcolonial contexts. She plans to pursue a master's degree exploring media and neocolonialism, aiming to deepen her understanding of modern mechanisms of control.

'Before Los Angeles, there was South Wales': Computing the Impact of the 2019-2020 New South Wales Bushfires

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Abstract

In response to the devastating 2019-2020 New South Wales bushfires, which caused unprecedented ecological and economic damage, this study seeks to prove the importance of computational tools by using python as a remote sensing tool to compute pre and post bushfire Landsat-8 images of New South Wales. It calculated the extent of the damages in terms of burnt areas and changes in vegetation during the incident using indices such as the Normalised Burnt Ratio (NBR) and the Normalised Difference Vegetation Index (NDVI). Results reveal a difference of 98.38% and 35.81% between the mean and standard deviations of NBR of the post and pre fire periods, respectively. Additionally, the study reveals the total burnt area in 2020 as 6412.67km2 (641267 ha) and the total high severity burnt area as 72.54km2 (7254 ha). This study demonstrates the effectiveness of python for geospatial analysis, offering a reproducible and adaptable approach for assessing wildfire impacts. However, limitations such as threshold-based classification and memory constraints draw attention to the need of advanced machine learning and statistical models to replace thresholding techniques in remote sensing, thus enabling consideration of local vegetation type and condition to improve classification accuracy.

Keywords: Bushfire, New South Wales, NBR, NDVI, Remote Sensing

Introduction

One of the most significant events globally this year is the devastating wildfire in Los Angeles, California, United States. The event caught global attention and emergency responses due to its widescale humanitarian, economic and ecological losses. As of February 2, 2025, 29 people are reported to have died [1], about 37,000 acres of land (in total) burnt, and rebuilding efforts expected to cost tens of billions of dollars [2]. Yet, before the wildfire in Los Angeles, there has been a more catastrophic incident with disastrous impact on humans and the ecosystem – the New South Wales, Australia bushfire of 2019.

The incident was so severe that the Australian Institute for Disaster Resilience (AIDR) [3] reports that the 2019-20 bushfire season was the worst ever in New South Wales history. Not only was the temperature higher than average, but the disaster also led to the loss of 26 lives, 2,448 homes, and 5.5 million hectares (ha) of land; furthermore, the ecological and economic impacts were unprecedented [3]. This incident drew the attention of the world and numerous studies were done to quantify the extent of the damage. Filkov et al. [4] quantified the ecological and humanitarian loss at 19 million ha, 3000 houses and 33 lives, by March 2020. On the health impact, Yu et al. [5] reported an increase in respiratory and cardiovascular mortality due to the incident. Even worrisome is the findings by Ullah et al. [6] that the bushfire incident destroyed about 50% of national parks in the state of New South Wales.

Quantifying and understanding the human, economic, and ecological impacts of natural disasters like wildfires and bushfires is important for planning effective emergency responses and long-term recovery strategies [7, 8, 9, 10]. Previous studies have focused on a combination of the humanitarian, economic and ecological impacts of the 2019 New South Wales Bushfire using various remote sensing tools like GIS (Geogrpahical Information System) [6, 11]. Furthermore, some previous studies used sentinel-2 images to quantify these impacts [12, 13, 14]. It is against this background that the current study was established. Hence, this study expands on previous studies by using python as a remote sensing tool to compute pre and post bushfire Landsat 8 images of New South Wales. It aims to calculate the extent of the damage in terms of burnt areas and changes in vegetation during the incident.

Two objectives of this study are:

(i) To calculate the difference in vegetation (in km2) between the 2019 (pre) and 2020 (post) New South Wales using the Normalised Difference Vegetation Index (NDV).

(ii) To calculate the burnt areas difference between the 2019 (pre) and 2020 (post) New South Wales using the Normalised Burnt Area Index (NBR). This analysis will provide insights into the spatial distribution and severity of the fire damage, which is crucial for understanding the ecological consequences and informing future fire management strategies.

The main programming tool used was python due to its numerical libraries and extensions that make it easier for geophysical data analysis [15]. Compared to other methodologies, such as traditional GIS software, python offers greater flexibility and automation capabilities, allowing for more complex and reproducible analyses. Also, python's open-source nature promotes collaboration from diverse global communities, thus accelerating the development of tools and innovations [16]. Finally, the landsat-8 images of the 2019 and 2020 New South Wales were downloaded from the United States Geological Survey website [17].

Methods

Software and versions: To ensure reproducibility of all codes, Anaconda (version Anaconda3-2023.09-0-Windows-x86_64) with Jupyter Lab (version 4.0.11) was used. Libraries such as pandas, numpy, rasterio, matplotlib, and skimage were employed.

Data: Two Landsat images – one from 2019 (referred hereafter as NewSW Prefire) and another from 2020 (referred hereafter as NewSW Postfire) were obtained from the United States Geological Survey website [17].

User Inputs: The code has been written in a way that changes can be easily made to user inputs, thus the code can be used again and applied to other geographical areas or time frames. Also, the code has been structured to use only predefined user inputs, therefore making it adaptable, reusable, and reproducible. One way the code has become versatile for various applications is by providing an easy way for users to modify the inputs based on the cells according to their needs. While the inputs are specifically fitted for the New South Wales Bushfire, the code can be easily applied to other satellite imagery by just changing the user inputs and image preprocessing steps. This can be achieved by normalizing the naming convention of variables to improve readability, thus allowing users to understand the code without any independent knowledge of its inner workings. It aims to increase productivity and prevent confusion when reviewing or adapting the code.

Accessing Landsat-8 Band Data and Preprocessing: To open and read the pre- and post-fire satellite raster bands, the rasterio library was used to handle GeoTIFF files efficiently. Separate variables were defined for each spectral band (blue, green, red, NIR, and SWIR) for both 2019 (NSW Pre-fire) and 2020 (NSW Post-fire) datasets. Then, the loading of variables was done by specifying paths to each band's file directly. These bands were then read into memory through the `.read(1)` function, which accesses the first data layer of each raster file. This ensures that all bands are consistently loaded into separate variables for analysis.

While the use of a loop function could have been used to avoid repetition of commands and streamline the coding process, the preferred approach prioritises clarity for a user with a beginner or intermediate level understanding of python. Therefore, irrespective of the long code lines, the consistent naming of variables improves the readability of the code and enables easy integration with subsequent steps of analysis.

Calculation of Indices:

Normalized Burn Ratio (NBR): Calculated as NBR = (NIR - SWIR) / (NIR + SWIR)

Normalized Difference Vegetation Index (NDVI): Calculated as NDVI = (NIR - Red) / (NIR + Red)

Statistical Analysis: Mean, median, standard deviation, minimum, and maximum values were calculated for each band. Finally, total burnt area and high severity burnt areas were determined using threshold-based classification of NBR values.

Visualisation: Raster layers were flattened using ‘np.ndarray.flatten’ for visualisation. True color (RGB) composites were created by rescaling the red, green, and blue bands to an 8-bit spectrum (0–255) using ‘skimage.exposure.rescale_intensity,’ then composited into a three-channel true color (RGB) image. Color Infrared (CIR) composites were generated to assess vegetation health, incorporating NIR, red, and green bands.

Results

From figure 1, it can be generally inferred that the reflectance of the NewSW Postfire raster layers were higher in comparison with the NewSW Prefire. Considering vegetation typically absorbs light, this could possibly mean there is lesser vegetation cover in NewSW Postfire compared to NewSW Prefire. Regardless, the changes need to be more evident, hence, the use of a combined NewSW Prefire and NewSW Postfire histogram plot to show changes.

As previously guessed, the red, green, and blue reflectance values from 2020 (Postfire) are relatively higher compared to the ones from 2019 (Prefire) (figure 1A). For SWIR, the changes are not enormous. This confirms that there is lesser vegetation cover in 2020 compared to 2019 as higher reflectance values in red, blue, and green correlates negatively with NDVI according to Herbei et al. [19]. The true color composites (RGB) indicates a massive decrease in vegetation during the post-fire period in New South Wales (figure 1B), but to determine and map of the affected areas more accurately, the same images need to be observed with Colour Infrared Composites – CIR. The CIR shows a dramatic decline in vegetation health (figure 1C); represented by the reduction in NIR reflectance [12]. This would be the expected result following a large-scale fire event. That there are more dark patches in the post-fire imagery supports substantial vegetation damage or loss, where

large areas have changed to bare or non-vegetated surfaces. The 2019 dominant healthy vegetation was drastically reduced in 2020, and post-fire areas were dominated by burnt surfaces and exposed soil. However, water bodies in both images remain distinctively very dark and sharp (compared to burnt areas), indicating little or no change during this period.

Normalized Burn Ratio (NBR) (Study Objective 1):

The Normalised Burn Ratio (NBR) was used to quantify differences in burnt areas between the prefire

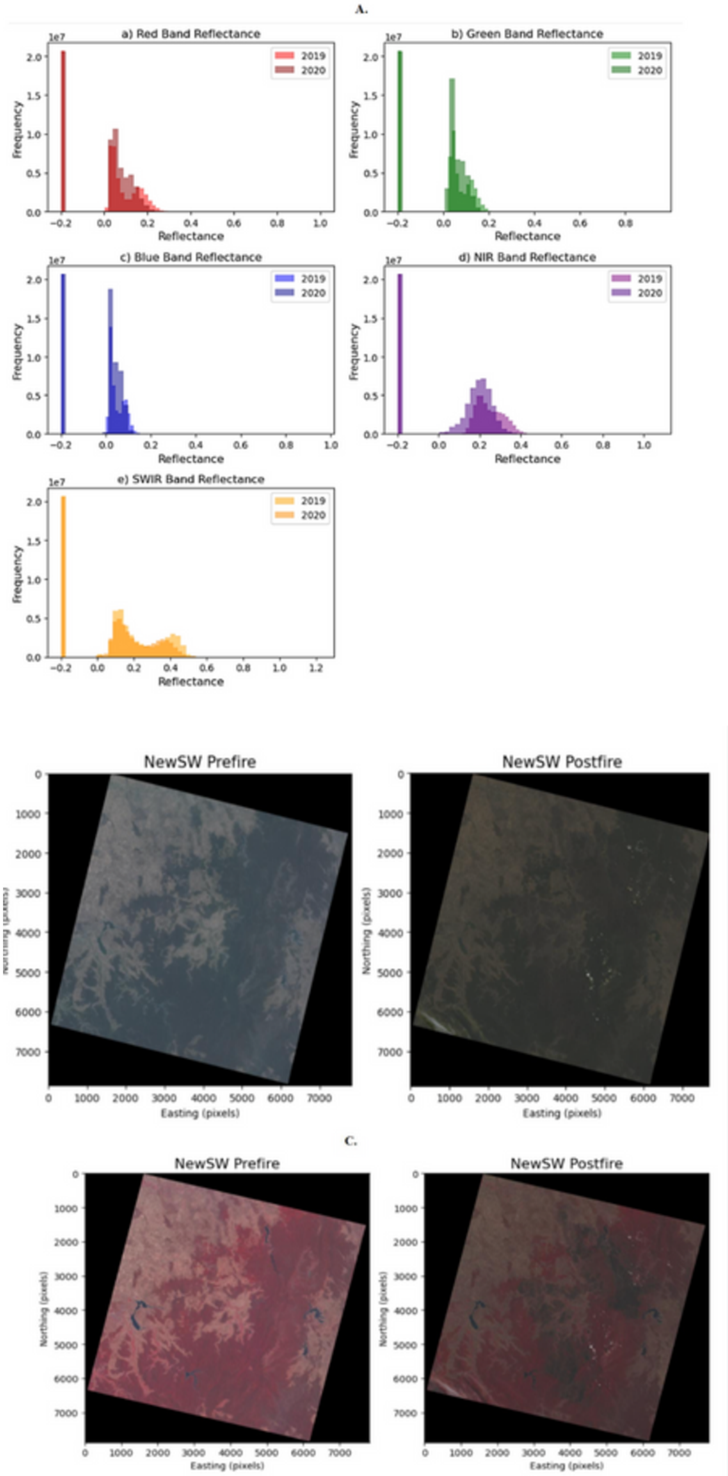

Figure 1: Visualising Changes in New South Wales Prefire and Postfire Band Reflectance.

(2019, referred to as NewSW Prefire) and postfire (2020, referred to as NewSW Postfire) periods in New South Wales. A comparison of the NBR of New South Wales in 2019 (Prefire) and 2020 (Postfire) (figure 2A). The result indicate that by 2020, New South Wales had lost a large amount of vegetation. The differences between pre and postfire vegetation was calculated by subtracting the Prefire NBR from that of the Postfire (NewSW Postfire – NewSW Prefire), and visualised. The dark brown patches shows the area where the burning was most extreme.

Analysis of NBR: The mean and standard deviation values of the NBR in Prefire and Postfire period were calculated to quantify differences. For New South Wales Prefire, the mean value was calculated as ~ (5 decimal places) 0.0556 while that of Postfire was calculated as 0.0009, representing a huge difference of 98.38%. Additionally, the standard deviations of the Prefire and Postfire period of New South Wales as ~ (5 decimal places) 1.1515 and 0.7391 respectively, thus, a difference of 35.81%.

Subsequently, the extent of burnt area - in terms of total burnt area in 2020 and the total area of extreme burns were calculated. Histogram and image show (imshow) plots were used to show the rate of changes (figure 2B and C). Results show the total burnt area in 2020 was 6412.67km2 (641267 ha) while the total high severity burnt area was 72.54km2 (7254 ha). Furthermore, results revealed that NBR values of postfire (2020) was relatively lower - indicating significant burns, consistent with lower NBR values.

Normalised Difference in Vegetation Index (NDVI) (Study Objective 2): As was previously done with NBR, the Normalised Difference Vegetation Index (NDVI) was used to assess changes in vegetation (NDVI) was used to assess changes in vegetation health between the prefire (NewSW Prefire) and postfire (NewSW Postfire) periods. Results (figure 3A) shows a tremendous change in vegetation between both periods – consistent with what to expect in the aftermath of a bushfire.

Analysis of NDVI: The mean and standard deviation values of the NDVI in Prefire and Postfire period were calculated to quantify differences. For New South Wales Prefire, the mean mean value was calculated as ~ (5 decimal places) 0.3254 while that of Postfire was calculated as 0.2957, representing a difference of 9.13%.

Furthermore, histogram and imshow plots were used to show the rate of changes (figure 3B and C). Results show that values of postfire (2020) was relatively lower as NDVI values increase - indicating loss of vegetation.

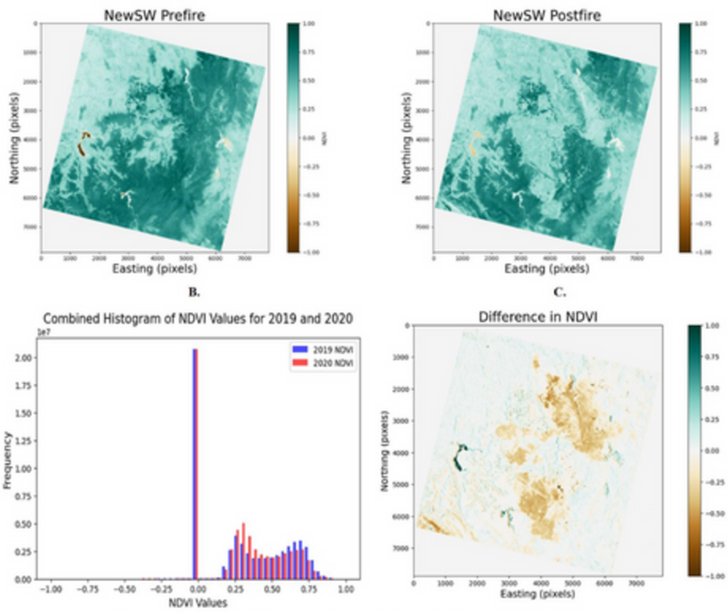

Figure 3: Summary of Changes in Vegetated Areas in New South Wales Postfire.

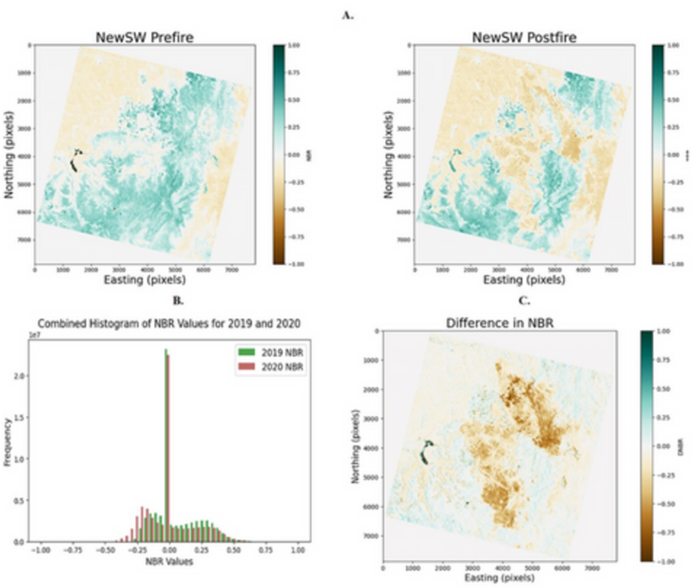

Figure 2: Computing and Visualising Changes in New South Wales Prefire and Postfire Band Reflectance.

Discussions.

Computing the NDVI and NBR of the New South Wales Pre and Post Fire has unsurprisingly revealed the enormous ecological losses in the aftermath of the bushfire incident. This finding corroborates the findings from previous studies by FitzGerald [2], Filkov et al. [4], and Ullah et al. [6]. While bushfires are quite common in Australia, the extent of damages in the 2019/2020 season were likely exacerbated by severe drought, heat waves, relative humidity, and wind speed [20]. The finding also supports Yu et al. [5] argument that the bushfire was aggravated by climate change - with decreased rainfall and high temperatures leading to increased risk of fires.

Furthermore, findings from this study quantify the total burnt area of New South Wales post fire to be 6412.67km2 (641267 ha) - with the total high severity burnt area being 72.54km2 (7254 ha). This result is close to the findings from Singh et al. [21] whom argued the total burnt area is 6731km2 (673100 ha). As might be expected when computing ecological damages from satellite images taken at different times, the extent of damages from this study is lower compared to the findings from Nolan et al. [22] and Boer et al. [23] whom both reported far greater values (>100,000 ha). A possible reason for these discrepancies is that satellite images for the studies might have been taken at different times as the burning intensifies, thus images taken later are likely to show more damages compared to those taken earlier.

This study has demonstrated the effectiveness of python in remote sensing – most especially in computing changes from satellite images. The codes from the study was written to read and process efficiently a variety of spectral bands and output, reflectance values, indices, and visual representations. It can be adapted slightly to accommodate different regions or datasets. However, there are some possible sources of error. The large raster sizes caused errors in memory allocation and required changes like down sampling or optimization. This type of change can lower the spatial resolution and lead to a loss of detail. Although ΔNBR thresholds are effective, they are blankly applied to the whole area, with no consideration for local changes in vegetation types or conditions, thereby possibly reducing accuracy. The choice of ΔNBR thresholds were based on standard ranges from literatures [9, 21], though these may not capture the local ecological variation and could therefore over- or under-estimate burn severity at some sites. However, testing of the sensitivity of results to small changes in thresholds—e.g., lowering the boundary between low and moderate severities from 0.27 to 0.25 could lend increased confidence to the classifications. Also, reflectance values were scaled to an 8-bit range (uint8) to assist visualisation, which may involve a small loss of information compared with using confidence to the classifications. Also, reflectance values were scaled to an 8-bit range (uint8) to assist visualisation, which may involve a small loss of information compared with using floating-point values

Going forward, a possible area for future improvement would be the use of advanced machine learning and statistical models to replace thresholding techniques - enabling consideration of local vegetation type and condition to improve classification accuracy. For example, algorithms like Random Forests or Support Vector Machines can classify burn severity more accurately by incorporating inputs such as spectral bands related to topography and land cover. This would increase precision in classification by reducing cases of misclassifications - caused from uniform thresholds, often inadequate to capture the variety of landscapes.

Conclusion

This study successfully quantified the impact of the 2019–2020 New South Wales bushfires using Landsat-8 imagery and remote sensing techniques in python by computing the Normalized Burn Ratio (NBR) and Normalized Difference Vegetation Index (NDVI) for pre-fire (2019) and post-fire (2020) conditions. Analysis of both NDVI and NBR confirmed loss of vegetation and burn severity. Thus, the results reinforced findings from previous studies and further highlights the ecological impact of post-fire vegetation loss.

The study also demonstrates the versatility of python as an effective tool for geospatial analysis and remote sensing, offering an adaptable framework for assessing wildfire impacts in different regions. However, challenges such as memory allocation constraints and the limitations of threshold-based classification highlight areas for improvement. Future research could integrate advanced machine learning models to enhance burn severity classification by incorporating local vegetation characteristics, land cover types, and topographical variations.

To conclude, this study prove the importance of computational tools for disaster assessment and mitigation. As climate change continues to increase wildfire frequency and intensity, data-driven approaches like the one employed in this study will be critical for informed decision-making, emergency response planning, and long-term ecological recovery strategies.

Meet the Author

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