Queer(y)ing Agent-Based Modelling: An example from LGBTQ workplace studies

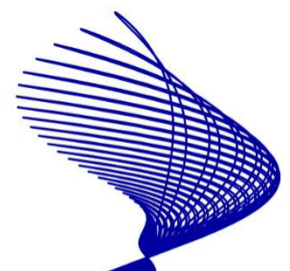Matthew A. Hall, Peter Barbrook-Johnson, Sait Bayrakdar, Andrew King

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Queer(y)ing Agent-Based Modelling: An example from LGBTQ workplace studies

Matthew A. Hall[1], Peter Barbrook-Johnson[2], Sait Bayrakdar[3], & Andrew King[4]

Abstract

Since the early 2000s, workplaces have been a focus of various LGBTQ policy interventions – addressing prejudice in selection processes, workplace bullying/harassment, as well 'soft' approaches to inclusivity. This working paper explores the contribution agent-based modelling (ABM) can make to the study of LGBTQ workplace inequalities and, conversely, how intersectional and queer theoretical insights from LGBTQ studies can inform future developments in ABM. We introduce an example LGBTQ workplace model, developed as part of the CILIA-LGBTQI+ (Comparing Intersectional Lifecourse Inequalities amongst LGBTQI+ Citizens in Four European Countries) project, to illustrate how ABM can address methodological binarism and bridge macro and micro accounts within LGBTQ studies of the workplace. The model is intended as an important starting point in developing the role of ABM in LGBTQ research and for bridging qualitative- and quantitative-derived insights. Likewise, in the working paper, we reflect on some of the theoretical and methodological tensions encountered in developing the model, and how we approached negotiating these through the research process.

Keywords: Agent-Based Modelling, LGBTQ, Intersectionality, Complexity, Workplace

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Acknowledgments

Introduction

Since the early 2000s there has been an expansion of equality legislation addressing workplace discrimination against lesbian, gay, bisexual, trans and queer (LGBTQ) people. The Equality Act (2010) in the UK, for example, legislates against discrimination on grounds of certain protected characteristics including sexual orientation or gender reassignment. Such legislation also becomes the foundation for more local implementation of policies and practices within workplaces, from human resource procedures to reporting grievances and promoting cultures of inclusivity and diversity (Richardson and Monro, 2012). However, these interventions have varied in their success, with studies indicating that LGBTQ people continue to face discrimination (Bachmann and Gooch, 2018; DeSouza et al., 2017), differentiated career progression and earnings (Aksoy et al., 2018; Wang et al., 2018; Bryson, 2017) and lower levels of job satisfaction (Bayrakdar and King, 2021) than their cisgender and/or heterosexual counterparts. There is also a growing body of research documenting how the intersections between gender identity, sexual orientation and other sources of inequality, such as ethnicity, social class, gender, age and earlier lifecourse experiences (Equality and Diversity Council, 2017; Colgan, 2016) can mediate the effectiveness of workplace policies for individuals. Despite this, a recent policy analysis of four European countries (Castro Varela et al., *forthcoming*) has highlighted an absence of engagement with intersectionality within policy domains. In this paper, we propose that methodological binarism within LGBTQ workplace studies contributes to this occlusion of intersectional policymaking and thereby the opportunity to address complex inequalities faced by LGBTQ people.

Building on previous work describing the fruitful application of intersectionality theory and complexity theory to address social inequalities (McPherson and McGibbon, 2010; McGibbon and McPherson, 2011), this paper demonstrates the contribution that agent-based modelling (ABM) – a computational modelling methodology used to study social and policy questions - can make to advancing the intersectional study of LGBTQ lives. In turn, the paper also considers how intersectional and queer perspectives can inform the practice of ABM. Indeed, the paper argues that a double-queer(y)ing needs to take place: one that further challenges methodological binarism in LGBTQ studies and one which simultaneously encourages ABM to acknowledge diversity and difference using insights from LGBTQ lives. To achieve this, we draw upon an example ABM of LGBTQ[1] workplace inequality and career progression, developed as part of the wider project exploring intersectional lifecourse inequalities of LGBTQI+ citizens in four European countries (CILIA-LGBTQI+). We then reflect on the processes (and challenges) of designing this model to *meaningfully* incorporate intersectional and queer insights before exploring its potential to inform intersectional policymaking.

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[1] In line with the wider CILIA-LGBTQI+ project, this model was originally built to represent LGBTQ and "I" agents. However, due to a lack of existing data on intersex experiences within labour markets, alongside a too small a sample of intersex respondents within the CILIA-LGBTQI+ project to draw conclusions about workplace experiences, we have had to drop the "I" from the model.

LGBTQ Workplace Studies, Social Categories and Methodological Binarism

Across many disciplines, including psychology, sociology and social work, there has been a growth of studies focusing on LGBTQ lives. This has facilitated policymakers in beginning to understand the sorts of challenges, inequalities and discriminations faced by LGBTQ individuals. It is beyond the scope of this paper to comprehensively outline the copious theoretical and methodological currents that have influenced the trajectory of LGBTQ studies. However, two points are particularly pertinent: (1) the amassing insights afforded by intersectionality theory; and (2) an apparent methodological binarism in approach to managing social categories (Maton and Howard, 2016; Kelemen and Rumens, 2012).

Firstly, over the last decade, intersectionality has very much come to the fore (Taylor et al., 2010). With its roots in black feminist scholarship (see, Crenshaw, 1989; Hill-Collins, 2000), it has called attention both to differences *within* and *between* all those grouped together under the acronym LGBTQ, as well as those who are excluded. It emphasises the importance of not reifying gender identity, sexual orientation and variations in sex characteristics at the expense of other forms of identity and social division, such as (but not limited to) gender, social class, ethnicity, race, disability, citizenship and religiosity. Perhaps most crucially, intersectionality rejects the idea of additive forms of discrimination, indicating instead the need to take a more situated, nuanced approach that recognizes both structural inequality and agentic inter-actions (King, 2016). Secondly, in emphasising this imperative to consider complex lived experiences, as opposed to theoretically reductionist approaches, LGBTQ studies have tended to bifurcate and pivot around a quantitative and qualitative binary divide (Kelemen and Rumens, 2012; Brown and Nash, 2010). A good example of this can be observed in LGBTQ workplace studies.

Research exploring labour market outcomes of LGBTQ individuals has advanced largely as two separate streams. On the one hand there is a rich, and ever-growing, literature using qualitative methods to explore LGBT[2] experiences in the labour market through in-depth interviews with employees from different age groups and sectors. These studies document not only the negative treatment of LGBT individuals at their workplaces, but also some of the behavioural strategies adopted in attempt to negate its negative impact (Msibi, 2019; Gray, 2013; Shih et al., 2013; Button, 2004). They also explore nuances of the social and professional interactions of LGBT individuals with their employers, colleagues and support networks (Rumens, 2011; Willis, 2011). On the other hand, a separate stream of studies explores the differentials in labour market outcomes by exploiting the available quantitative data sources. These studies explore the penalties (and in some cases rewards) in recruitment and earnings (Aksoy et al., 2018; Wang et al., 2018; Bryson, 2017), promotions and non-pecuniary outcomes such as job satisfaction (Bayrakdar and King, 2021; Hammarstedt et al., 2018; Drydakis, 2012) – albeit leaving much explanation (causal mechanisms) to speculation.

As such, the quantitative stream of research, with its roots in economics and organisational studies, has only marginally engaged with intersectional variance in LGBTQ workplace experiences – instead favouring small numbers of discrete social categories for identifying statistically significant social differences. The priority is eloquent simplification of available data for producing testable hypotheses. Too many social categories, or non-discrete

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[2] We note here the concerning dearth of studies addressing trans, queer and particularly intersex (TQI+) experiences in the labour market.

overlapping groups contingent on time and place, require too large a sample size to reach any significant or reliable conclusions (O'Connor et al., 2019). Thus, detail is often rejected as 'random noise' obscuring statistical relationships (Chattoe-Brown, 2013: 3.1). Whereas the qualitative stream, rooted in feminist and queer theoretical frames, champion subjective accounts and contextual detail – embracing these as the very substance of social research. Social categories need not be fixed or quantifiable but rather explored critically in relation to how they are constructed, performed and experienced within the heteronormative confines of workplace and labour market settings (Browne, 2010).

These two streams appear to develop separately and without much conversation between one another – to the detriment of each. The inclination to reduce complex social phenomena to neat quantifiable categories can come at the cost of insight and relevance (Chattoe-Brown, 2013: 3.3). For example, a simple model may fit a dataset, yet reveal little to nothing useful about society, or erase marginal cases as anomalies (Browne, 2007). Likewise, the qualitative inclination towards detail and subjective narratives can neglect much of the evidential criteria for making generalisations. Exclusively qualitative-derived claims of intersectionality theory risk being viewed by policymakers as overly analytic or trivial (O'Connor et al., 2019:24) and, as such, reduce opportunities to encourage investment in policy solutions informed by intersectional insight.

In this working paper we want to follow the approach, suggested by others (Kelemen and Rumens, 2012) to move away from methodological binarism in studies of sexuality and gender identity in the workplace. If we are to forward intersectional insights as a fertile basis for workplace policymaking, there is need for stronger collaboration between these two streams of research. We now move on to consider complexity science, and specifically agent-based modelling (ABM), as a possible rapprochement to this divide.

Social Science and Complexity

Accompanying the call for pluralism is a growing movement within social and policy research advocating use of a wider set of methodological approaches – grouped together for their shared underpinnings in complexity science. As such, complexity science is not one unified theory, but a collection of theoretical perspectives (McGibbon and McPherson, 2011). Among these is complexity *theory*, with a distinct emphasis on the study of complex adaptive systems (Begun et al., 2003; McGibbon and McPherson, 2011; Byrne and Callaghan, 2014). These systems can be considered 'complex' in so far as they are challenging to predict and comprise features such as, interactions between diverse actors (agents), change over time, non-linear relationships and feedback between components, and where outcomes are path dependent (Boehnert et al., 2018). They are also considered 'adaptive' in that the system and its actors have capacity to change, or even learn, over time (Boehnert et al., 2018; Begun et al., 2003). Such complex systems are often more than simply the sum of their parts, with regularities emerging from the interactions and self-organisation *between* those parts.

The influence of complexity science's methodological and theoretical frameworks has been felt across many domains of natural and social science, such as health care, epidemiology,

computational sociology, economics and artificial intelligence (McGibbon and McPherson, 2011; Gilbert and Troitzsch, 2005). However, its influence has been patchy in places (Barbrook-Johnson et al., 2021; Teixeira de Melo et al., 2020; Byrne and Callaghan, 2014). Applying its principles to social science means focusing on the richness, nuance, and complexity of social processes. Likewise, it means emphasising interactions as much as individuals, exploring feedbacks and nonlinearity, and considering a whole system as one, rather than isolated individual components or sub-systems. For some social science disciplines this is a dramatic and painful shift which involves challenging long-standing theory and methods. For others, these tendencies are already well-embedded and often already exist, simply going by different names (Anzola et al., 2017a, 2017b).

Some methods are particularly well-situated for studying complex social issues because of their ability to capture and explore one or several characteristics of complexity, such as: causal mechanisms relying on multiple interdependent factors; nonlinearity between influence and outcomes; positive and negative feedback loops; interaction between individuals, organizations, and their environment; heterogeneity in actors; emergence of novel macro-level phenomena; and profound uncertainty (see Boehnert et al., 2018 for a comprehensive list). Examples of these 'complexity-appropriate' methods include: Qualitative Comparative Analysis or 'QCA' (see Blackman et al., 2013); an entire series of systems mapping approaches from Soft Systems Methodology (see Checkland, 2000); Participatory Systems Mapping (see Barbrook-Johnson and Penn, 2021; Penn and Barbrook-Johnson, 2019); Bayesian (Belief) Networks (see Neapolitan, 2004); Systems Dynamics (see Sterman, 2000); and, indeed, Agent-based Modelling (ABM).

What is Agent-based Modelling?

ABM is a computational modelling approach in which we develop computer models to represent and explore social and policy processes, such as those theorised to culminate in career inequalities. It has become increasingly popular over the last forty years (Barbrook-Johnson et al., 2017, Axelrod, 1997; Gilbert and Troitzsch, 2005) with many examples in academic research, and a growing number in applied policy analysis (Gilbert et al., 2018). In keeping with its computational approach, ABM consists of three core components; *inputs*, *processes* and *outputs*.

Inputs will usually consist of existing data, such as relevant demographics and distributions for people. In the absence of such data, hypothetical parameters might be used instead and then calibrated, alongside testing a model's 'sensitivity' to changes in these parameters. Theory can be equally important input, as can participatory input from stakeholders. Accordingly, the model itself forms the processes through which these inputs are then run. They are operationalisations of the very social processes, or theories, that we are interested in exploring and improving our understanding – built by writing computer code (see fig.1) to explicitly model (i) an environment, (ii) agents and (iii) interactions. Firstly, the virtual *environment* will usually represent some form of social space, whether geographical or a more abstract conceptual space, such as a friendship network or job market. Secondly, this environment is inhabited by *agents* – these are autonomous decision-making entities and can represent people,

such as LGBTQ citizens, groups or organisations, such as workplaces – who, thirdly, *interact* with each other and with their environment.

```
to update-citizens

    ;; update scores, age, and position, and die if older
    ask citizens with [ age > 16 ] [ set correlation-ability-outcome 1 - abs ( career-outcome - ability )
                                     set age age + 1
                                     ifelse -205 + (age * 5 ) > 200 [ set ycor 200 ]
                                                                    [ set ycor -205 + ( age * 5 ) ]
                                     if age > 60 [ if random-float 1 < 0.05 [ set dead-agents dead-agents + 1
                                                                              die ]
        ]
    ]

    ;; regulate social capital
    ask citizens [ if social-capital > 1 [ set social-capital 1 ]
                   if social-capital < 0 [ set social-capital 0 ]
    ]

end
```

Figure 1. Extract of CILIA-LGBTQ Model Code

By simulating multiple agents interacting (according to our theories) over time, behaviours unfold, and agents influence one another and their environment. We then explore any emergent properties or interesting phenomena happening within the model that were not directly written into it. These emergent patterns and behaviours can be recorded as model outputs. Outputs can be displayed in real-time on a model's interface (see fig.2) or exported into separate statistical analysis software, such as *IBM SPSS*, for detailed exploration of multiple model runs and comparison between different parameters (see, *'Model Results'* section below). Typically, models are developed with different scenarios to be 'run' and compared. These may represent different hypothetical futures, different policy interventions, or different theoretical assumptions. The comparisons allow the behaviour of the model, and the impact of different scenarios to be explored in detail. Fundamentally, the aim is never to make point-predictions about the future as this will always be a fruitless task in a complex social system (Gilbert et al., 2018). Rather the purpose is to explore the influence of different mechanisms in the model and make broad comparisons between forecasts and scenarios. For models specifically designed with theoretical explication in mind, these comparisons are particularly useful for helping us better understand the social processes, and refine the theories, underpinning the model itself (Poile and Safayeni, 2016).
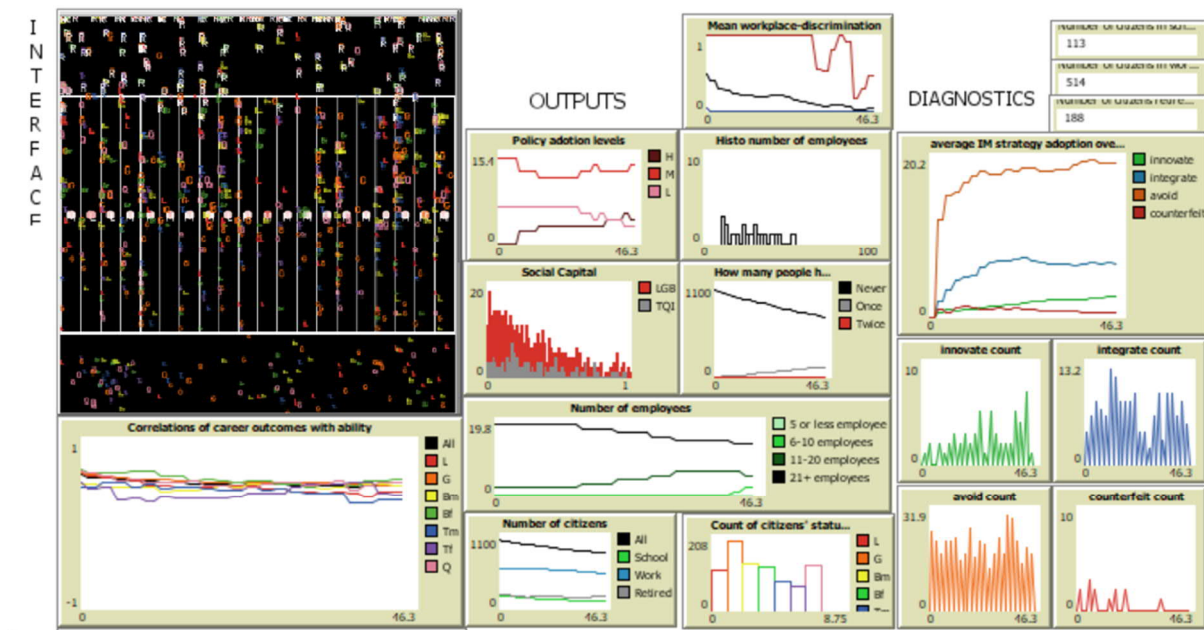
Figure 2. Example of CILIA-LGBTQ Model Interface

Many authors have written about the value ABM can offer to the social sciences, including Squazzoni (2010; 2012; 2014), Chattoe-Brown (2013), and Gilbert (2019). However, there can be a bit of a divide between those who use ABM and those who do not. Johnson (2015) situates it as one of the best methods to use when heterogeneity of agents is a core component of one's theory and where interaction is important – such as when agents influence one another, either directly (e.g. employer-employee or colleague interactions) or indirectly (e.g. competing for jobs or influencing a workplace's policy-adoption) – and when there is feedback between these interactions. They typically fall within three modes of use within the social sciences: (i) exploring theoretical questions and assumptions; (ii) performing some form of policy or intervention analysis (exploring 'what-if' type questions); or (iii) as part of a participatory research process with stakeholders, where the model often supports engagement by being developed or critiqued by stakeholders (Gilbert, 2019; Johnson, 2015).

Thought Experiments and Abductive Reasoning
As such, rather than an *inductive* or *deductive* approach, ABM has been described as a third way of doing social science (Axelrod, 2003). Epstein (1999) refers to this as the *generative* approach. Candidate causal explanations for a phenomenon are generated by implementing causal processes and mechanisms in a model and exploring their implications. In so doing, one can also explore the merits, inconsistencies, gaps and deficiencies, of a theory (Macal, 2016: 145) and enhance traditional approaches by aiding theory development, informing future data collection, and/or being used as a tool for teaching complex concepts to stakeholders (Barbrook-Johnson et al., 2017).

Perhaps most distinctively, the phenomena we are interested in, such as emergent inequalities, are studied indirectly – a model is first built, analysed and *then* related back to reality. This is in quite stark contrast with more traditional modelling approaches where data on the phenomena of interest is *first* collected and then summarised (or simplified as it were) into a model. As such, ABM can also be considered a method for abductive reasoning (see Elsenbroich et al., 2006). Probable conclusions are reached based on what we know (or think we know) by simulating a proposed sequence of interactions. This is not much different at all to classic 'thought experiments' within philosophy (Di Paolo et al., 2000) where one systematically follows a set of designated assumptions (consequents or antecedents) to their logical conclusions – hopefully learning more about these assumptions, and refining them, in the process of doing so. Silverman (2018: 34) neatly summarises this as a "self-contained means with which to probe the boundaries of the theory which informs that experiment […which] can provoke a reorganisation of an existing theory as it brings previously-known elements of that theory into a novel focus". As *computational* thought experiments, ABMs simply facilitate simulation of more complex processes.

Bridging Macro and Micro Accounts

It is this 'third way' of doing social science that we suggest offers a rapprochement to the aforementioned methodological binarism apparent within LGBTQ workplace studies. ABM provides a particularly novel means of combining quantitative and qualitative insight. Moreover, it achieves this in an arguably more meaningfully way than some other 'mixed methods' approaches, where all too often multiple methods are simply reported alongside one another in the same project (Chattoe-Brown, 2013).

Likewise, ABM addresses causation without limiting us to overly neat linear, statistically significant, or mathematically tractable, ways of thinking about cause and effect. By enabling us to model non-linear and bi-directional processes, we can explicitly link micro and macro accounts within our theories. For example, we can simultaneously model the impact of workplace discrimination on individuals' career outcomes and transitions, as well as the impact of individuals' behaviours on workplace discriminatory practices.

To illustrate further using the example of career inequalities, a typical structural narrative may describe how a workplace environment impacts the conditions, and in-turn the behaviours, of LGBTQ employees. If an LGBTQ employee experiences regular discrimination at work, this may impact their career outcomes as well as influence certain behaviours, such as finding a new employer. Additionally, other macro structural factors, such as labour markets and workplace policies, may limit or enhance the behavioural opportunities of LGBTQ employees. However, these accounts only tell half the story. We may also be interested in how the agency of LGBTQ employees in response to discrimination feedback, collectively, on their workplace environment or labour markets. By positioning individual agents as the primary unit of analysis, ABMs explore exactly these types of bi-directional processes. We can explore the logical, and perhaps not so predictable, conclusions of what happens when we combine these structural and agentic accounts within the *same* model.

Managing Social Categories in ABM

Having outlined some of the most apparent uses of ABM for social science, it is also appropriate to explore how these align with current developments in LGBTQ workplace studies as well the ways in which LGBTQ studies can shape developments in ABM methodology. Whilst ABM has become increasingly interdisciplinary (Chen, 2012), and has potential as a universal platform for the social sciences (Borrill and Tesfatsion, 2011), there remains plenty of scope for improvement in accommodating the diverse needs of research disciplines. In particular, we need to question the compatibility of ABM with recurrent theoretical insights from contemporary LGBTQ research; namely, intersectionality and queer theory.

An Intersectionality-Consistent Method?

ABMs are ideal for representing heterogeneity (Johnson, 2015; Gilbert et al., 2018). We can distribute multiple characteristics between large numbers of agents and simulate these over long periods of time. We can thus explore populations, subpopulations and intersections that would usually be considered too small for statistical significance and ignored (or glossed over) by other studies (Chattoe-Brown, 2013). In turn, this also enables us to approach social categories, like gender, sexuality, ethnicity and social class, in much more sophisticated ways than quantitative approaches do. Specifically, we can begin to explore complexity in how discrimination and inequality impact individuals at the intersections of these social categories across the lifecourse.

McGibbon and McPherson (2011) draw a useful parallel between the concept of 'synergy' and intersectional inequality. Using the example of women with both housing insecurity and mental health stresses, they describe how these two struggles synergise in ways that defy overly simplistic additive analysis (2011: 65). Both struggles are sources of inequality, however, each also interacts with the other. Poor mental health can amplify and limit solutions to housing insecurity, whilst housing insecurity can be a source of poor mental health and a barrier to accessing support. Rather than a simple linear relationship, we would expect to see a positive feedback cycle between the two.

Moreover, they suggest how the ways in which these social and health inequalities synergise over time may change in the context of systemic oppressions that are faced by women (McGibbon and McPherson, 2011: 71). Similarly, Taylor (2007) demonstrates ways in which class and sexuality can interact in the lives of working-class lesbian women, whilst Pedulla (2014) proposes how intersections of race and sexuality may moderate each other's effect on earnings in unique and perhaps unexpected ways. This is a level of complexity embraced by intersectional and queer perspectives, and yet challenging to traditional statistical analyses. However, ABM can embrace these non-linear relationships and complex interactions. There is a strong theoretical consistency between intersectionality theory and complex adaptive systems approaches (McGibbon and McPherson, 2011).

Likewise, ABMs can also be utilised explicitly to draw attention to the impact of such complex approaches to social categories. As Chattoe-Brown (2013: 7.1) suggests:

"As with debates between qualitative and quantitative researchers, those who draw attention to detail need to [be able to] show not just that there is detail but that it has

effects (in terms of quantitative outcomes for example.) It is not clear this can be done without simulation."

In this way, ABM can directly help to explore, demonstrate and defend the importance of certain details of a theory that might otherwise be left out of a model. O'Connor et al. (2019), for example, use their model to demonstrate how intersectional inequality between social groups can arise in the cultural emergence of bargaining norms even when all social categories have identical preferences and abilities. In so doing, they directly contribute to calls for intersectional considerations within the wider methodological literature.

Nonetheless, with exception of O'Connor et al. (2019), there has been little attempt to forge a bridge between intersectionality theory and ABM representations of specific social systems, such as the workplace and labour markets – let alone LGBTQ experiences within these systems. At first this may appear slightly peculiar for a method revered in its capacity to represent heterogeneity (Johnson, 2015; Gilbert et al., 2018). However, as our reflections on designing an LGBTQ workplace model suggests (see below), this may be due to a preoccupation with simplicity among modelers and limitations in modelling critical and post-structural accounts of social categories. For the field of LGBTQ studies, specifically, we need to consider the compatibility of ABM with 'queer' perspectives.

A 'Queer(able)' Method?

Whilst we argue that ABM is consistent with intersectional perspectives, the extent to which ABM is amenable to 'queering' heavily rests upon what we mean by 'queer' and what we consider the minimal requirements for a 'queer methodology'.

Perhaps most superficially, queering can describe the application of a method to non-normative subjects. And, in so doing, visibilising sexual/gendered lives and practices often simplified out of larger population models (Browne, 2010, see also Brown and Knopp, 2006). As outlined above (and demonstrated in our example workplace model below), ABM is suited to this kind of research. In addition to representing individual LGBTQ agents in name, they can also utilise demographic, attainment and behavioural data generated directly from sexual and gender minority subjects, alongside structural conditions in which they interact.

However, although often used synonymously with LGBTQ, this misses the critical and subversive capacity of a queer lens (Giffney, 2004:73). A superficial application of ABM to 'queer' subjects does not necessarily challenge normative identities and misses any potential to deconstruct normative research. A more critical application of a queer lens to ABM requires deconstructing any identity categories and assumed binaries within the model. LGBTQ studies have long conceded that categories such as homosexual, heterosexual and other identities are historically- and culturally-specific social productions (Jackson and Scott, 2010) with many theorists having focused specifically on deconstructing such identities and exposing their fluid, performative and contingent qualities. Furthermore, Browne (2007) describes how research on LGBTQ populations can more than often (re)create rather than objectively measure identities and other social categories. Queer identities and lives can be further marginalised or subsumed within normative lesbian, gay, bisexual, trans (etc.) categories.

Likewise, LGBTQ research can incorporate their own plethora of homo-normalisations that privilege some lesbian and gay voices and norms above others (Duggan, 2002; Browne, 2010),

such as the rarely contested racialised, gendered and classed discourses of 'the pink pound' and 'the educated gay' (Badgett, 2003). Reflecting on her own involvement in developing a large population survey of LGBT participants at Brighton Pride, Kath Browne (2007) exposes the perhaps irreconcilable challenge for quantitative approaches to measure plural, fluid and contingent identities. She describes how, in the process of conducting the quantitative research, she necessarily erased the margins and homogenised the categories of gay men and women – a process she described akin to selling her 'queer (academic) soul' (Browne, 2007: 3.3).

ABM is, to some extent, not limited to representing social categories as fixed. They can be operationalised as fluid and contingent upon certain dynamics within a model. Existing studies have already utilised ABM to explore the historic and cultural emergence of normative identity categories (see, Rousseau and van der Veen, 2005; Lustick, 2000). Nonetheless, incorporating this degree of complexity into how we represent social categories requires making trade-offs in complexity elsewhere if the model is to remain analysable (Gilbert and Troitzsch, 2005). For example, models directly exploring the emergence of such categories tend to be far more abstract and simpler in their representation of the social settings in which they occur. Such a trade-off may not be as appropriate when aiming to explore processes of discrimination within specific settings, such as workplaces – it is the emergence of inequality, rather the social categories, in which we are primarily interested. This does not mean to say that a queer lens cannot be applied to add levels of complexity to social categories used within a model. Deconstruction could be substituted for *analytically meaningful* complexification of social categories.

McCall (2009: 50) describes three approaches that are adopted by intersectionality researchers based on their stance on use of categories. On the one end, the main aim of an anti-categorical approach is deconstructing categories and strict definitions to reflect the irreducibly complex nature of social life. As with Browne (2007; 2010), Badgett (2003) and Duggan's (2002) criticisms of quantitative methods, this approach asserts that categories are not only too simplistic to understand social life, but also reinforce existing inequalities by reproducing fixed social fictions. On the other end, McCall describes an intercategorical approach which uses categories to explore inequalities across multiple dimensions. While this approach still can have a critical view of categories, it uses them to document existing inequalities that are formed on the basis of these categories. As such, most conceivable applications of ABM to specific social and policy issues, such as LGBTQ workplace inequalities, may be better aligned with an intercategorical exploration of identity, rather than a complete deconstruction of categories.

CILIA LGBTQ: An Example Agent-Based Model

To demonstrate the value of using ABM in LGBTQ studies of workplace inequality using a specific example, this section of the paper outlines a model developed as part of the CILIA-LGBTQI+ project. We begin by summarising the model before reflecting on the strategies and challenges we faced in incorporating queer and intersectional insights and discuss how models, such as this, may contribute to developing and advancing intersectional perspectives.

Model Summary

Whilst noting the literature on workplace inequalities discussed above, we wanted to build a model to explore the dynamics and emergence of intersectional workplace inequality among LGBTQ employees, but also take into account the impact of several important mediating factors: social capital; different types of policy intervention aimed at workplace equality, diversity and inclusion (EDI); and LGBTQ people's behavioural strategies in response to discrimination. We were only able to find one existing ABM that explores consequences of sexual orientation in the workplace. Bonaventura and Biondo (2016) used ABM to simulate the effects of sexual orientation disclosure on unemployment rates, job satisfaction and job segregation in the USA, finding the presence of more 'out' workers to increase overall workforce utility. However, their model does not explicitly measure career inequalities (beyond unemployment rates as a measure of extreme inequality) and only explores simple binaries of homosexual/heterosexual and disclosure/non-disclosure. Likewise, rates of sexual orientation disclosure are operationalised as a set parameter, rather than itself an emergent feature of workplace dynamics. Our CILIA-LGBTQ workplace model was also inspired by other models of inequalities in the labour market (Takács and Squazzoni, 2015) and educational inequalities (Grow and Van Bavel, 2015) for designing a simple idealised job market and use of the Pearson correlation coefficient as a measure of emergent inequality.

The model is built in NetLogo (Wilensky, 1999), a free and open source software environment developed for building ABMs, with an active and large research user community. There are two types of agent represented in the model; LGBTQ citizens and workplaces. LGBTQ citizens' 'behaviour' in this model is their progression through their careers, specifically the three transition points of school to work, mid-career progression, and retirement. At each point, their chances of being discriminated against are calculated based on their and their workplaces' characteristics. Figure 3 outlines the logic of the model, illustrating how citizens and workplace characteristics influence career progression and chance of discrimination.

The LGBTQ citizens each have individual parameters for their age (in years), LGBTQ status (L, G, Bm, Bf, Tm, Tf, or Q), class (working, middle), ethnicity (white, non-white), social capital (a score between 0 and 1), ability (a score between 0 and 1), and career outcomes (a score between 0 and 1). Meanwhile, the workplaces each have parameters for their underlying discriminatory attitude (i.e. akin to an institutional culture, a score between 0 and 1), and adoption of protective policies (i.e. organisational policies such as HR policies dealing with discrimination, values can be high, medium, or low). The population of agents (both citizens and workplaces) and their parameter values are setup using data for England from the UK Longitudinal Household Survey Wave 3 (Institute for Social and Economic Research, 2020), and Workplace Employment Relations Study 2011 wave (NIESR, 2015).
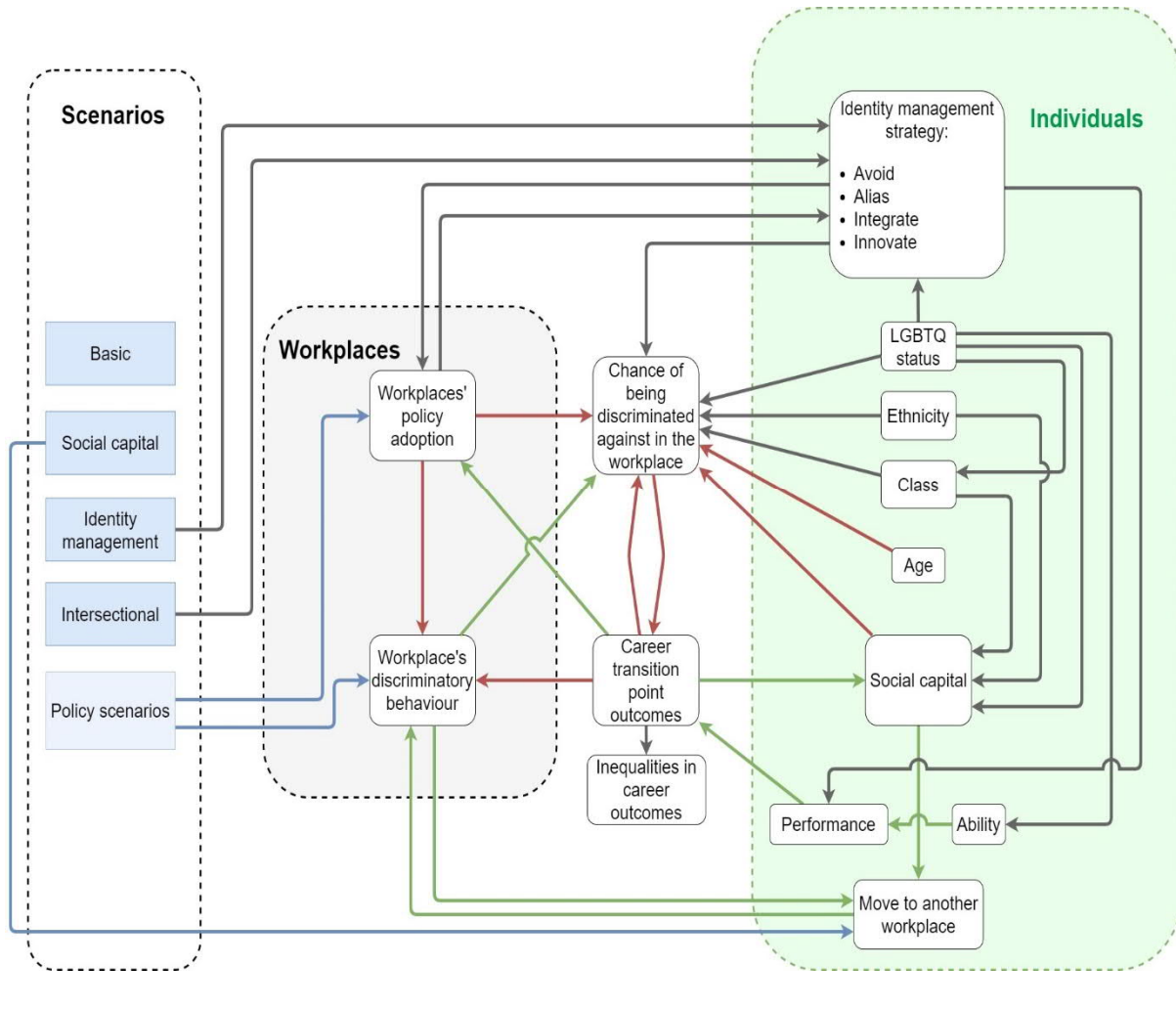
Figure 3. Overview of CILIA-LGBTQ Model Logic. Boxes represent agent characteristics or model outcomes, and the arrows represent the direction of influence between them.

Social capital and identity management strategies are included in some scenarios of the model. Social capital can be used by citizens to move to less discriminatory, or more protective, workplaces, whilst identity management refers to how a citizen discloses their sexual/gender identity within their workplace. The strategy adopted by each citizen is contingent on their own characteristics as well as their workplace. For example, if an LGBTQ citizen works within a particularly discriminatory workplace and has little social capital they may choose to avoid disclosure of their identity at work or create a cisgender/heterosexual alias for themselves. Workplaces' underlying attitudes and protective policy adoption can change through time, either by external policy intervention (i.e. a policy scenario) or through influence from their workforce (i.e. if a workplace has relatively high numbers of LGBTQ citizens, it will become less discriminatory and/or more protective, relative to others).

The scenarios of interest in the model are: (i) theory-based, exploring different rules for the effects of social capital and identity management on model behaviour, and (ii) policy-based, exploring different public policy interventions. Table 1 outlines these scenarios:

Table 1. Model Scenarios Overview

| Scenario type	Research question	Implementation
Social capital	*(Theory-based)* What is the impact of social capital on the dynamics of LGBTQ workplace inequality?	Scenario 1: Social capital is not present in the model, it has no impact. Used as a baseline to compare with second social capital scenario. Scenario 2: Social capital is implemented as a parameter of citizen agents (a score between 0 and 1). Middle class, white, Lesbian, Gay, and Bisexual agents tend to have higher social capital (reflecting patterns in the England data). Agents with a high score are both, less likely to be discriminated against, and can move to other workplaces if they are being discriminated against. This implementation represents social capital as a resource that agents can draw on to help themselves, not as something which helps others.
Identity Manage-ment	*(Theory-based)* What is the impact of LGBTQ identity management strategies on the dynamics of LGBTQ workplace inequality?	Scenario 1: LGBTQ citizens do not adopt identity management strategies in the model. This is used as a baseline to compare with the other two scenarios. Scenario 2*: Identity management is implemented as four possible strategies for an LGBTQ citizen to adopt during their workplace transition: innovate; integrate; avoid; or create an alias. Each of these require certain conditions or contexts to be met (e.g. high social capital, low workplace discrimination, or having recently moved workplaces) and have different consequences for the career transitions of the individual LGBTQ citizen adopting them (e.g. vulnerability to discrimination or social capital losses/gains) and their workplace (e.g. discriminatory workplace culture and level of policy adoption). These strategies represent the extent and nature of identity disclosure. Scenario 3*: The implementation of identity management in the model varies depending on the specific LGBTQ status of the citizen and other intersecting characteristics such as gender, social class, ethnicity and stage of transition (if Tm or Tf). These may be variants in the conditions required for adopting each identity management strategy or in consequences for the individual citizen and/or their workplace**.
Public Policy	*(Policy-based)* What is the impact of different public policy interventions on LGBTQ workplace inequality?	Scenario 1: There is no public policy influencing the model. A baseline to compare with the other two scenarios. Scenario 2: 'General improvement', every ten timesteps in the model, the underlying discriminatory attitude of workplaces reduces, representing a slow but constant cultural shift, or repeated efforts by public policy to encourage less discrimination via 'soft' means, i.e. marketing campaigns or education and training. Scenario 3: 'Force adoption': a one-off public policy to force full adoption of protections by workplaces. Workplace agents' parameter value shifts to 'high', but can drop again after. Represents a one-time push by government which is not followed up by future administrations.
Citizens' social capital factors into their strategy adoption and so this scenario assumes social capital is implemented in the model. **Variants were informed using qualitative lifecourse interview data from the wider CILIA LGBTQI+ project.**		

Model Results

The primary output measure is the correlation coefficient between citizens' ability and career outcome parameters (i.e. one measure of discrimination) broken down by each of the LGBTQ groups. We also present the mean, minimum and maximum underlying discrimination attitudes of workplaces, through time. The following results are limited to an exploration of the theoretical scenarios outlined above. They are also kept brief for the purpose of illustrating the types of dynamics that models, such as this one, can generate and their relevance for intersectional analyses. A more in-depth analysis of the causal explanations underlying these results is outside the scope of this paper but would, nonetheless, be an important element of any applied policy analysis.

For workplaces (fig. 4, below), we can see the significant impact that each theoretical scenario has on discrimination attitudes. Whilst the minimum (min.) value stays consistent across all four scenarios, the mean values are highest when social capital is distributed among citizens (panel 2). Moreover, this is also when the most discriminatory workplaces (max.) maintain a consistently high discriminatory attitude. Once identity management dynamics (panel 3) are introduced to the model, we see both a reduction in the discrimination of the most discriminatory workplaces, as well as a slight reduction in discrimination of the average (mean) workplace. Once we introduce intersectional variation to the conditions and consequences of the identity management dynamics (panel 4), these reduce further and form a lower peak.
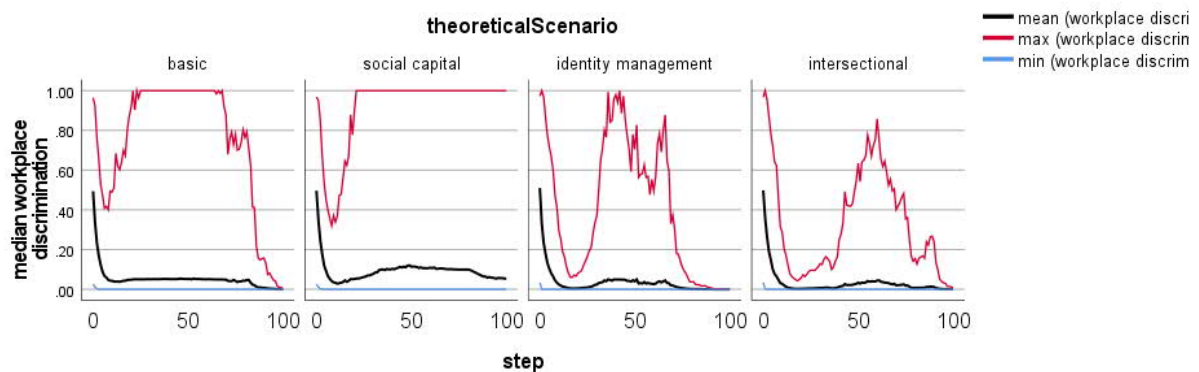
Figure 4. Workplace Discrimination | 3,000 citizens | 320 model runs | No public policy scenario | The plot shows the average mean, min and max discrimination attitudes of workplaces of model runs over 100 timesteps (x-axis). Each panel plots these results for different theoretical scenarios (from left-to-right: basic, social capital, identity management and intersectional).

These results suggest: (i) social capital (as implemented in the model) reinforces inequality between citizens, allowing citizens with it to prosper at the cost of those without, and allows the most discriminatory workplaces to languish unchanged, as citizens with enough social capital leave them; and (ii) collectively, the identity management practices of individual agents (as implemented in the model) may have marginal impact on the average workplace, but can significantly moderate attitudes of the most discriminatory workplaces over time. This is

because it only takes the presence of one or two citizens disclosing their gender/sexual identity (innovate or integrate) to reduce extremely high discriminatory values of a workplace, in turn, leading to a positive feedback of more colleagues willing to disclose. Workplaces already low in discriminatory attitude have less to benefit from addition disclosures.
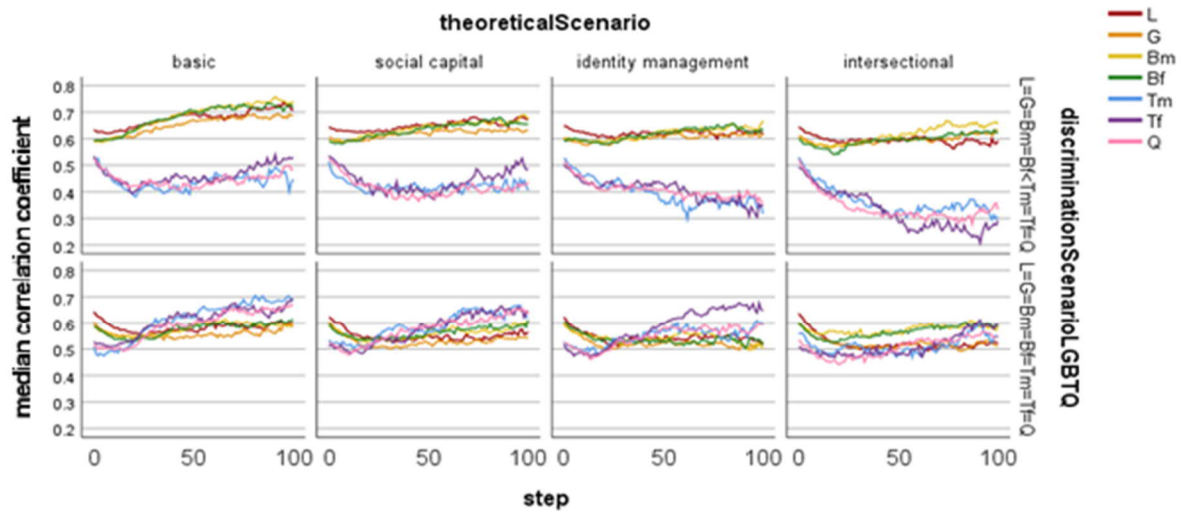

Figure 5. LGBTQ Inequality | 3,000 citizens | 320 model runs | No public policy scenario | The plot shows the average correlation coefficient between ability and career outcome parameters (i.e. one measure of discrimination) for each LGBTQ status over 100 timesteps (x axis). Each vertical panel plots results for different theoretical scenarios (from left-to-right: basic, social capital, identity management and intersectional) whilst horizontal panels compare results between initial levels of discrimination faced by each LGBTQ status (bottom = equal, top = T and Q exposed to higher levels).

However, this significant reduction in workplace discrimination over time does not *necessarily* correspond with greater career outcome equality for citizens (fig.5). Despite a gradual reduction in workplace discrimination, the correlation between agent's ability and their career outcomes only marginally improve for LGB citizens in the basic and social capital scenarios and remain fairly consistent over time in the identity management and intersectional scenarios. For TQ citizens, this trajectory is particularly dependent on the initial levels of discrimination faced by each LGBTQ status. The bottom panel (fig.5) displays results for model runs where LGBTQ citizens all experience the same levels of discrimination, whilst TQ citizens are exposed to higher levels of discrimination than LGB citizens in the top panel. When exposed to the same levels of discrimination, TQ citizens' career outcomes gradually correlate more with their ability over time in all scenarios (though to varying extents). However, when exposed to higher levels of discrimination than their LGB counterparts, the correlation for TQ citizens remains fairly stable over time under basic and social capital scenarios. Moreover, this correlation significantly reduces over time under identity management and intersectional scenarios, resulting in increased inequality between the TQ and LGB status citizens.

These results suggest that (i) slight differences in *initial* distributions for discrimination for each identity at the beginning of the simulation sets agents on completely different trajectories once we begin factoring for how people manage their identity under these conditions; and (ii) qualitative differences (observed from our lifecourse interviews[3]) in the conditions and consequences of identity management for each LGBTQ status can further amplify these trajectories. Nonetheless, these results still only reflect the dynamics of a singular social category (LGBTQ status).
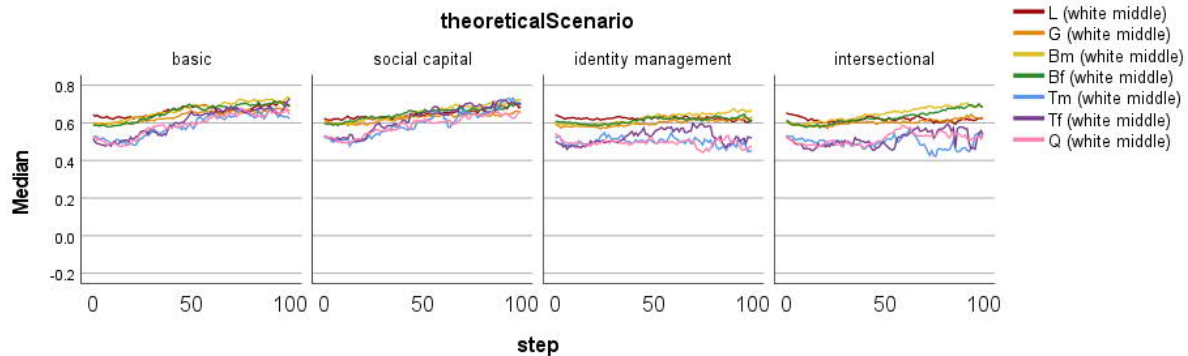

Figure 6. White, Middle Class LGBTQ Inequality | 3,000 citizens | 320 model runs | No public policy scenario | The plot shows the average correlation coefficient between ability and career outcome parameters (i.e. one measure of discrimination) for each LGBTQ status of white, middle class citizens over 100 timesteps (x axis). Each panel plots results for different theoretical scenarios (from left-to-right: basic, social capital, identity management and intersectional).

If we disaggregate these results further by exploring the intersections of ethnicity and social class with LGBTQ status, the trajectories for each respective scenario are far from identical. For example, white middle class TQ citizens' (fig.6) career outcome and ability correlation increases significantly more over time than that of non-white working class TQ citizens' (fig.7) under the basic and social capital scenarios. Likewise, the correlation for white, middle-class citizens (regardless of LGBTQ status) remains higher than 0.4 for all theoretical scenarios and either increase or remain fairly consistent over time. Non-white working class TQ citizens, however, do not tend to experience significant increases over time and, under the intersectional scenario, can experience significant decreases – with non-white, working-class Q citizens even reaching a negative correlation where high ability (albeit weakly) predicts lower career outcomes. Furthermore, the intersectional scenario introduces inequalities emerging between white, middle class LG and B citizens (fig.6, panel 4) that do not emerge between non-white working-class LG and B citizens (fig.7, panel 4).

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[3] These lifecourse interviews were with (N=48) LGBTQI+ respondents across England and were all conducted between June 2019 and March 2020 as a part of the wider CILIA-LGBTQI+ project. They covered respondents' lives, identities, past experiences, experiences of discrimination and inequalities, as well as their thoughts about the future.
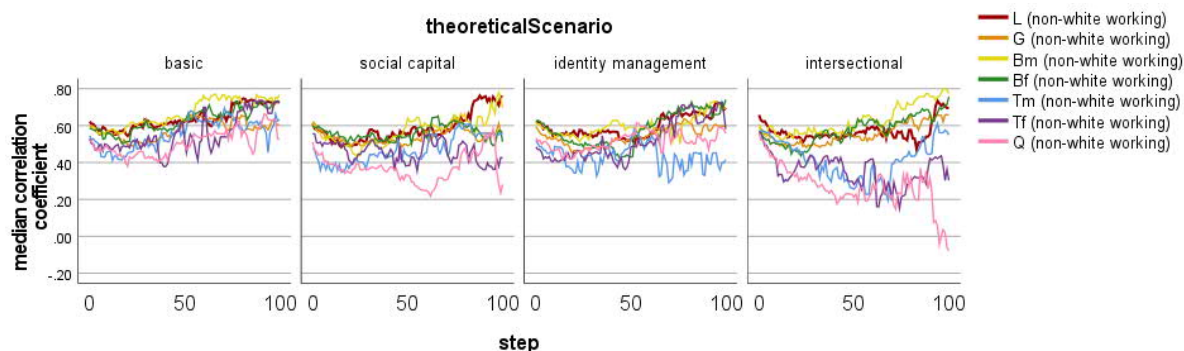
Figure 7. Non-white, Working Class LGBTQ Inequality | 3,000 citizens | 320 model runs | No public policy scenario | The plot shows the average correlation coefficient between ability and career outcome parameters (i.e. one measure of discrimination) for each LGBTQ status of non-white, working class citizens over 100 timesteps (x axis). Each panel plots results for different theoretical scenarios (from left-to-right: basic, social capital, identity management and intersectional).

These results suggest that intersections of ethnicity and social class are relevant to understanding emergent LGBTQ inequalities in all theoretical scenarios, particularly as we begin accounting for increased agency (i.e. the identity management and intersectional scenarios). Comparing trajectories of LGBTQ citizens, when accounting for ethnicity and social class (figs.6–7), can reveal significantly different dynamics to that of aggregate LGBTQ categories (fig.5).

Discussion

These brief model results illustrate our ABM's ability to observe non-linear relationships between the variables of which we are interested, as well as plausible causal mechanisms for each of these. For example, we were able to observe positive feedback between sexual/gender identity disclosure and changes in discriminatory attitudes of workplaces over time – including the contexts in which such dynamics were most prominent. Here disclosure appears to have a much larger cumulative effect on the most discriminatory workplaces, with diminishing returns among workplaces that are already inclusive. We can also observe the direct impact of different theoretical scenarios (as we have implemented them) on key output measures, and why they have impact that they do, by tracing back their causal mechanisms. Likewise, any 'unusual' or counterintuitive results running counter to empirically observed phenomena can be used to scrutinise and refine the theories that have been implemented. For example, a theory may need complete reassessing or only adjustments made to one or two minor assumptions in order to produce more intuitive or empirically sound results. As such, the model facilitates an iterative process between validation and theory development.

Furthermore, our model suggests that there is a quantitative impact of the qualitatively-derived details we extracted from our lifecourse interviews. The minor intersectional variations in how identity management practices operate in accordance with LGBTQ status, ethnicity and social class (in terms of conditions and consequences) do appear to affect our measures of career outcome (in)equality when disaggregated and compared alongside one another. The results also highlight the relevance of any initial levels of discrimination experienced by each intersection. For example, intersectional variations in identity management practices have a larger impact on the trajectory of career outcome (in)equality the larger the initial levels of discrimination each intersection is subjected to. Here, our ABM illustrates possible contexts in which these dynamics are most relevant and, as such, should be useful for informing future empirical studies and data collection.

Negotiating Data Limitations

An often-overlooked value of ABMs is simultaneously a common criticism afforded to them - they are regularly data-hungry. When used for exploring policy scenarios, they require at least: (i) nationally representative data to setup a realistic looking population of agents; (ii) data about any interventions for scenarios, (iii) data about the impact of interventions on behaviour (at the individual level); and (iv) typically longitudinal data about outcomes, to validate against. The process of building and using a model can thus make very clear what data is available, how usable it is for the modelling process, and where there are gaps. In addition, the process of examining results, and the questions they throw up, can also inform future data collection, creating demand for data that was not there before (Barbrook-Johnson et al. 2017). As such, building this model drew our attention to the current lack of measures for workplace discrimination as well as the shortage of data for each intersection-ed LGBTQ category.

Nonetheless, issues arise when there is limited data to inform certain parameters – especially those considered important to a model. When developing the CILIA-LGBTQ model, it quickly become apparent that there was not enough publicly available data on people who identify as trans or queer in relation to labour market characteristics to meet our needs. We thus had to make extra assumptions about them, such as levels of access to social capital, compared to other groups where there was sufficient data. Furthermore, although initially included within the model, an entire absence of relevant data (both quantitative and qualitative) on intersex populations resulted in us tentatively dropping this category altogether. We did not want to falsely suggest that intersex populations were meaningfully represented in any way within our model. To do so would have undermined how little we know about intersex lives and the substantial need for research in this area. Further thought should go into how data on intersex lives is collected for similar projects.

Likewise, whilst there is data available to document LGB labour market characteristics and disadvantage (NIESR, 2015; Institute for Social and Economic Research, 2020), splitting this group further by class, ethnicity and disability proves ineffective as this creates very small cell counts and reduces statistical power. In such cases, a modeller would usually feel pressure to exclude these intersections altogether so as to avoid introducing too many assumptions to the model's parameters. We approached this issue by developing the model with scaled parameters for those values we were uncertain of, or for which we had little supporting data. We were then

able to calibrate these to identify plausible values after running sensitivity analyses on the whole array of parameter space – a significantly larger undertaking the more uncertain parameters there were. Meanwhile, we utilised qualitative lifecourse data from the wider CILIA-LGBTQI+ project to inform the behaviours of LGBTQ agents within the ABM, as well as different policy interventions we could implement as scenarios to compare.

Tweaking the distributions, behaviours or policy scenarios we have applied to the model should also facilitate making cross-national comparisons. The next stages in developing this model involve precisely this. We can interchange between input data collected from UK/England surveys with comparable survey data from Germany and Portugal in order to explore the impact of differences on model behaviour and output generated from these contexts. Nonetheless, the extent of this cross-national comparison will be limited by the current lack of cross-national data allowing us to study LGBTQ trajectories in the labour market in a comparative fashion. Existing cross-national generational population surveys such as ESS and EU-SILC allow us to capture only the individuals in same-sex partnerships. Single LGB individuals as well as all TQI+ are therefore left unrecorded in these surveys, leaving researchers using these data sources with considerably selective samples. Moreover, the same-sex partnership data from some countries are cleared from these surveys by omitting these cases or recoding the data in the process of data-cleaning (Schönpflug et al., 2018). The numbers of individuals in same-sex partnerships for other surveys are suspiciously low and raise questions about data quality. As a collaborative project consisting of four partner teams across four European countries, we somewhat navigated this issue by producing and sharing a template data table (see, online repository). This enabled us to identify the concepts we needed data for in the model and possible (albeit variable) proxies for these concepts that might be available from each country. Whilst not all projects will have the benefits of cross-national teams, a similar approach could be undertaken by stakeholder organisations.

Implications for ABM

The mandate for inclusivity, representation, and intersectionality in LGBTQ studies has the potential to be in direct opposition to one of the core axioms of modelling (of all types) – that all else being equal, a simpler, more abstract model is better than a more complicated one (Gilbert, 2019). This is akin to the concept of Occam's razor (i.e. choose an explanation with the fewest assumptions). However, it also reflects a pragmatism and desire for elegance in modelling, in which simpler models are understood to be easier to understand and analyse, are less computationally demanding, and more elegant (Helbing, 2012). Simplicity is seen to represent clarity and neatness of thought.

As our model demonstrates, this presents a significant challenge for developing models to explore ever-increasing intersections, or category combinations, as well for integrating queer insights. Our use of seven sexual/gender identity categories (L, G, Bm, Bf, Tm, Tf, Q) alongside two social class (working/middle) and two ethnicity (white/non-white) categories amounts to 28 unique intersections to explore. Inclusion of just one more social category (even if simplified to a binary, such as abled/disabled or urban/rural) would bring these intersections up to 56. Combine these 28 intersections with the four theoretical and three policy scenarios (see, Table 1), and you have 336 sets of results to interpret, and understand the underlying

causal mechanisms behind, before even considering their sensitivity within the parameter space of any uncertain values. Furthermore, each additional category increases the minimum number of agents needed to explore these intersections. For example, to generate enough citizens at the intersection of middle-class, non-white "Tm" and "Tf" in our model for a reliable analysis we used 3,000 agents each. More agents require more computational power and slows down our models. This is especially important to consider if each agent is programmed to interact with every (or a large proportion) of agents at each timestep. Our example model could manage such large numbers of agents primarily because most of their interactions between one another are indirect (e.g. each citizen directly interacts with their workplace, which is also interacted with by other citizens). A more complex model with unmediated interactions between *every* agent would be highly demanding for a model intended for an intersectional analysis of two or more statistically infrequent categories (such as a middle-class trans men of colour).

Nonetheless, the ABM community is perhaps unusual when compared with other modelling communities, as this maxim of simplicity does not go entirely unchallenged. There is an ongoing debate between those who support a 'KISS' ('keep it simple stupid') approach to modelling and those who support 'KIDS' ('keep it descriptive stupid') or 'EROS' ('enhancing realism of simulation') approaches (see Jager, 2017; Jager and Janssen, 2003; 2012) – i.e. more detailed or complicated models. This debate is relatively nuanced and lengthy, so we will avoid describing it in detail here (see Edmonds and Moss, 2005). However, to summarise briefly, it centres around differences of opinion pertaining to the pros and cons of simplistic or more descriptive models, and when it is appropriate to adopt each approach.

Arguably, it is possible to defuse any potential dispute here by reaffirming that purpose should always drive model design decisions. For example, whilst simpler agents may be more useful for predicting the behaviour of large macro-level phenomena, complex agents may be better suited for exploring individual agent or small group behaviours (Balke and Gilbert, 2014). Likewise, if we intend to build a small and easily comprehended model for the purpose of testing a theory or quickly comparing generic types of policy we may prefer to use a KISS approach, whereas engaging stakeholders may benefit from either a simple comprehendible design or realism (Johnson, 2015). However, if our aim is to compare similar or specific policies, or to capture nuanced differences across multiple concepts between scenarios (as an intersectional approach presupposes), a KIDS or EROS approach would be justified. Despite this debate, and the clear need for pragmatism in response to a model's purpose, there is still a widespread and often unquestioned drive for simpler models which can inadvertently serve to discourage intersectional approaches to ABM.

Integrating Intersectionality with Model Purpose
Owing to its strong qualitative tradition and a rich focus on context, LGBTQ studies have embraced an intersectional approach. This means that, when building an ABM, we may wish to include all sorts of additional parameters for people and/or contexts. Using our model again, we might consider further increasing complexity by adding different types of workplace (i.e. sector, location, historical norms) which are important to labour market dynamics and which intersect meaningfully with people's attributes. However, with so many possibilities for increasing complexity, a line needs to be drawn somewhere irrespective of one's take on the

KISS-KIDS-EROS debate. There is little value in a model that is just as complex as the real world (Gilbert and Troitzsch, 2005). Deciding where to draw this line is the challenge. There is a tension in reconciling these potentially competing forces to make a model simple and data-driven, whilst also being inclusive and intersectional. Making design decisions about what to include/exclude from a model is an art, not a science and, as ever, should be driven by a model's purpose. If we are to complicate a model by including multiple social categories, then intersectionality should be an explicit component of our research purpose, rather than simply added for the sake of detail and realism.

Another issue which we have sidestepped until now is whether, in modelling LGBTQ people in any setting, we also need to model the wider cisgender and heterosexual population alongside them (as in Bonaventura and Biondo, 2016). Their inclusion makes perfect sense when we consider how the behaviours and situations we are modelling are highly likely to be impacted by their behaviours. However, when we consider that the LGBTQ population is estimated at around 3% of the total English population (van Kampen et al., 2017), proportional inclusion of cishetero agents (on top of the 3,000 LGBTQ agents) means an exponential rise in both the complexity of the model and weight of computation required to run it. Excluding the cishetero population thus becomes an appealing simplification to make, and indeed, one we made in our example model. In effect, the workplace agents, with varying discriminatory attitude values, serve as highly simplified substitutes for an otherwise much larger number of cisgender and heterosexual colleagues in the model. In practice, decisions need to be made about how important the interaction between LGBTQ agents and cishetero agents is for a particular model. If the interaction is genuinely core to the research questions and model purpose, they will likely need to be included. In any other situation, considering the costs in lost simplicity and higher computational weight, we would suggest removing them.

Alongside deciding which identities to include/exclude, we also needed to consider diversity in the actual behavioural rules we model. Representing multiple intersecting identities with varied distributions for each key parameter value (e.g. social capital) is one thing, but a deeper level of representation is only reached by considering diversity in behavioural rules and consequences for different types of agent. For example, in addition to a lower social capital, BAME trans citizens may not respond to workplace discrimination, draw upon social capital, or manage their identity in the exact same way as white LGB employees. Taking on such a rich definition of diversity and inclusion also comes at the price of a significantly more complicated model. Decisions about the depth (rather than just breadth) of representation required from a model also have to be resolved. Do we want to prioritise (a) a diversity of types of agents with little diversity in behavioural rules, or (b) a diversity of decision rules with a more restricted diversity of agent type? To have both arguably stretches the reconciliation between simplicity and representation so far as to break it.

Incremental Complexity: A Modular Approach

One way, however, in which this reconciliation can be maintained is by taking a modular approach to model design. As mentioned, ABMs allows us to explore in detail the workings of our mechanism or theory. We can implement it in a model, push and pull at it, change parameters and settings, change its contexts, and explore how it reacts to these and what results

it produces. Accordingly, in a modular fashion, we can add and remove additional components to extend or simplify our theory. In this mode, we focus less on the macro-level phenomena we are trying to reproduce, but on comparing and contrasting the outcomes/results of different implementations and theories in the model. Simultaneously, the stringent demand for validation using (likely limited) existing data also decreases (Poile and Safayeni, 2016). This is what we have done with our example CILIA-LGBTQ model by comparing between incrementally complex, as opposed to entirely separate, theoretical scenarios (see fig.8). So, let us consider this a little further.
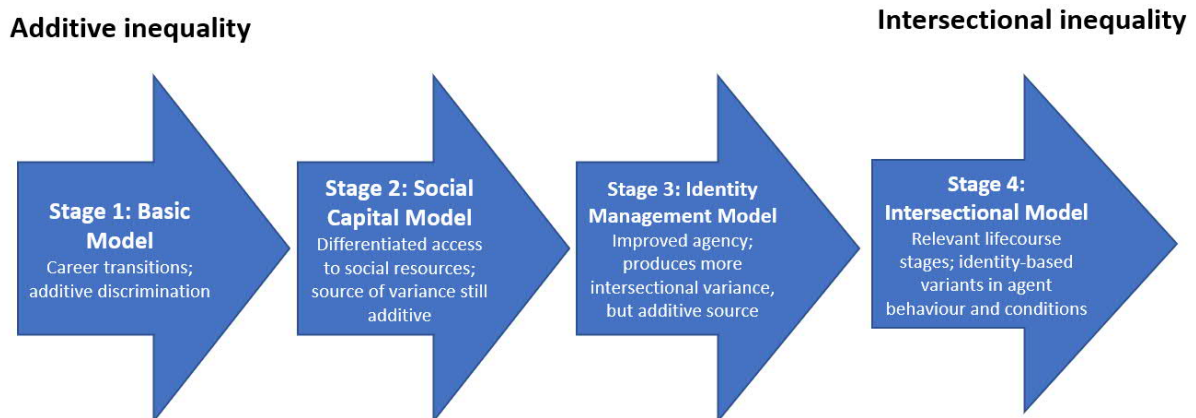
Figure 8. Incremental Complexity from a 'simple' additive model of LGBTQ workplace inequality to a complex intersectional model of inequality and agency.

We iteratively developed the model in four distinct stages (each a model in its own right) according to the complexity of the theoretical scenarios we wanted to explore. Each one of these stages were progressively more meaningful in their application of intersectionality. The first of these, the 'Basic Model', implements career transitions (school-work, mid-career and retirement) and simple additive forms of discrimination based on citizens' LGBTQ status, ethnicity and social class. Each source of discrimination essentially chips away at citizens' transition scores at each transition period. The second stage, the 'Social Capital Model', then introduces differentiated access to social resources between citizens based on their LGBTQI status, ethnicity and social class. This provides some intersectional variance in behavioural opportunities, such as capacity to move to workplaces that are less discriminatory. However, the source of this variance is still additive; a citizen's social capital, just like their experience of discrimination, is the sum of that afforded by each of their social identities. This does not capture the central tenets of an intersectional analysis, which rejects overly simplified additive models of (in)equality (King, 2016).

Stage 3, the 'Identity Management Model', further addresses this issue by facilitating more agentic inter-action between citizens and their workplaces. Rather than have their agency limited to moving workplaces, this iteration introduces four possible identity management strategies contingent on an agent's access to social resources, experiences of discrimination, and current workplace environment. Again, this increases intersectional variance in model

output considerably (see figs 5–7), but still only as a consequence of the additive impact of discrimination and social capital. The model does not account for structural and lifecourse differences between social groups and how these can limit, or enhance, their behavioural opportunities. The main assumption in this model (stemming from the exclusively lesbian and gay, and occasionally bisexual, focus of the identity management literature) is that identity management is qualitatively the same for all LGBTQ citizens and regardless of intersecting factors such as social class, ethnicity, gender, relationship status and stage of gender transition. This reflects some of the earlier criticisms of homo-normalisations in LGBTQ research where some lesbian and gay norms and voices are privileged above others (Browne, 2010: Badgett, 2003; Duggan, 2002). Likewise, this assumption is in direct opposition to findings arising from our LGBTQI+ lifecourse interviews, and so are explored further in the model. Would similar model behaviours and career inequalities still emerge if we account for some of the qualitative differences induced from these interviews? As Chattoe-Brown (2013) suggests, here we can use simulation to directly compare assumptions and explore the plausible macro-level impacts of qualitative details we may otherwise be inclined to leave out of our model. This become the basis for a more definitively intersectional final iteration of the model.

Though these discussions may seem abstract, and in the end only apply directly to our one model, the process of iterating through theorising, modelling, and reflecting, provides an invaluable thinking tool, which we could not have done without ABM, or a similar modelling approach. As such, we can ensure that we sufficiently understand the behaviours of a simpler model before increasing complexity and tracing the causal processes responsible for any significant changes in model output. We can further interrogate the model to understand why this is and learn a little bit more about the theory we have implemented in the process of doing so.

Complexification and Negotiating with 'Queer Moments'

Reflecting back on Browne's (2007) concession that engaging in research that requires quantifying social categories is akin to selling one's queer academic soul (2007: 3.3), our ABM has arguably done precisely this. By relying on discrete sexual/gender categories ('L', 'G', 'Bm', 'Bf', 'Tm', 'Tf', 'Q') it has (re)created them and ignored some of the more fluid and contingent identities apparent within the wider CILIA LGBTQI+ project. Summarising an array of marginal identities as 'Q' was useful for statistical significance and feeding existing quantitative data (e.g. social capital) into the model, but nonetheless homogenised and fundamentally de-queered them. Ideally, the model would also have separated sexual and gender categories so that agents could be both lesbian and trans, for example. However, due to our input data, we were somewhat restricted in doing so – further illustrating how perennial issues with existing data can permeate into our own models. As such, ABM meets some of the same limitations for queering as quantitative approaches, not least because of a reliance on traditional methods for secondary data. Likewise, a complete deconstruction of social categories dismisses any means of simplification and quantification that are needed for operationalising complex social theories and processes into a computational model. As already suggested, we could build a model to explore the emergence (or not) of these social categories, if that was the particular purpose of our research. However, use of categorical information for

our model (in fact for any model) is inevitable, and thus an entirely deconstructive queer approach may be considered outside the scope of ABM.

Beyond a deconstruction of social categories and identities, queer(y)ing can also be used to interrogate cis/heteronormative assumptions built into a model. Kath Browne's (2010) interrogation of queer quantification for the 2011 census can also shed some light here. By deconstructing existing categories and negotiating the creation of new concepts and categories, such as the decoupling of gender, sexuality and behaviours, Browne demonstrates how anti-normative and disruptive moments can also feature in the formation of quantitative categories. Rather than stable and permanent, she contends that data and categories "can be redefined, reused and reassert diverse views that take account of diverse social realities" (Browne, 2010: 248).

Whilst not entirely disruptive once recuperated and solidified into the final product, these 'queer moments' (as Browne refers to them) are nonetheless valuable for contesting and making visible normative assumptions at various stages of the research process. This is an area where ABM research may have particular scope for integrating queer insights. ABM's particularly iterative nature (arguably more so than other methodologies) and the level of precision needed to translate conceptual models and theories to code (Poile and Safayeni, 2016: 2.9) regularly illuminates specificity gaps in the model's specification. Such gaps force a modeller to make what is often termed 'reasonable assumptions' in order to fill them (*ibid.*). These can be simple technical assumptions, such as minor details required to satisfy constraints of the computational language (e.g. what arithmetic operator to use) or, more significantly, theoretical assumptions, which require details added to any underspecified aspect of the conceptual model (Poile and Safayeni, 2016). Ideally these are made explicit and justified within a model specification and any subsequent publications. However, in practice, these can often go unacknowledged (Railsback and Grimm., 2012).

Moreover, the very concept of 'reasonable assumptions' suggests deferring to normative categories and concepts. Thus, we should seek to introduce 'queer moments' to ABM design to interrogate and disrupt what might appear a reasonable assumption to the modeller. Such moments occurred at various stages in the design of this model, such as our insistence on keeping T and Q categories despite poor existing data, and our incorporation of behavioural strategies beyond the simple binaries of disclosure/non-disclosure seen in similar models (see, Bonaventura and Biondo, 2016). Likewise, some distinct features included in the 'Intersectional Model', such as relationship statuses for B agents and 'pre', 'mid' and 'post' transitional phases for Tm and Tf agents, are notable examples of pushing the method in a direction we might not normally have taken it. Each of these inclusions represent incredibly varied and complex social processes in their own right and, as such, still required simplification when operationalised into the model. However, by purposefully applying a queer(y)ing lens to key stages in the iterative design process, we interrogated some normative assumptions about sexual and gender categories, as well as some descriptive binaries.

Furthermore, unlike quantitative approaches where normative categories become fixed in the research's design at an early stage, the outcomes of small changes to an ABM's assumptions can be explored directly with relative ease. Perhaps one advantage of ABM is that it allows researchers to reconfigure the model again and again, reset the parameters as well as reformulate assumptions and the rules of interaction between agents. These features of

modelling provide researchers not only the opportunity to run different scenarios or social processes using different agent characteristics and representations, but also to test alternative theoretical assumptions and categories. Thus, 'queer moments', in tandem with ABM's propensity for reformulation and scenario testing, allows one to directly explore, compare and document the system-level implications of any normative and queer assumptions (so long as these assumptions are identified in the first place).

Conclusion

This paper has explored the contribution ABM can make to the study of LGBTQ lives, and conversely, how the theory and traditions of LGBTQ studies can inform the practice of ABM. We have described and used the example of a model focused on LGBTQ workplace inequality to demonstrate our arguments. The purpose of this exploration was to make clear the potential mutual value of the combination of this modelling method and substantive research topic. Whilst ABM is suitable for exploring complex systems and heterogeneity in populations, this paper has highlighted some of the tensions in synthesising intersectionality and queer perspectives with ABM – namely its limitations in dealing with the anti-categorical (McCall, 2009). We have also, hopefully, addressed some of the ways in which these tensions can be negotiated.

As a suitable method for comparing alternative theoretical- or policy- scenarios, ABMs have particularly strong policy relevance. They can be especially valuable in helping policymakers with agency-focused lifecourse complexity – an area full of intersectional variation to be explored. The future value of ABM within LGBTQ research will almost certainly be in complementing existing methods and theory, not replacing them. Scepticism and wariness of 'modelling' or 'quantification' should be welcomed and challenged, as it should any approach that requires making normative assumptions. A conscious effort in challenging these types of assumption when designing a model – applying 'queer moments' – can not only draw research in unanticipated directions, it can visually illustrate the very real impact such assumptions have on the data we collect.

The CILIA-LGBTQ workplace model is intended as an important starting point in developing the role of ABM in LGBTQ research and for bridging qualitative- and quantitative-derived insight. Whilst research purpose should be the principle gauge for striking a balance between simplicity and complexity in a model, KISS has tended to dominate as a default axiom in simulation research. This is in part a legacy of more traditional modelling paradigms, but arguably also an artefact of the historic (and to some extent present) dominance of one or two particular research disciplines within social science applications of ABM. The recent call for more detailed models reflects a growing interest in ABM from a wider range of disciplines. For example, the EROS principle emerged from a demand for more psychologically plausible agents where theories of human behaviour are available (Schaat et al., 2017; Jager, 2017). As such, a renewed uptake of ABM across more diverse disciplines, such as feminist and LGBTQ studies, should further promote a more pragmatic stance towards simplicity within the modelling community as methodological conventions adapt to new research challenges of inclusivity, representation, and intersectionality.

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