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A Genetically Informed Approach to Trust and Attitudes towards Immigration

Studies on Swedish Twins in the Age of Immigration and Diversity

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Abstract

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As immigration becomes increasingly central to public discourse and policymaking, understanding why individuals differ in their attitudes and responses to immigration and diversity is crucial given the significant political and social implications. Social theories explaining variation in sociopolitical attitudes and behaviours are well established, but recent research in social science genetics reveals that genetic differences contribute to a wide range of life outcomes, including educational attainment, aspects of one's social environment, and political attitudes. These findings underscore the need to actively incorporate genetical information into social research.

This interdisciplinary dissertation investigates three key questions concerning public attitudes toward immigration and generalised trust, using a genetically informed perspective to account for both genetic confounding and individual-level heterogeneity. The analyses draw on a large cohort of Swedish twins, linked to rich survey data (2009–2010), register records, and molecular genetic information.

Paper 1 addresses the educational divide in immigration attitudes. While self-selection partly explains this divide, the findings suggest that higher formal education exerts a moderate liberalising effect. The study is the first to use genetic data to assess the role of education-related genetic predispositions in shaping immigration attitudes.

Paper 2 examines generalised trust as a source of immigration attitudes, distinguishing it from prosociality — the willingness to help others — and controlling for twin-shared confounding. Trust is robustly associated with more open views on immigration, independently of prosociality, though primarily linked to support for immigrant admission.

Paper 3 offers new explanations concerning the debate over whether ethnic diversity compromises social cohesion. Focusing on residential interethnic exposure as a common form of everyday contact with diversity, it finds a modest negative association with trust in strangers, but no consistent links to outgroup negativity or social engagement. Moreover, this association is concentrated among individuals genetically predisposed to higher neuroticism. The influence of interethnic exposure is therefore limited in scope and dependent on individual psychological predispositions.

Collectively, these papers shed new light on the foundations of natives' attitudes towards immigration and trust, and on broader debates surrounding immigration and social cohesion, while demonstrating how social science questions can be approached using genetically informed designs.

Keywords: Trust, Attitudes Towards Immigration, Social Science Genetics, Twins, Immigration, Diversity, Sweden

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List of papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I Feng, Q. (2024). Triangulating the Relationship Between Education and Attitudes Toward Immigration. *Journal of Experimental Political Science*, 1–16.

II Feng, Q. (2025). Trust, Prosociality, and Immigration Policy Views: Evidence from Swedish Twin Data. Unpublished manuscript, Department of Government, Uppsala University.

III Feng, Q. (2025). Residential Intergroup Exposure, Generalised Trust, and Neuroticism: Evidence from Micro-Context and Genetically Informed Data. Unpublished manuscript, Department of Government, Uppsala University.

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As I approached the manuscript conference, I began to truly realise that my PhD journey was coming to an end. The recognition felt both surprising and overwhelming – not only because of how much time had passed, but because of what this journey has come to mean. I found myself reflecting on several things: that I have been a PhD student, part of academia, for a seventh of my life; that I am only now beginning to embrace my identity as a researcher with my own questions and topics, something that, for a half-introvert like me, has required courage to acknowledge; and that I have changed from being averse to becoming used to the smell of cinnamon. These PhD years have undoubtedly been among the most transformative and meaningful of my life.

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Qinya Feng 冯沁雅
Uppsala, 2 April 2025

Contents

1 Introduction

Immigration has profoundly transformed the demographics and social structures of developed democracies across Europe and North America. It has the potential to drive economic growth, introduce new perspectives, and foster innovation (e.g., Hunt & Gauthier-Loiselle, 2010; Page, 2007). At the same time, immigration brings diversity and challenges, sparking critical debates about immigrant admission and rights, as well as the religious, political, and socioeconomic integration of minority groups. These issues have become central to public discourse, with right-wing parties and politicians gaining significant popular support by emphasising perceived economic and cultural threats from immigration and advocating restrictive immigration policies – even in societies traditionally viewed as open and inclusive (Ford & Jennings, 2020). Public and political disagreement on immigration and related transnational issues have crystallised into a cosmopolitan–parochial (or libertarian–authoritarian) divide, which now stands as a pivotal dimension in contemporary politics (De Vries, 2018; Dennison & Geddes, 2019; Ford & Jennings, 2020; Hooghe & Marks, 2018; Ivarsflaten, 2008).

The reactions of native majorities to immigration and shifting demographics not only influence contemporary political dynamics and policy orientations (Van Hauwaert, 2022), but also affect the lived experiences and life opportunities of immigrants (Esses, 2021). At the same time, a widely debated concern is whether a diverse social context can weaken social cohesion and interpersonal connections within society. According to Putnam (2007)'s influential "hunkering down thesis", in more ethnically diverse neighbourhoods, cities, or regions, citizens withdraw from public social life, resulting in a decline in all forms of social trust. The troubling implication is that diversity may undermine the very social foundations vital for well-functioning communities and democracies, including citizens' willingness to engage, cooperate, and share resources with one another. However, an extensive body of research and numerous reviews spurred by these concerns illustrate that the effects of diversity on social cohesion and trust are far from deterministic. Instead, they appear to be highly contingent on factors such as the geographical scale of analysis, the specific measures of social cohesion employed, and the forms of social interactions considered, whether explicitly or implicitly (e.g., Dinesen et al., 2020; Koopmans et al., 2014; Portes & Vickstrom, 2011; Schaeffer, 2016; van der Meer & Tolsma, 2014).

The political and social significance of divergent reactions to immigration and diversity motivates this dissertation to investigate why some native individuals embrace immigration and diversity, while others react with resistance and hesitation. Particularly, this dissertation focuses on attitudes towards immigration and generalised trust, which are central elements in the debates outlined above.

Research into attitudes towards immigration and trust is abundant across the social sciences. However, while much of the literature has elaborated on the role of national economic circumstances, demographic changes, institutional environment, elite rhetoric, shifting group identities, as well as individual economic setbacks, social interactional experiences, and psychological dispositions (e.g., Ceobanu & Escandell, 2010; Esses, 2021; Fussell, 2014; Hainmueller & Hopkins, 2014), it has largely neglected a significant source of individual variation: genetics.

All individuals, except for identical twins, differ in their genetic makeup. Decades of research using twin and family modelling have consistently demonstrated that genetic variation significantly contributes to differences in traits and behaviours, including sociopolitical attitudes. A 2015 meta-analysis of over 17,000 human traits found that on average approximately 50 per cent of individual variation across physical, psychological, and social traits can be attributed to genetic factors (Polderman et al., 2015). For traits considered predominantly social and political, genetic influences are similarly prevalent. Since the pioneering study by Martin et al. (1986), which showed that differences in attitudes towards various social issues could partly be attributed to genetics, researchers have provided consistent evidence of genetic influences on political ideologies, voting behaviour, trust, and outgroup attitudes. As reviewed by Hatemi and McDermott (2012), 20-60 per cent of the variance in sociopolitical traits examined can be explained by genetic factors. While these findings clearly show that genes are far from having a deterministic role in complex sociopolitical traits, they challenge the notion that sociopolitical attitudes are solely shaped by environments, prompting the need to consider genetics in social science research concerning individual differences.

Ignoring the role of genetics in social research therefore risks producing biased, incomplete, or even incorrect results. One major implication of potentially pervasive genetic influences is that when genetic factors affect both the independent and dependent variables of interest, they can create spurious or biased associations – that is, genetic confounding. This makes it essential to account for genetics, even in studies mainly interested in non-genetic factors and relationships (e.g., Rohrer & Lucas, 2020). For example, Ahlskog and Oskarsson (2023) demonstrate that across three broad domains of determinants for political preferences – socioeconomic factors, moral values, and psychological constructs – approximately half of the effect sizes in observational estimates with conventional controls stem from unobserved factors shared by twins, a substantial portion of which are genetics. As discussed further in this chapter, while disentangling genetic and non-genetic effects remains challenging, family and twin-based designs provide an effective approach, particularly comparisons involving identical twins, where observed differences cannot be attributed to genetic variation. Research employing such designs has shown that, for example, the positive associations between education and a range of desirable outcomes, including political participation (Dinesen et al., 2016; Gidengil et al., 2019), social trust (Oskarsson et al., 2017), and physical and mental health (e.g., Halpern-Manners et al., 2016; Lundborg, 2013), are often highly confounded.

However, genetic influences do not operate in isolation from environmental factors. Of particular relevance to social scientists is that genetic and environmental effects are mutually dependent on each other. On the one hand, genetic effects are neither fixed nor immutable; they are expressed through and shaped by environmental and structural conditions (e.g., Adkins & Vaisey, 2009; Feldman & Lewontin, 1975; Purcell, 2002; Shanahan & Hofer, 2005). On the other hand, environmental effects on individuals can vary due to genetic heterogeneity, as environments or interventions may impact some individuals more than others, leading to "unobserved" differences and inequality (e.g., Barcellos et al., 2018; Belsky & Pluess, 2009; Dias Pereira et al., 2022). To understand this interplay, recent advances in molecular genetics – particularly polygenic indices (PGIs), which aggregate hundreds of genetic variants associated with specific traits – complement traditional family and twin-based designs by offering new tools for explicitly integrating genetic measures into social science research to shed light on these contingencies and dynamics.

By actively incorporating genetic information into social research, we can attain clearer insights into causal relationships and the sources of individual differences, even when the focus is predominantly on non-genetic factors and relationships. As such, the overarching aim of this dissertation is to take the genetically informed perspective to explore how natives differ in their attitudes towards immigration, and how they react to immigration-induced social diversity. More specifically, I investigate how taking genetic confounding and heterogeneity into account alters our understanding of 1) whether and why education leads to positive attitudes towards immigration, 2) how generalised trust and prosociality influence overall attitudes towards immigration, 3) whether generalised trust, alongside other social cohesion indicators, is in turn reduced by exposure to local ethnic diversity.

To enable this interdisciplinary approach, this dissertation leverages a large cohort of middle-aged Swedish twins from the Swedish Twin Registry, linking these individuals to rich register and survey data. While there are reasonable concerns about the generalisability of the findings, which I address later in this chapter, this Swedish twin cohort has a unique combination of life experiences and institutional exposure. Born during the 1940s and 1950s, this cohort experienced institutions and a welfare regime which are believed to foster, sustain, and benefit from high trust. During their formative years, Sweden maintained a stable liberal democracy with a more homogeneous population compared to today. However, by their mid-life, Sweden becomes characterised by high immigration acceptance per capita among EU countries, a significantly more diverse population, and immigration and integration have emerged as central issues in public and political discourses.

This dissertation consists of three papers. Paper 1 investigates the consistently reported educational divide in attitudes towards immigration. While education is believed to foster tolerance, the association might suggest a genuine effect of education, but may also reflect self-selection, where individuals predisposed to pro-immigration views achieve higher education, including due to genetic predispositions. To examine this, Paper 1 employs a triangulation design using three natural experiments. The first two studies leverage plausibly exogenous variation in education: one from Sweden's comprehensive education reform, which created variation across regions and birth cohorts, and the other by comparing identical twins with differing educational attainment. Results indicate that higher education levels can indeed foster more open views on immigration, but the reform, which mainly increased secondary education, shows no clear effects. In the third study, using non-identical twins (whose genetic differences are random) and a polygenic index (PGI) for education – a summary measure of genetic differences associated with educational attainment – results show that genetic differences related to education partially explain variations in immigration attitudes. These genetic effects are mediated not only through obtained education but also through traits such as locus of control (a sense of personal control and efficacy).

Paper 2 shifts the focus from the dominant emphasis on psychological constructs such as social dominance orientation and right-wing authoritarianism (e.g., Craig & Richeson, 2014; Osborne et al., 2023; Peresman et al., 2023) that explain hostile intergroup attitudes to generalised trust and prosociality – key constructs in navigating interpersonal and intergroup relations in complex and interdependent societies. Trust in strangers is a robust predictor of openness to immigration, but its role relative to prosociality and the potential influence for genetic and familial confounding remains underexplored. Using models that compare twins, the findings reveal that trust strongly predicts more positive attitudes towards immigration, though part of this relationship is explained by genetic and early-life environmental factors. Notably, the role of generalised trust is distinct from prosociality – willingness to help others – and does not seem to be contingent on socioeconomic status or occupational competition and exposure to immigrants. These findings suggest that fostering generalised trust may be more effective than appealing to altruistic motivations in promoting positive attitudes towards immigration. Nevertheless, generalised trust seems to be more strongly linked to support for immigrant admission and less so to other value-laden policy preferences.

Paper 3 revisits the ongoing debate over whether diversity undermines social cohesion and trust, acknowledging the often-overlooked possibility that diversity is experienced in various ways and that individuals may react differently to it. Building on prior research using micro-context data as a proxy for casual interethnic exposure, the paper examines interethnic exposure in one's immediate surroundings as a common form of native-majority encounters with ethnic minorities. After an extensive list of conventional and genetic controls, the findings suggest that such exposure has a modest negative association with generalised trust but little association with prosocial tendencies or social engagement. This indicates that while casual encounters with immigrants may be associated with slightly lower trust, they do not necessarily influence individuals' "mutual regard" or their willingness to participate in social life in the same way. Addressing the genetic basis of trust, the study shows that polygenic indices (PGIs) for several traits influence generalised trust. Furthermore, using the PGI for neuroticism, the modest negative association with trust appears to be primarily driven by individuals predisposed to neuroticism – a tendency towards heightened sensitivity to social environments and negative emotions. This individual heterogeneity could be crucial to consider when investigating how people approach daily social contexts involving diversity.

In summary, this dissertation demonstrates how typical social science questions can be studied with an awareness of genetic influences and genetically informed designs. It addresses crucial questions within the nexus of immigration, diversity, and trust, including how immigration attitudes are linked to a politically salient predictor – educational attainment, and to key constructs in approaching interpersonal relationships – prosociality and social trust, while teasing out whether and how the latter are influenced by exposure to local ethnic diversity.

This introductory chapter is structured as follows. In Section 2, I present the motivations and theoretical background for the dissertation. I discuss explanations for the educational divide in attitudes towards immigration, which form the basis for Paper 1 (published as a short research article). I then outline definitions and theoretical perspectives on the foundations of generalised trust. This part is central to Paper 2, which examines its relationship with immigration policy views, and Paper 3, which investigates how local interethnic exposure influences trust and related behavioural and attitudinal outcomes. Following this, I review the literature on ethnic diversity and social cohesion, linking it to recent discussions on intergroup contact and contextual effects, which provides the background for Paper 3.

Section 3 addresses the conceptual understanding and methodological motivations for adopting a genetically informed perspective. I discuss the implications of the role of genetics and the interdependent relationship between genetics and environment for social research, with a particular focus on genetic confounding and gene-environment interplay. I introduce the rationale behind the twin comparison design (discordant twin design), which is employed in both Paper 1 and Paper 2. I also introduce recent advances in molecular genetics, particularly polygenic indices which have become increasingly integrated into research across social sciences to investigate individual differences (e.g., Freese, 2018; Harden, 2021; Mills et al., 2018). Relevant polygenic indices are employed in Paper 1 and Paper 3.

In Section 4, I introduce Sweden and the Swedish twin cohort, which serves as the case for this dissertation. Section 5 provides an overview of the three papers, detailing their motivations, research designs, and key findings.

Finally, I summarise the dissertation's main contributions and implications, before discussing limitations and suggesting future directions to conclude the chapter.

2 Theoretical background and motivations

2.1 Formal educational attainment and divided views on immigration

Formal educational attainment is one of the most powerful individual-level predictors of immigration attitudes across democracies, that is, highly educated individuals tend to be more positive towards immigration (Dražanová et al., 2023; Hainmueller & Hiscox, 2007; Hainmueller & Hopkins, 2014). While the relationship between education and immigration attitudes can be understood based upon the literature on the "educational stratification" of values, attitudes, and political engagement (e.g., Jennings & Niemi, 2014; Willeck & Mendelberg, 2022), some descriptive studies have also highlighted the particularly consistent association between educational attainment and attitudes towards immigration, which appears to be distinct from related individual attributes such as social class (e.g., Evans et al., 2022; Ivarsflaten & Stubager, 2012).

This section presents the theoretical background and empirical investigations on the educational divide in immigration attitudes that Paper 1 addresses. I summarise four general perspectives on the role of education: "Education-as-character-shaping", "Education-as-economic-security", "Education-as-cleavage", and "Education-as-proxy". The first three explanations suggest that education exerts a causal influence on attitudes. In contrast, the "Education-as-proxy" perspective argues for a distinctive interpretation that the educational divide is primarily driven by self-selection and sorting into higher education rather than the effects of education itself. I review recent studies employing various designs to assess whether education has a causal impact on immigration attitudes, which present inconclusive results. I argue that a genetically informed approach using a twin design is well-suited to disentangle the potential causal role of education from its function as a proxy, and this approach can be examined alongside other designs to enrich our understanding of the relationship.

The first "Education-as-character-shaping" view, as termed by Cavaille and Marshall (2019), is based on a large literature on tolerance and social liberalism, which highlights education's prospects in socialising and cultivating liberal values, cosmopolitan outlook and the norm of tolerance (Hyman et al., 1975; Inglehart, 1977; Lipset, 1959; Stouffer, 1955; Weil, 1985), although the exact mechanisms underlying "character-shaping" are somewhat vague (e.g., Jennings & Niemi, 2014; Jenssen & Engesbak, 1994; Surridge, 2016). Other than values and norms, this view also concerns the education system cultivating important cognitive capabilities in absorbing and internalising abstract values and concepts (e.g., Bobo & Licari, 1989; Jenssen & Engesbak, 1994; Lancee & Sarrasin, 2015; Surridge, 2016), to attach and apply relevant concepts, knowledge, as well as generalised principles when reasoning about concrete sociopolitical issues (Gaasholt & Togeby, 1995; Jackman, 1978; Jackman & Muha, 1984; Surridge, 2016), rather than relying primarily on prevailing categorical stereotypes or affective feelings about certain social groups (Brewer & Kramer, 1985; Jackman & Muha, 1984). Education system also creates a social sphere where students have more opportunities to interact with people with diverse backgrounds which can encourage the broadening of perspectives (Napier & Jost, 2008; Surridge, 2016), thereby increasing tolerance towards diverse social groups.

The second perspective, which I summarise as "Education-as-economic-security", emphasises that education provides individuals with the resources and skills to compete in the labour market, thereby enhancing their economic security. The absence of an education premium becomes particularly significant in the context of globalisation, especially for those facing economic disruptions such as industrial recessions, intensified competition, or job insecurity due to more substitutable skills (e.g., Dancygier & Donnelly, 2013; Lancee & Pardos-Prado, 2013; Mayda, 2006). For those lacking meritocratic education, restrictive attitudes towards immigration may emerge as a response to "disadvantage and insecurity in the universal struggle for personal gain" (Gaasholt & Togeby, 1995, p.267). Such insecurity drives individuals to defend their self and group interests, which results in intolerance, prejudice, and hostility towards outgroups.[1]

These two perspectives would predict that those with high education qualifications and experience would perceive immigration as less threatening in general, since education would imbue more tolerant perspectives to approach social differences and complexity, and education would buffer individuals against precarious circumstances and potential losses from economic and industrial transformations.

The third "Education-as-cleavage" view, recently advanced by research on sociopolitical transformations in Western European societies (e.g., Cavaille & Marshall, 2019; Ford & Jennings, 2020), is more encompassing than the previous two and runs deeper into contemporary sociopolitical changes and divides. Individuals without qualifications, especially higher education, often find themselves more negatively impacted by industrial transformations and globalisation, both economically and symbolically (as reflected in perceptions of social status and marginalisation (Gidron & Hall, 2020)), contrasting with those who benefit from these changes (e.g., Ford & Jennings, 2020; Hooghe

[1] This explanation, however, may be considered weak, as it would predict that higher-educated individuals oppose high-skilled immigrants while lower-educated individuals oppose low-skilled immigrants. Yet, the strikingly consistent sociotropic pattern emerged in general public attitudes is that high-skilled immigrants are generally preferred, while low-skilled immigrants are widely disliked (e.g., Hainmueller & Hopkins, 2015; Kustov, 2021; Weber et al., 2024).

& Marks, 2022). At the same time, education may have evolved into a key marker in the social structure that influences political choice on the transnational divide in Europe (Bornschier et al., 2021; Häusermann & Kriesi, 2015; Hooghe & Marks, 2022; Stubager, 2009).[2] Education based social groups are connected to distinctive sets of political affinity and vote choices with highly educated groups typically support more liberal and progressive agendas on issues such as immigration and environment. The cleavage perspective attributes these patterns to processes rooted in educationally distinctive life experiences, social networks, political elite appeals, and political group identity formation, that exacerbate the polarisation across the educational divide (De Jong & Kamphorst, 2024; Hooghe & Marks, 2022; Stubager, 2009; Westheuser & Zollinger, 2024; Zollinger & Attewell, 2023). However, these processes likely do not emerge or solidify immediately upon entering or completing a specific level of education (Cavaille & Marshall, 2019). Instead, they reflect the downstream impacts of education – such as life circumstances and opportunities derived from qualifications, the development of social networks and closure, and the formation of group identity – that take shape and solidify later in the life course.

The "education-as-proxy" perspective, already influential in the literature on political participation (cf. Persson (2015) and Willeck and Mendelberg (2022)), cautions against attributing a substantial causal role to the processes and consequences of acquiring education itself. Instead, this view suggests that educational attainment serves as a proxy for predisposing factors that both enable individuals to pursue higher education and foster tolerant attitudes towards immigrants and immigration.[3] Educational attainment likely reflects a combination of social and material background, early socialisation and exposure within families, with peers, and in neighbourhoods, as well as dispositional factors, that emerge or exert an influence prior to advancing across education ladders. Consequently, receiving education in itself does not exert a causal influence. Simply increasing access to education without addressing these underlying factors is unlikely to result in significant changes in attitudes. This view is partially supported by previous and recent research suggesting that political attitudes including attitudes specifically towards immigrants and ethnic minorities already differ for high school students (Jennings & Niemi, 2014; Lancee & Sarrasin, 2015; Weber, 2020). Many studies also give indications that prominent factors typically associated with educational achievement also strongly predict attitudes towards immigration, although these findings are also largely descriptive. For example, Margaryan et al. (2021) show that better parental education (resulting from a German education reform) can extend to

[2]In this cleavage politics literature, alongside education, urban/rural division, sex, and occupation are also identified as significant group markers for political divides in the European public.
[3]In addition to an interpretation of self-selection, it is also possible that educational institutions or disciplines select and benefit students with certain related qualities and attributes (Van Laar et al., 1999).

affect the attitudes of the children. In addition to skills and resources transmitted to children, family rearing practices, styles (climate) and interactions, on the one hand, can influence children's abilities and aspiration for educational achievement (e.g., Spera, 2005), on the other hand, can also influence the child development of key psychological dispositions (such as authoritarian orientation) and prejudice and discriminatory behaviour (e.g., Adorno et al., 1950; Allport, 1954; Osborne et al., 2023). Empirical research also often reports parental-child concordance in ethnic and racial prejudice (e.g., Degner & Dalege, 2013), and political attitudes and behaviour in general (e.g., Jennings et al., 2009; Willoughby et al., 2021).[4]

These views have rather different implications for interpreting the educational divide in immigration attitudes, but a first and foremost question is whether it is primarily driven by the "education-as-proxy" explanation – that education itself does not cause tolerant and positive attitudes but instead serves as a proxy for other background attributes. If the "education-as-proxy" explanation holds true, alternative explanations may hold less relevance. As with all studies using observational data, recovering the causal relationship with a covariate adjustment strategy is subject to omitted variable bias. Comprehensively accounting for the confounding factors, that education may proxy for, is challenging, as some factors are unmeasurable while others may suffer from low validity in their measurements. Adjusting for potential confounding factors might also introduce post-treatment biases in either direction if the variable influences immigration attitude but it is itself a consequence of education.

Existing research aimed at uncovering the quasi-causal effects of education on immigration attitudes typically adopts two primary approaches, predominantly focusing on Western Europe. The first approach leverages compulsory education reforms implemented across European countries during the second half of the 20th century. The second approach employs longitudinal data and design that focus on within-individual variation derived from transferring through education levels in the adolescence and young adult period (Lancee & Sarrasin, 2015; Velásquez & Eger, 2022; Weber, 2020). Research based on compulsory education reforms in Europe generally reports a positive effect of education on immigration attitudes, albeit with heterogeneous effect sizes between countries (Cavaille & Marshall, 2019; D'Hombres & Nunziata, 2016; Margaryan et al., 2021). Notably, a similar reform in Norway does not find any significant effect (Finseraas et al., 2018). In contrast, two studies employing within-individual variation in education with longitudinal data from

[4]Parent-child concordance does not imply direct parent-children transfer, it can involve multiple interactive perceptual and behavioural pathways linking parents and children (Westholm, 1999). In studies of intergroup and political attitudes, the magnitude of concordance can also be contingent on parent-child relationship quality, parental politicisation and consistency, as well as the reinforcing or challenging influence of other actors such as effects from peers (e.g., Jennings et al., 2009; Miklikowska, 2016). Moreover, as will be discussed later, intergenerational transmissions involve not only environmental transmissions, but also genetic transmissions.

Switzerland and Germany find little effect caused by education and demonstrate the prevalence of self-selection: individual transitions up the education levels do not appear to mark significant differences in attitudes towards immigrants and ethnic minorities, either in the short or medium term (Lancee & Sarrasin, 2015; Weber, 2020).[5]

Despite evidence from multiple country contexts using longitudinal design and education reform designs, prior studies have limitations in capturing educational variations. Compulsory education reforms primarily allow research to exploit differences stemming from additional years in middle school. It is essential to acknowledge the varying levels of education, particularly higher education, which is considered pivotal in shaping disparities in attitudes (e.g., Campbell & Horowitz, 2016; Chandler & Tsai, 2001). Meanwhile, the effects of educational attainment on attitudes towards immigration appears constrained to the short-term impacts observed in young individuals, as existing longitudinal data may not fully represent the downstream effects of education that have yet to materialise at this stage.

Paper 1 seeks to address these limitations by introducing a twin comparison study that leverages differences in educational attainment between twins to investigate whether higher levels of education, including attending tertiary education, can be a causal explanation for the educational divide in immigration attitudes or whether it is a proxy that reflects familial factors shared by twins. Moreover, using a largely overlapping pool of Swedish twins, Paper 1 also investigate the effect of the Swedish compulsory schooling reform on immigration attitudes, which can be compared with existing similar studies. Since the twins were surveyed in mid-life, Paper 1 can examine the long-term downstream effects of educational attainment. As a complement to strategies that apply the same research design across diverse contexts (e.g., examine the effect of education reforms across countries as in Cavaille and Marshall (2019)), Paper 1 adopts a unique alternative strategy by employing multiple research designs within the same context. This allows for the comparison of results while holding country-specific factors, time periods, and sample characteristics constant.

2.2 The conceptions and foundations of generalised trust

Social trust is perhaps one of the most extensively studied constructs in the social sciences. In particular, generalised trust, i.e., trust in strangers, has been associated with many desirable individual and societal outcomes. High generalised trust of individuals tend to correlate with well-being, life-satisfaction,

[5]For related attitudes along the cosmopolitan/transnational dimension, existing studies on education and Euroscepticism did not find any effect of education on preference of joining the EU or on European integration or education reform in four European countries with a fuzzy regression discontinuity design (Kuhn et al., 2018, 2021).

as well as health across developed countries (Helliwell et al., 2018; Kawachi, 2018); extending to the societal level, high generalised trust is often linked to economic growth, effective governance, and universalist welfare states (Fukuyama, 2001; Kumlin & Rothstein, 2005; Nannestad, 2008; Zak & Knack, 2001).[6] In addition to being treated as a significant construct in its own right, generalised trust is also commonly analysed as an attitudinal indicator of social cohesion and solidarity (e.g., Banting & Kymlicka, 2017; Larsen, 2013; Schiefer & Van Der Noll, 2017; van der Meer & Tolsma, 2014).

This section presents an overview of the conception and foundations of generalised trust that provides the main theoretical background for Paper 2. A primary motivation for Paper 2 is that there has been considerably less focus on understanding the role of trust as a predictor for people's views on immigration and immigration policies, in contrast to more elaborated investigations on individual differences in constructs such as right-wing authoritarianism. The angle that generalised trust can in fact be a source for citizens' views on how immigrants should be accepted and treated, also stands in contrast to the extensive body of work on how rising immigration and diversity may have consequences on trust, a topic reviewed in more detail in the subsequent section and explored in Paper 3. I outline three perspectives on the foundations of generalised trust that can help understand how generalised trust is related to attitudes towards immigration, as explored in Paper 2. The forth experiential perspective of generalised trust provides a basic rationale for examining how trust may be influenced by ethnic diversity in social contexts, as explored in Paper 3.

While a comprehensive review of the trust literature across disciplines is impossible to present here, it is essential to establish a clear working definition of trust and specify the type of trust and perspectives addressed in this thesis, given the diverse disciplinary approaches and varying assumptions surrounding trust.[7]

This dissertation adopts a working definition of trust as "a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another" (Rousseau et al., 1998,

[6] Similar as the relationship between democracy and economic development, it is unresolved whether higher levels of generalised trust of most citizens drives these outcomes, which makes trust highly valued, or if such demanding trust in strangers arises as a result of these beneficial societal conditions (e.g., Nannestad, 2008).

[7] For example, trust is sometimes discussed as individual decisions and behaviours; at other times as a dispositional trait; and yet in other times as a property of social relationship, or an aspect of social capital and cohesion. Many existing theorisations and discussions lie between focusing on state trust (state evaluations of trustee's trustworthiness in trust games) and dispositional trust. They might be summarised as centred on 1) dispositions of trustors, 2) perceptions of trustees (e.g., the ability, morality of trustees), and 3) the relation between trustor and trustee (including situational structures such as interdependence, and sociocultural distance such as familiarity and similarity). For studies on state trust, dispositional trust can be regarded as one factor for state trust.

p.395). This definition encapsulates key elements of trust that are widely shared across disciplines. On the one hand, trust becomes irrelevant in situations where risks or potential vulnerability (for both trustors and trustees) are absent, as these conditions eliminate the need for trust to arise; on the other hand, trust cannot exist if one does not, for any reason, hold positive expectations regarding the intentions or behaviour of the other party in the relationship.

Driven by these core properties of trust, there has been a long tradition to explore the role of trust in resolving social dilemmas where individual interests conflict with group and collective welfare (e.g., Van Lange et al., 2017). The existing theoretical (Luhmann, 2017; Warren, 1999)[8] and meta-analytical work (based on game experiments) (Balliet & Van Lange, 2013) suggests that trust is probably more important for achieving collectively beneficial and cooperative outcomes, when social relations are characterised by complex interdependence and when conflicts of interest or risks are higher.[9]

Interpersonal trust is inherently relational, comprising key elements such as the trustor, the trustee, and the object or context of trust (Hardin, 2001; Schilke et al., 2021). Generalised trust, however, represents its most abstract form. Generalised trust is commonly operationalised using survey questions with unspecific trustee and contexts such as: "Generally speaking, would you say that most people can be trusted, or that you can't be too careful in dealing with people?"[10] Unlike particularised trust, which is directed towards specific individuals and often involves predefined contexts and relational features, generalised trust encompasses an overarching belief in the trustworthiness of unknown others and entails a willingness to accept vulnerability in social interactions in general (Warren, 1999).

The existence of trust in strangers presents a puzzle, particularly when considering the parochial tendencies inherent in human behaviour. Parochialism suggests that people tend to trust the ingroups that they belong to or identify with, such as kin, people of the same ethnicity and nationality, or sometimes even arbitrarily divided groups, which undermines intergroup cooperation and potentially escalates intergroup conflicts. The negative outgroup bias in trust is observed in both survey based measures (Delhey et al., 2011) and measures in behavioural experiments (e.g., Romano et al., 2017, 2021). Some account suggests that the prosocial or altruistic motivation, the motivation to benefit

[8] As Warren (1999) notes, "increasing interdependencies extend the vulnerabilities of individuals, while increasing complexities reduce the chances that individuals can monitor the vulnerabilities to which they are subject ⋯⋯trust reduces complexity for individuals while providing them with a sense of security by allowing them to take for granted most of the relationships upon which they depend".

[9] Nevertheless, although trust is considered especially important in these circumstances, as demonstrated by Cook et al. (2005), trust is neither a necessary nor essential condition for cooperative outcomes.

[10] For other measures of generalised trust, such as the lost-wallet survey questions and behavioural measures from trust games, little information about the trustee is given to the trustor, but there are somewhat created relations for trust to manifest and to be observed.

others even at personal cost, can explain how trust in strangers emerge (give the benefit of one's trust to the trustee), at least in some cases (Mansbridge, 1999; Thielmann et al., 2021). However, altruism of the trustor may not be a general cause for why generalised trust emerge (e.g., Simpson & Willer, 2015), and trust and altruism have distinctive properties, causes[11] and consequences.[12] Potential vulnerability of the trustor is a core prerequisite condition for trust to be relevant, but it is not a condition for prosociality or altruism.

What, then, are the foundations of generalised trust? I distinguish three main perspectives on generalised trust which offer varying interpretations and emphasise distinct key elements, with a broadly shared definition as outlined earlier. As argued in Paper 2, all these perspectives predict that generalised trust can contribute to more positive attitudes towards immigration. Meanwhile, these perspectives differ in their assumptions about why trust extends to unknown strangers. Such differences carry implications, both for understanding the sources of individual variation in generalised trust and for shaping how immigrants and immigration policies are perceived and evaluated.

First, from a moral value perspective, generalised trust reflects a socially embedded moral value and principle, along with an optimistic worldview about human nature and society (Uslaner, 2002). This socially widely committed morality is evolved and maintained, with informal institutions including social norms of reciprocity and social sanctions (Mansbridge, 1999; Simpson & Willer, 2015; Uslaner, 2002), economic equality and equality of opportunity (Uslaner & Brown, 2005), and fair institutions (Rothstein & Stolle, 2008). Giving trust in strangers in most contexts and try to be cooperative is essentially a moral value tied to the broader principles of inclusivity and fairness. Echoing this perspective, Kirkland et al. (2023) show that generalised trust has a clear link to greater moral expansiveness, that is, people's moral concern ranging from the family to outgroups and more distant animals and plants, across countries. Trusting individuals are more likely to uphold moral principles centered on cooperation and fairness, making them less inclined to harbour prejudice against immigrants or support discriminatory treatments. For individuals, the morality of being trusting is primarily shaped by early pre-adult socialisation, maintained by fair and stable formal and informal institutions, and is

[11] Developmental studies on the development of trust and prosociality also find that these traits develop through distinct processes. Evans et al. (2013), for example, show that as children age, they tend to become more trusting, but this increase is not driven by an increase in altruism. And children do develop cognitive ability to discern when to trust in response to structural changes such as game structures and trustee's characteristics.

[12] Altruism or prosociality is frequently invoked as a complement to the limitations of considering solely self-interest or egocentric motivation. Empirical studies and formal modelling of voting behaviour, welfare policy preferences, and political orientations (e.g., Dimick et al., 2018; Fowler & Kam, 2007; Van Lange et al., 2012; Zettler & Hilbig, 2010), and more recently immigration policy preferences (Kustov, 2021), have attempted to incorporate altruistic motivations.

not easily swayed by immediate rational calculations or most experiences in interpersonal interactions.

Building on this perspective, trust reflects social cohesion by embodying a society's shared moral commitments to honesty, cooperation, and adherence to social norms. When individuals trust others, including strangers, they are not only expressing their own moral values but also assessing the broader moral fabric of society. As such, trust serves as a cognitive marker of social cohesion, often referenced in discussions of social cohesion and solidarity. It functions both as an indicator of collective commitment to fairness and inclusivity and as a mechanism for fostering cooperation.

Second, the psychological disposition perspective, sees generalised trust in strangers much like a personality trait (Rotter, 1971).[13] This view implies that generalised trust should show meaningful and consistent individual differences that would underpin relevant situations where trust emerges in daily life. In other words, people of higher generalised trust show consistency in varied relational structures with different social distance and interdependence characteristics (e.g., in conflicts of interests, information uncertainty, and power imbalance). Supporting this view, recent research using the experience-sampling approach shows that self-reported generalised trust is associated with lower state trust variability (Weiss et al., 2021), and inter-individual differences in the means of generalised trustworthiness expectations are stable during the sampling period (Baumert et al., 2017; Weiss et al., 2021).

Generalised trust as a psychological disposition/tendency is considered to contain psychological security, an optimistic worldview (having faith and confidence in others' benign intentions)[14], and a sense of control over one's own life (Delhey & Newton, 2003; Uslaner, 2002), while being psychologically prepared for potential vulnerabilities. Individuals with high generalised trust thus see others and the world as less threatening and competitive, which aligns some core characteristics of right-wing authoritarianism. Notably, trust in strangers has been used as a proxy for authoritarian tendencies (e.g., Sullivan et al., 1981), since one defining feature of the authoritarian personality is "distrust of other people, their motives, and their impulses" (Sullivan et al., 1981, p.95) and has been shown to correlate positively with political and social tolerance concerning other social groups including ethnic minorities and immigrants (Marcus, 2020; Sullivan et al., 1981). From this perspective, like personality traits, trust in others is developed from early childhood, tends to

[13]Individual differences such as personality traits is an abstraction used to explain consistency and coherency in an individual's pattern of affects, cognitions, and behaviours. What a person feels, thinks, wants, and does changes from situation to situation but shows a patterning across situations and over time that may be used to recognise, describe, and understand a person. But individual differences are not assumed to be stable within individuals.

[14]The survey items used for generalised trust originally appear in the "faith in people" scale, which was developed to measure people's belief in human nature (Rosenberg, 1956).

persist in later life, and only changes modestly as a result of experience thereafter.

Third, following the rationalist tradition, generalised trust is argued to be a form of social intelligence (Yamagishi, 2001, 2011). Rather than adherence to the moral value of being trusting, generalised trust is viewed as a sophisticated ability developed through iterative experiences in cooperative and competitive social interactions. Individuals who are better able to discern reliability and trustworthiness in others as they engage in repeated interactions gain more cooperative benefits, reinforcing their generalised trust. Conversely, those who are cheated or fail to take risks in potentially fruitful interactions tend to experience greater losses, leading to lower trust and perpetuating a vicious cycle of distrust (Yamagishi, 2001). Related to this view, general intelligence, despite only partially reflecting the sort of trustworthiness-discerning cognitive sophistication, is found to be positively associated with generalised trust (Dinesen & Bekkers, 2017; Oskarsson et al., 2012; Sturgis et al., 2010). This social intelligence understanding suggests that trusting individuals rely less on stereotypes of other ethnoracial and social groups as shortcuts when assessing and predicting other's trustworthiness, compared to those with lower trust (Herreros & Criado, 2009).

The three non-exclusive foundations of generalised trust – universalist moral values, psychological security, and cognitive sophistication – distinguish trust from being merely a moral value, psychological trait, or cognitive ability. Also, they all imply that generalised trust has a dispositional component. This is partly supported by the observed stability of measured generalised trust at the individual level among mature adults, indicating consistent differences in trust levels between individuals across time and life course within societies (Dinesen & Bekkers, 2017; Uslaner, 2002).[15]

An alternative and compelling perspective is that social trust, including generalised trust, is not dispositional but profoundly experiential, recalibrated over time through exposure to new experiences. Notably, Van Lange (2015) argue that trust is deeply rooted in personal social interactions, exposure to others' experiences and information via social networks, and media signals about norm violations. Transformative experiences in new societal and institutional environments, such as immigration, are often cited as strong evidence for this experiential view of trust (Dinesen, 2013). While identifying the effects of social experiences faces challenges, particularly in ruling out self-selection (e.g., van Ingen & Bekkers, 2015), the literature explores a broad array of life experiences that may shape trust. Participation in civic life, especially through voluntary associations, and educational experiences are often considered key factors in fostering trust in strangers. Conversely, negative experiences such

[15] At the societal level, generalised trust is similarly regarded as "a fairly stable cultural feature of society" (Bjørnskov, 2007, p.17), showing cross-society differences, at least when assessed using common survey operationalisation.

as crime victimisation, discrimination, unemployment can diminish trust (Dinesen & Bekkers, 2017; Mewes et al., 2021).

Some scholars argue that interactions and experiences beyond narrow social ingroups – such as family, friends, and those similar to oneself – are particularly important for expanding the "radius" of trust, fostering trust in strangers (Ermisch & Gambetta, 2010; Freitag & Traunmüller, 2009). However, "outward exposure" (Ermisch & Gambetta, 2010) is far more complex when it involves social groups that differ, or are perceived to differ, in attributes such as appearance, language, or values. This complexity is reflected in the extensive debates on ethnic diversity and social cohesion, where generalised trust often serves as a key indicator. Further discussions are provided in the next section.

2.3 Diversity effects and the varieties of diversity

The value of immigration and diversity in enhancing economic performance and fostering innovation is widely acknowledged (e.g., Hunt & Gauthier-Loiselle, 2010; Page, 2007). However, there remains a persistent concern that increased diversity might undermine social cohesion – the interconnectedness among individuals and the capacity for collective action that sustains and promotes thriving societies. These include generalised trust, other attitudes and expectations of how others will engage and cooperate, and formal and informal civic activities, which are believed to underpin and reflect these beneficial properties (e.g., Chan et al., 2006; Schaeffer, 2016; van der Meer & Tolsma, 2014). These concerns underpin what is often referred to as the progressive's dilemma. This dilemma suggests a potential conflict between maintaining social cohesion and solidarity – including generous welfare provisions – and embracing the benefits of diversity and the principles of equal respect for a wide range of peoples, values, and ways of life (e.g., Banting, 2010; Collier, 2013; Goodhart, 2004; Larsen, 2022).[16]

This section offers a brief overview of relevant literature and outlines motivations for Paper 3, which investigates casual interethnic exposure as a common way of experiencing diversity. To provide context, I begin with a brief review of the broad discussion on the relationship between ethnic diversity, social cohesion, and trust. I then examine key patterns and critical debates that have emerged from extensive empirical studies focusing on the individual level. To clarify the motivation for focusing on casual interethnic exposure, I

[16]The relationship between diversity and social cohesion can be regarded as a part of the larger discussion on diversity and societal development. Diversity, conceptualised and measured in various ways, has been argued and found to negatively correlate with broadly defined socially efficient and desirable outcomes, such as (fewer) social conflicts, public goods provision, governance quality, public health, economic development, political participation, and democracy, a pattern referred to as the "Diversity Debit" thesis (see, e.g., Gerring et al., 2015).

highlight the connection between research on diversity effects and the literature on contextual effects of social composition. This connection, articulated in a recent body of work, underscores the necessity of distinguishing between the various ways individuals encounter and engage with individuals from diverse ethnic groups. Lastly, I argue that incorporating the moderating role of preexisting individual predispositions is crucial for understanding how and for whom specific experiences of diversity may exert some impact. By addressing these questions, Paper 3 aims to contribute to a more nuanced and cumulative understanding of the implications of diversity for individuals and societies.

For broad accounts on why ethnic diversity may undermine social cohesion, Koopmans et al. (2014) and Schaeffer (2016) synthesise three main accounts that emphasise different fundamental causes. The first account emphasises that diverse social groups also entail cultural and preference differences over public goods provision. Preference heterogeneity can cause misunderstanding and hinder community and social coordination processes. The second account posits that ethnically clustered social networks often emerge amidst diversity. Since social control and functioning is believed to rely on dense networks to exercise sanctioning and defamation, ethnically clustered networks are believed to potentially hinder sanctioning and information flow across ethnic boundaries, thus inhibit societal order and connections. These two accounts emphasise how diversity can induce anxiety and uncertainty about the existence of common goals, shared norms, identities, and obligations, resulting in a sense of social anomie and reluctance to participate in public life (van der Meer & Tolsma, 2014).

Another more influential account uses outgroup bias and intergroup conflict theory from social psychology as a starting point. The intergroup conflict theory (broadly defined) (Blumer, 1958; Bobo, 1999; Quillian, 1995) centres on the cognitive perceptions of conflict and threat from the presence of other social groups, with heightened concerns over group positions as well as competing material and symbolic resources, resulting in prejudice against outgroups. The controversial "hunker down thesis" (Putnam, 2007, p. 144-153) posits that these forms of outgroup negativity and antipathy would translate to outgroup distrust (ibid., p.142-143), and lead people to avoid not only interethnic interaction but also social interaction with ingroups as a process of social isolation and withdrawing from various forms of social activities and collective life that cultivate ingroup bonds. The consequence includes that, at least in the short run, trust of all forms will be lower, altruism and community cooperation rarer, and people have less faith that they can actually make a difference.

Finally, the main account arguing for a potential neutral or positive role of diversity for sustaining social cohesion draws on intergroup contact theory. Intergroup contact theory (Allport, 1954), which has inspired numerous studies and has been extensively tested across fields (e.g., Paluck et al., 2021; Pettigrew & Tropp, 2006), proposes that, under equal status and cooperative conditions, contacts with other social groups can increase knowledge about each other, find commonalities, develop mutual trust, and eliminate stereotypes.[17] While the original theory only focused on prejudice reduction, this contact-theory-backed account contends that diversity and heterogeneity, through contacts of positive qualities, can indeed facilitate intergroup relation and strengthen social cohesion.

After Putnam's provocative "Hunker down" thesis, which predicts social withdrawal and a decline in cohesion and solidarity, empirical studies have proliferated on this topic. These studies largely concentrate on country cases where recent immigration waves drive ethnic diversity, with data and designs varying in level of analysis, measures of ethnic diversity and measures intended to capture some dimensions of social cohesion. However, the empirical findings are highly mixed. As van der Meer and Tolsma (2014) summarise, for almost every study supporting the "Hunker down" thesis, there is one that consistently rejects it, with a plurality of the studies reviewed finding mixed effects. Portes and Vickstrom (2011) further argue that ethnic diversity per se does not inherently erode social cohesion, and conclude that the relationship between diversity and cohesion is better characterised by its weak and contingent nature.[18]

To advance this fragmented research field, scholars have made the effort to synthesise findings, summarise several key areas of debate, and characterise sources of contingencies. A first pattern identified from the mixed findings is that studies focusing on specific measures of social cohesion that pertain to intra-neighbourhood cohesion (such as social activities and interaction specifically with neighbours) (e.g., Gijsberts et al., 2012; Koopmans et al., 2014; Letki, 2008; Schaeffer, 2013; van der Meer & Tolsma, 2014), rather than interethnic activities or abstract generalised trust, mostly confirm a negative association between ethnic diversity and social cohesion. The disagreement in findings can be partially attributed to the coverage of intra-neighbourhood social cohesion measures used in the analyses (van der Meer & Tolsma, 2014, p.467-469). Similarly, when only focusing on trust of different types, Dinesen et al. (2020) show that the largest negative association is found for trust in neighbours, while associations with ingroup trust, outgroup trust, as well as abstract generalised trust, are weaker. This overall pattern suggests that the negative implications of ethnic diversity may mainly manifest within intralo-

[17] Allport (1954) identifies four criteria for cooperative contacts, including working together, equal status, pursuing common goals, and with authority approval or support.

[18] From a sociological perspective, Portes and Vickstrom (2011) criticise Putnam (2007) for a mechanic understanding of social cohesion that social cohesion largely emerges and relies on homogenous communities. They argue that while the worry about loss in communitarianism might be reasonable, the extent of influence would be trivial for societies with more organic forms of social cohesions and functioning as the social and political sources of social cohesion are derived from social organisations and institutions and other basic social processes that can, for example, offer fair opportunities for everyone.

cal cohesion, as reflected as, for example, more reluctance to help a neighbour and lower expectations on a lost letter in the neighbourhood being returned.

Another identifiable empirical consistency is that studies examining ethnic diversity at lower spatial aggregate units, such as neighbourhoods or districts, more frequently reveal a negative association. This observation is substantiated by meta-analyses based on studies utilising common measures of ethnic diversity (administrative statistics) and social cohesion (survey measures) (Schaeffer, 2013, 2016), and is further supported by investigations focusing on individuals within neighbourhoods that employ experimental measures of ethnic diversity (e.g., priming ethnic and religious diversity) or longitudinal designs that help address self-selection (Koopmans et al., 2014). Dinesen et al. (2020)'s quantitative meta-analysis specifically on social trust further shows that the strength of association is the strongest at the local neighbourhood level, with no significant association at the country level. Consequently, a main conclusion drawn by Dinesen et al. (2020) is that "proximity to interethnic others, as captured by ethnic diversity observed at local levels, is an important condition that accentuates the negative relationship between ethnic diversity and social trust." (p.461)

Guided by contact theory, a prominent body of work has investigated how contact might condition the observed relationship between diversity and social cohesion and trust, as diverse contexts also offer opportunities for intergroup contact of positive valence with those diverse others who make up one's social environment. These studies indicate that while higher contextual diversity is often linked to lower levels of social trust, this negative association may be partly mediated by different ways of interethnic contacts (e.g., Koopmans & Veit, 2014; Schmid et al., 2014) or the association is weaker for those with positive interethnic contacts (e.g., Gundelach & Freitag, 2014; Stolle et al., 2008; Sturgis et al., 2011) (i.e., interethnic contacts ameliorate the negative implication of ethnic diversity). Thus, scholars drawing on contact theory hold that the connection between contextual diversity and social cohesion related outcomes need to be disentangled, as distinct types of contact entails varying implications (Hewstone, 2015; Ramos & Hewstone, 2021).[19] This discourse shifts the debate from viewing diversity as inherently detrimental to social cohesion and trust towards a more nuanced understanding of how and in what ways diversity relates to these outcomes.

This discussion parallels recent developments in the literature on contextual effects of social composition (contexts consist of people from other social groups). This discussion also frequently draws on contact and threat theory as motivations, as how diversity is experienced and affects individuals concerns

[19] Building on this reasoning, it is often argued that the lack of such contact, often resulting from segregation, is a main factor behind the observed negative relationship between diversity and social trust, particularly in research that fails to adequately consider the effects of segregation (Borkowska & Laurence, 2024; Hewstone, 2015; Kasara, 2013; Sturgis et al., 2014; Uslaner, 2013).

the fundamental question of how local social contexts shape people's attitudes and behaviours. In social life, there are various ways, with distinct characteristics, of being exposed to or interacting with outgroup members. From this perspective, it almost becomes natural to expect a contingent nature of the link between ethnic diversity on individual attitude, behaviour, and overall social cohesion. To unify the fragmented research fields and facilitate a coherent aggregation of findings, Nathan and Sands (2023) proposes that the types of contexts and contacts studied in the literature can be summarised along two crucial dimensions. The first is the depth of intergroup interactions, ranging from casual to cooperative engagements. The second is the duration of interactions, varying from brief to sustained contact. These dimensions allow for the classification of contexts and contacts in studies into four broad categories. Cooperative and sustained interactions, such as attending a course or school or in workplaces, align more closely to the types of positive contacts discussed in Allport (1954).[20] Cooperative and brief interactions, such as solving a single-shot task together, are mostly evaluated in field experimental research on prejudice reductions programmes. Casual and brief interactions appear in experimental studies that examine the immediate attitudinal consequences after casual encounters on public transportation (Enos, 2014).

Finally, casual and sustained interactions include, for example, "familiar strangers" or refugee arrival on Greek islands that served as temporary transit destinations for large groups of refugees (Dinas et al., 2019), where individuals are exposed to (the same) outgroup members repeatedly. Importantly, casual interactions are prevalent in daily life, and in fact, Allport (1954) himself cautions that casual contacts should be differentiated from other forms of contacts, and they might leave "matters worse than before"(p.263-264). Such casual interactions are better understood as mere exposure; while they may be frequent, they generally involve limited substantive engagement between individuals (Dinesen & Sønderskov, 2015; Spater, 2022; Steinmayr, 2021).

In this vein, Dinesen and Sønderskov (2015) employs spatial proximity as a proxy for casual interethnic exposure and proposes an information-cue-based mechanism linking local diversity to generalised trust. They recognise the cognitive basis of generalised trust and argues that interethnic exposure can serve as a visible and salient source of cues on the trustworthiness of people in one's surroundings and society. In a way, their view echoes Allport (1954)'s view that visible differences associated with ethnic groups can be used to mark outgroups, which can imply perceptions of other differences associated with those outgroups (p.131-135). Dinesen and Sønderskov (2015) point out that merely "'being around' interethnic others" (Dinesen et al., 2020, p.444) is a key condition that affects willingness to trust strangers, with the premise that people typ-

[20] On this point, Nathan and Sands (2023) highlight a "conceptual stretching" issue in many studies on contextual effects invoking intergroup contact theory: the types of context or contact studied often differ substantially from the interactions described in Allport (1954), even though contact theory is explicitly tested.

ically display aversion and lower trust towards outgroup people (e.g., Delhey et al., 2014; Romano et al., 2017). As individuals assess the trustworthiness of the generalised other partly based on experiences (e.g., Glanville & Paxton, 2007; Van Lange, 2015), encountering a higher number of visible ethnic outgroup members – whom they typically trust less – in proximity suggests an increased degree of negative cues regarding the overall trustworthiness of others (Dinesen et al., 2020; Dinesen & Sønderskov, 2015). This visible-cue-based inference and updating mechanism can be connected to the two main empirical consistencies in the diversity-social cohesion literature outline above. It provides an explanation on why diversity measured at more spatially disaggregated levels, which better captures interethnic exposure, shows a stronger negative correlation with social trust. It also sheds light on the relationship with generalised trust, which, though weak, can extend beyond intralocal cohesion, to influence a broader expectation of trustworthiness towards strangers in society.

However, Dinesen and Sønderskov (2015) do not investigate whether the set of relevant indicators of social cohesion are influenced in a similar manner or to a similar extent as generalised trust, which is also something that the broad accounts tend to be ambiguous about. Attitudes and behaviours pertaining to social cohesion and solidarity are distinct constructs. For instance, while trust and volunteering sometimes correlate, they are grounded in different foundations and natures. Does superficial exposure also influence people's willingness and behaviour to engage with and help others? Paper 3 in this dissertation seeks to build upon Dinesen and Sønderskov (2015) to address this gap by examining a wider set of relevant outcomes.

Furthermore, individuals may perceive and experience diversity differently, but research so far is invested in elaborating the consequences of contextual or structural characteristics, so little consideration is given to individual heterogeneity. In fact, Allport (1954) identified the personality of the individual experiencing the contact as one of six key aspects necessary to understand the effects of intergroup contact (p. 261–280).[21] Understanding who is affected and in what ways can have significant implications for policy and societal responses. Sniderman et al. (2004), for instance, highlight the distinction between contextual triggers that galvanise those already predisposed to, e.g., be concerned about an issue, and those that mobilise people universally regardless of individual predispositions. This difference can be significant, as the former increases intensity (e.g., in attitudes or policy support) among some specific subgroups, while the latter broadens the affected group. Paper 3 thus seeks to take into account the moderating role of individual predispositions

Existing research on how individual predispositions may moderate the impact of exposure to diversity primarily focuses on explaining the rise of anti-

[21] The other five aspects include the quantitative aspect, the status aspect, the role aspect, the social atmosphere surrounding the contact, and the areas of contact.

immigrant sentiments and support for right-wing parties. Although these aspects do not directly pertain to social cohesion, they provide critical insights into the underlying dynamics. Drawing on the dual-process model of prejudice, Sibley et al. (2013) predict and show that the effect of neighbourhood ethnic diversity might differ because of variation in the chronic perception of the social world as a dangerous and threatening place. For individuals high in right-wing authoritarianism, the perception of a threatening environment intensifies these effects; conversely, for those who tend to view their surroundings as safe, such patterns are diminished or may not materialise at all. They also hint that this variation may reconcile why regional diversity leads to increased positivity towards racial minorities in some contexts but increased negativity in others. Divergent effects by predisposition factors can result in null results when viewed on average. For instance, Schaub et al. (2021) examined a refugee settlement program in Eastern Germany and found null effects on immigration and right-wing attitudes on average. However, results varied by political ideology: surprisingly, negative effects were observed for left-leaning individuals, while right-leaning individuals displayed positive effects, leading to converged attitudes overall. The authors suggest a belief-updating process that affects left-leaning and right-leaning individuals in opposite directions to explain this convergence.[22] Therefore, examining how exposure to diversity yields varied effects by individual predispositions is valuable not only for refining theories but also for gaining practical insights of diversity's impact.

Building on this understanding, Paper 3 extend beyond exploring the main relationship between casual interethnic exposure and a set of outcomes, to investigate the moderating role of neurotic predispositions. Neurotic predispositions are characterised by individual differences in sensitivity to social contexts and susceptibility to negative emotions (e.g., anxiety) and emotional instability. These characteristics partially capture psychological antecedents of generalised trust, which is rooted in psychological security (see Section 2.2). The hypothesis is that those who are predisposed to be neurotic are more sensitive to social cues and are likely to exhibit a negative association between interethnic exposure and generalised trust. This hypothesis is tested using a genetics-based measure of neuroticism predisposition.

Using genetically informed measures to examine heterogeneity is a relatively novel approach in the social sciences but is more established in interdisciplinary fields exploring the role of genetics in human behaviour. Shifting from theories centred on non-genetic factors, structures, and processes, the next section focuses on the role of genetics, in connection with non-genetic factors, in shaping individual differences.

[22] Schaub et al. (2021)'s interpretation is that individuals leaning to the authoritarian right may positively update their priors, and those on the left are prompted to correct overly optimistic initial beliefs after exposure to refugees.

3 The role of genetics and genetically informed methodologies

This section outlines the motivation for adopting a genetically informed approach in this dissertation and discusses the methodologies employed. It begins with an overview of twin and family modelling studies, which provide compelling evidence that genetic differences partially explain, and do not solely determine, individual variation in complex behaviour. This is followed by a discussion of key concepts and studies, particularly those about genetic confounding and gene-environment interplay, which illustrate the intertwined relationship between genetics and the environment. Next, the section introduces two methodological approaches used in this dissertation: (1) twin comparison design (also known as the discordant twin or co-twin control design), which leverage within-twin-pair variation to help account for genetic and shared confounding when analysing non-genetic factors, and (2) molecular genetics approaches, which offer greater flexibility for integrating genetics into social research but also require careful and critical engagement.

Before human genotyping techniques matured, classical twin studies were commonly used to explore genetic influence. This is an approach that remains popular today. Classical twin modelling studies monozygotic twins (MZ twins, identical twins) and dizygotic twins (DZ twins, fraternal twins). MZ twins are virtually identical in their genetic makeup, while DZ twins share on average 50% of their segregating genes. Based on genetic relatedness and environmental similarity, classical twin modelling partitions the trait correlations of twins into three sources: additive genetic component (A); common/shared environmental component (C), that is, all environmental variation that serves to make people in the same family more similar, such as family and neighbourhood socialisation; and unique/nonshared environmental component (E), that is, all environmental variation that is unique to each twin, such as influence from different friends and unique events, and contains random measurement error. The basic rationale for using twins reared together to examine genetic influences is straightforward: identical twins are more similar in terms of genetics than non-identical twins; with the assumption that the environmental similarity for identical twin pairs and non-identical twin pairs is equal, if identical twins turn out to be more similar than non-identical twins, this would suggest that the additional genetic similarity of identical twins contributes to trait similarity and variation.

Thousands of behavioural genetics studies using twin and family modelling have consistently shown that a non-trivial component of individual variation in broadly defined human behavioural traits and outcomes in a population is due to genetics (Plomin et al., 2016), i.e., heritable.[23] Twin and family modelling requires a set of assumptions that have often been critiqued.[24] But the consistent finding of a genetic component in individual variation across study samples, periods, regions, has led to the first law of behaviour genetics, "All human behavioral traits are heritable"(Turkheimer, 2000).

An important piece of the social science genetics puzzle, however, is that genetic influences for complex human traits are not independent of the environment. The effect of genetics can operate through environmental mechanisms, and it can be moderated by environmental conditions. These dynamics underscore the need for moving beyond a simplistic dichotomous view of genetics and environment to achieve a more nuanced understanding of their complex interplay – essential for inquiries focused on social influences and those examining genetic influences alike.

3.1 The role of genetics for social research

Genetic influences on traits can operate through environmental pathways. For example, genetic factors may influence a wide range of mediating traits, such as personality, preferences, or behaviours, that in turn influence the social contexts and relationships an individual engages in. A person with a heritable predisposition for extraversion may actively seek out social environments rich in interaction, while someone with a heritable predisposition towards introversion might avoid such settings. These environments can in turn affect other traits, such as social skills or career success. In this way, genetic factors exert their influence on traits through environmental mechanisms. And these dynamics have practical implications for interpreting environmental effects; what may appear to be purely environmental influences could, in part, reflect underlying genetic contributions.

[23] Heritability is a fundamental concept in behaviour genetics studies. Formally, heritability is defined and estimated as the proportion of variation of a trait in a population that is due to genetic variation. By definition, heritability is a population based rather than individual based concept. It is important to note that the magnitude of heritability, which is essentially a ratio, does not imply a stronger or weaker absolute effect of genetics on a trait. If the variance of a trait in a population is rather small or in high equality, even high heritability could still mean little space for genes to make a substantive difference on the trait. Likewise, low heritability does not mean little genetic effect on a trait. It could be due to high trait variation, high environmental variation, and/or due to low genetic variation. For example, consider the largely genetic trait of having two arms: because there is no genetic variation in this trait within the population, heritability is effectively zero, even though the development of two arms is determined by biological and genetic processes. Exceptions, such as accidents or developmental anomalies, may alter the number of arms but do not reflect underlying genetic variation. From another perspective, since nearly everyone has two arms, non-identical twins are just as similar as identical twins in this trait, resulting in a heritability coefficient of zero for the number of arms.

[24] More information can be found in the appendix.

As illustrated in Figure 1, genetic confounding can occur when some genetic factor influences both a social factor of interest (e.g., education, which is tied to a set of structures, norms, social interactions, and can be considered as a trait or outcome as such) and an outcome variable of interest (e.g., attitudes towards immigration), creating a spurious or biased association between the two variables. Individuals with certain genetic predispositions may be more likely to select into specific environments or social contexts, while also contributing to particular traits, behaviours, or life outcomes. Consequently, the genetic factor can give the misleading impression that the environment alone is responsible for the observed outcome, while the association may be partly or even largely driven by genetics.

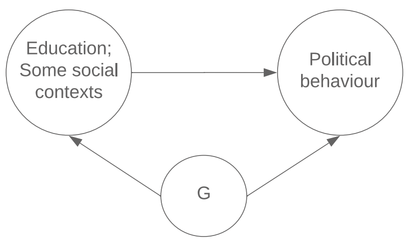

Figure 1. Illustration of genetic confounding.

Another pivotal concept in understanding the interdependent relationship between genetics and the environment is gene-environment interaction. Gene-environment interaction refers to the idea that genetic factors can alter the effect of environmental conditions, and vice versa. Figure 2 is a simplified illustration. In this context, environment is a broad notion that can be of different levels (e.g., individual, family, neighbourhood, society), domains (e.g., social, physical), and time periods (e.g., life courses, historical changes) (Boardman et al., 2013).

For some studies, gene-environment interaction emphasises that genetic influence on a trait can vary across environments, which corresponds to (a) in Figure 2. For example, genetic effects on certain behaviours and outcomes may only emerge after life shocks or in risky social environments. In other instances, genetic influences may be buffered or amplified by social norms or structural constraints (e.g., Boardman et al., 2012). Explorations along this line, especially those related to social inequality and health, are typically interested in, for example, how family socioeconomic background (e.g., Ghirardi et al., 2024), school environment (Boardman et al., 2012; Cheesman et al., 2022), and social institutional conditions (e.g., Engzell & Tropf, 2019) can moderate genetic influences. These studies emphasise the importance of social contexts in interpreting genetic influences.

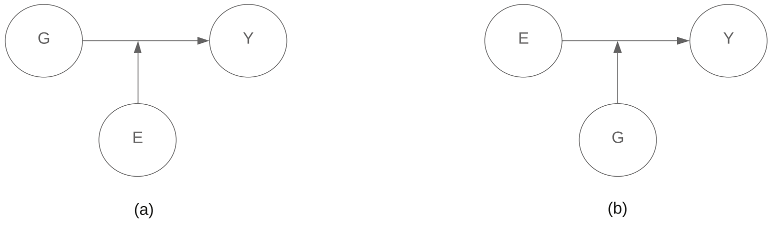

Figure 2. Illustrations of gene-environment interaction.

From another perspective, gene-environment interactions can also suggest how the effect of certain environments varies depending on individuals' genetic predispositions, as illustrated by figure 2 (b). A classical theoretical model in this line is the diathesis-stress model originally proposed for depression. It describes that individuals with specific genetic vulnerabilities (the "diathesis") are more likely to experience adverse outcomes when exposed to stressful environmental conditions. Later, Belsky and Pluess (2009) introduced the differential susceptibility model, which extends this idea by suggesting that some individuals are more malleable or susceptible than others to both negative and positive environmental influences (relative to the outcome). Although these theoretical models originate from different fields and carry distinct statistical implications (e.g., Zhang & Belsky, 2020), they provide insights into how environments can affect individuals differently – amplifying outcomes for some while leaving others less impacted.

The understanding that genetics can influence traits through environmentally mediated processes and interact with non-genetic factors suggests that incorporating genetics into inquiries focused on environmental mechanisms is far from far-fetched.

3.2 Twin comparison studies

Twin comparison designs have long been used to assess effects of exposures for which randomised studies are impossible and measurement of all relevant confounding is unobtainable (e.g., Ashenfelter & Krueger, 1994; McAdams et al., 2021; Pingault et al., 2018; Sjölander et al., 2022; Vitaro et al., 2009). The idea is to use the fact that siblings often share a lot of unobserved variables, including family characteristics, social networks, neighbourhood environments, and genetics.[25]

[25] For comparisons and connections between twin comparison studies and classical twin modelling as well as other associated modelling frameworks, see e.g., Hagenbeek et al. (2023),

As a way to address genetic confounding, the twin comparison approach accounts for genetics by differencing out shared Family factors (F) that subsumes genetics (e.g., through a fixed effect model; or by demeaning the variables by the average of a twin pair). Since identical twins are identical in their genetic makeup, genetics or gene-caused confounding factors are completely removed; while for nonidentical twins and siblings who still differ in genetics, residual genetic confounding can still exist.[26]

As with all designs, twin comparison studies face several challenges and biases. Firstly, more restricted effective sample size and statistical power due to correlations within twin clusters, coupled with potential attenuation bias from measurement error in the independent variable could, under some circumstances, render findings of null effects from twin comparison studies less informative. Second, a twin comparison design does not guarantee a causal interpretation. While it is generally assumed that some differences between twins raised together stem from exogenous factors – such as random life events like accidents – and some argue that a substantial portion of these differences may be exogenous in nature (e.g., Plomin, 2024), there is no certainty that all within-pair differences are entirely exogenous.[27] Therefore, even if some within-twin-pair effects are observed, one still needs to consider individual specific confounding factors, i.e., factors that do not exert similar influence on twins. For example, birth weight is often associated with various life outcomes, and twins can differ by a small amount at birth. If birth weight, through some mechanisms, influences both variables in the relationship under examination, birth weight can be regarded as a non-shared confounding factor.

However, several clear advantages of twin comparisons underscore the value of this control-by-design approach for observational studies. First, within-family variation blocks or rules out a range of confounding factors that are otherwise unlikely to be exhaustively accounted for in a conventional control-by-observable approach (e.g., Rohrer, 2018; Turkheimer & Harden, 2014). Secondly, especially when the effect of interest can not be studied using other causal-oriented designs or environmental manipulation, twin comparison serves as a strong alternative approach to gain some valuable (initial) insights. Moreover, by comparing results from naive models using variation across all indi-

Kohler et al. (2011), Rasmussen et al. (2019), Turkheimer and Harden (2014), and Turkheimer et al. (2014).

[26] Twin comparison designs can control for confounding by passive gene–environment correlation (the possibility that parent–child associations are attributable to genetic relatedness) even though siblings differ genetically. This is because the random assignment of alleles at conception means that genetic differences between siblings do not correlate with differences in environmental exposures.

[27] There are various sources of discordance between twins, including non-shared life experiences (e.g., random events), in utero environmental factors (e.g., uneven blood supply), epigenetic modifications (e.g., cytosine methylation affecting gene expression), genetic mosaicism (e.g., de novo mutations), and other forms of developmental stochasticity (e.g., random molecular movements) (e.g., Czyz et al., 2012; Plomin, 2024; Tikhodeyev & Shcherbakova, 2019).

viduals and twin comparison models, it gives us a sense of the magnitude of shared confounding factors.

3.3 Molecular genetics based approach

In contrast to using twins as "shortcuts", the genomic revolution has supplied more opportunities to measure genetic information and incorporate this information into research. The widespread availability of genotyping technologies, combined with access to large datasets, has made it possible for researchers to conduct Genome-Wide Association Studies (GWAS). In a GWAS, associations between thousands to millions of genetic variants across the genome are examined, enabling researchers to investigate the genetic architecture underlying traits of interest in unrelated individuals. Genetic variants refer to regions in the genome that differ across individuals, with the most common type being single nucleotide polymorphisms (SNPs), where a single nucleotide in the DNA sequence (e.g., A, T, G, or C) differs at a specific location. A SNP exists as two possible versions, called alleles (e.g., A and T). The more/less common allele at a certain locus in a population is referred to as the major/minor allele. For each SNP, an individual can inherit 0, 1, or 2 copies of the minor allele (e.g., AA, AT, and TT), representing the combinations of alleles inherited from each parent. Genotyping identifies these variants, which, despite humans sharing 99.9% of their DNA, contribute to individual differences.

In a conventional OLS-based GWAS, a specific trait of interest, such as height, is regressed onto each SNP separately, with standard covariates.[28] This entails running millions of regression models to identify associations between SNPs and a trait. A genome-wide significant SNP needs to have a p-value (for its association with the target trait) that is lower than a multiple testing adjusted significance threshold, typically, $p < 5 \times 10^{-8}$. GWAS research has expanded rapidly in the past fifteen years, with large sample sizes and a wide variety of traits such as educational attainment, cognitive ability, psychological traits, physical and health related traits.[29]

Large-scale GWASs often identify hundreds or even thousands of SNPs significantly associated with the trait under study, with each SNP typically exerting a tiny effect. This finding supports the concept of *polygenicity in human complex traits, where many SNPs contribute modestly to phenotypic outcomes*

[28] Typically, these covariates include age, sex, and principal components computed from the genetic-relatedness matrix.

[29] Large-scale GWASs often involve multiple participating cohorts, but GWASs do not require pooling all data together. Typically, cohort analysts who have access to individual level data upload the (within-cohort) statistical associations between the target trait and each measured SNP of the individuals in the cohort. The cohort-level results only contain within-cohort statistical associations, and do not contain individual-level data. The lead analysts of the GWAS then meta-analyses all cohort results to produce the overall GWAS results.

(Chabris et al., 2013, 2015).[30] This theoretical and methodological development also explains why earlier studies on candidate genes often fail to be replicated. Candidate gene studies only focus on a handful of predefined genetic variants that are hypothetically relevant to the trait of interest, such as the relationship between 5HTTLPR (a genetic variant of the serotonin transporter gene) and depression (Caspi et al., 2003). Since the influence from only a handful of genes are likely to be very small, candidate gene studies based on a few thousand individuals were underpowered to identify genetic related influences.

Estimates from GWASs can be used in multiple follow-up applications, but the most relevant for social science research is the polygenic index, which help overcome limitations in candidate gene studies.[31] A polygenic index (PGI) is a quantitative variable that summarises genetic association to a target trait by combining multiple genetic variants and their associated weights (effect sizes), derived from a GWAS.[32] It can be constructed for individuals for whom there is genetic data that includes the SNPs used to construct the index. PGI has several advantages compared to other approaches. Compared to the variance decomposition approach in twin modelling, PGI can be included as a standard variable in regression analyses. This means that PGIs can be used to represent the "G" in the illustrations of genetic confounding (Figure 1) and gene-environment interaction (Figure 2) described above. Meanwhile, since a PGI captures the combined explanatory power of numerous measured SNPs, it offers greater explanatory power than individual SNPs. This advantage is both statistical, as it increases the power of analyses that use PGIs, and conceptual, as it encompasses an array of mechanisms associated with the included SNPs (Benjamin et al., 2024).

[30] For example, for the first three discovered SNPs in one of the first GWASs on educational attainment (EA1), each explained only about 0.02% of variance in education, which corresponds to a difference of about one month of schooling per allele (Rietveld et al., 2013). The most recent GWAS meta-analysis for education (EA4), has a combined sample size of about 3 million individuals and identifies 3,952 approximately uncorrelated genome-wide-significant SNPs.

[31] For a summary of follow-up applications, see e.g., Benjamin et al. (2024).

[32] As a simplified example for illustration, we can consider a case of only two SNPs in the genome. As aforementioned, for each SNP a given individual can have either 0, 1 or 2 minor alleles. If we assume that GWASs on educational attainment show that each additional minor allele for the first SNP is significantly associated with 1 week of increase in educational attainment, and 2 weeks of increase in educational attainment for the second SNP. Then, a PGI for education can be calculated by adding the number of minor alleles for the first SNP multiplied by 1, and the genotype for the second SNP multiplied by 2. PGI is defined as:

$$\mathrm{PGI}_i = \sum_{j=1}^{K} \hat{\beta}_j X_{ij}$$

$\hat{\beta}$ represents the estimated coefficient for SNP j, as obtained in the GWAS discovery sample, and X_{ij} denotes the number of alleles (0, 1, or 2) that individual i has for that SNP.

Interpretations and applications of polygenic indices

Before introducing applications of PGIs in social research, there are some key caveats in applying and interpreting PGIs despite notable advancements. Firstly, PGIs only partially capture genetic variants that are associated with the target traits. Therefore, the explanatory power of PGIs is much better than a handful of genes but is still limited and is attenuated by measurement error. Secondly, PGIs capture some genetic effects from measured genetic variants but also other residual confounding. Take genetic nurture for instance: parents who share genes with children, can exert influences on children, not necessarily through genetic transmission, but through their own genes mediated by their own behaviour (e.g., by creating supportive conditions) (Kong et al., 2018). However, within a family or a pair of siblings, genetic inheritance from a pair of biological parents is random due to Mendelian segregation during meiosis. As a result, genetic differences between siblings, as captured by a PGI, are not correlated with any potential environmental confounding factors. Consequently, within-family analysis can help estimate the (local) causal effect of a PGI. Paper 1 in this dissertation therefore performs within-family analysis when examining genetic influence. More detailed explanations on polygenic index are provided in the Appendix.

In short, PGIs are best interpreted as noisy measures that partially capture the underlying additive genetic factor linked to the traits. This makes PGIs much like many social science variables. Indicator variables and summary scales of latent constructs, such as socioeconomic status, are often imperfect, contain error, and may be confounded (Burt, 2024).

The effects of a PGI is expected to capture a combination of all mechanisms through which measured genetic variants *ends up* affecting the trait (Benjamin et al., 2024). For numerous social and behavioural traits, the underlying mechanisms may involve mediation by many social, behavioural, neurobiological, and physiological phenotypes, due to reasons such as prevalent pleiotropy (one gene affecting multiple traits) in human complex traits (Watanabe et al., 2019). For instance, an education PGI robustly predicts wealth by influencing financial decision making aside from educational attainment per se (Barth et al., 2020). As described in the beginning of this section, these mechanisms underlying PGI effects may also involve social and environmental interactions where an individual's genetically influenced traits lead them to select or elicit specific environmental exposures, further shaping the development of the outcome.

In social research, PGIs are not typically used for prediction in the same sense as in health or disease studies. For complex behavioural traits like education, PGIs explain only a small proportion of variance, particularly compared to traits like height or BMI. Instead, genetically informed social research combines PGIs with various designs (e.g., family-based and unrelated individual designs) to improve research validity and efficiency, understand individual differences, and shed light on various social mechanisms, even genetics is not of central concern.

Socioeconomic and health outcomes are the most studied in existing research using PGIs. Among the handful of political behaviour studies incorporating PGIs (e.g., Aarøe et al., 2021; Ahlskog et al., 2025), Dawes et al. (2021) find significant effects of the PGI for education on turnout in the US and Sweden, corroborating previous findings of political participation based on twin studies (e.g., Alford et al., 2005). They also show that the effects of a PGI for educational attainment on political participation might be influenced by the information richness of electoral contexts.

Apart from testing whether insights from traditional twin and family modelling hold, PGIs can be employed as control variables (e.g., Benjamin et al., 2024; Cesarini & Visscher, 2017). Since a PGI is fixed at conception, it cannot be reversely affected by the treatment/independent variable, therefore PGI controls can forestall the introduction of post-treatment bias.[33] A PGI could be used to (partly) control for omitted variable bias in observational studies where the treatment of interest might be correlated with genetic factors and other factors influenced by genetics. Using PGIs in this context could be useful if researchers do not have siblings or family samples but family/genetic confounding can be significant, or some variables are important but are only measured post treatment (Fletcher, 2023). Using PGIs as control variables means that one treats the previously unmeasured G just as an observed variable (cf. Figure 1). The upside is that it does not compromise effective sample size in the same way sibling comparison studies do, but the downside is that PGIs only partially capture genetic influence associated with some traits. In relation to this point, studies have also used PGIs to see whether the associations between neighbourhood characteristics and individual outcomes can be explained by genetic confounding, e.g., genetic related sorting. Belsky et al. (2019) find that genetic-related self-selection does not account for the significant associations between general neighbourhood disadvantage and outcomes like obesity and mental health, but does modestly explain associations with teen pregnancy and poor educational outcomes, suggesting that neighbourhood effects for these outcomes should be interpreted cautiously.

Another main application of PGI is to study gene-environment interplay (Benjamin et al., 2024). Multiple studies have employed PGIs to test heterogeneous effects of quasi-experimental policy reforms or other events – how the effect of a treatment varies among individuals by genetic predisposition (illustrated as (b) in Figure 2). For example, Barcellos et al. (2018) show that a UK compulsory schooling reform has stronger effects on reducing body size for people at high PGI for BMI, which suggests that the educational reform might

[33] Because of this property, PGIs can be used for balance tests in randomized controlled trials (RCTs). For RCTs, including PGIs to reduce noise and increase precision for treatment effect estimation may also be a more cost-efficient way than increasing sample size (e.g., Rietveld et al., 2013).

have narrowed the genetically associated disparity in health. With a wide range of socioeconomic and health outcomes, Ahlskog et al. (2024) study the heterogeneous effects of a Swedish education reform, and find that among females from high socioeconomic background families, the reform had a larger effect on earnings for those with a lower education PGI, after correction for multiple hypothesis testing.[34]

Political research has also utilised polygenic indices to investigate the formation of political preferences from the perspective of gene-environment interaction. Ahlskog (2024) address the puzzle of how cognitive performance is linked to economic conservatism, as existing studies provide ambiguous and mixed evidence. Using a PGI for cognitive performance, the study demonstrates that genetic predispositions associated with cognitive performance lead to conservative economic preferences among individuals raised in affluent environments, but more progressive preferences among those growing up in relative poverty. In other words, the direction of the cognitive performance PGI's effect on economic conservatism depends on family economic background. While the PGI exhibits no main effect, it has significant, class-dependent effects that are both sizable and discordant in sign. This pattern supports the proposed mechanism that cognitive performance, and the genetic factors associated with it, does not directly shape economic policy preferences. Instead, it influences individuals' capacity to align or optimise their policy preferences according to their class background and material interests. Therefore, incorporating PGIs with an understanding of gene-environment interaction offers a novel perspective for advancing investigations into the development of political behaviour and preference.

[34]However, among 105 pre-registered tests examining heterogeneous effects of the reform, only two significant interactions remained after correcting for multiple hypothesis testing. This result might imply that the education reform does not act as a "great equaliser." Alternatively, it could reflect limitations related to sample sizes and the still insufficient predictive power of PGIs (Ahlskog et al., 2024).

4 The case of Sweden and the SALTY cohort

4.1 The case of Sweden

Like other countries in Northern Europe, Sweden has a relatively recent history of mass migration compared to countries such as the United States, Canada, and Australia. In the 1950s and 1960s, labour shortages led to a wave of labour immigration. By the 1970s, immigration shifted towards humanitarian migration, with refugees arriving from Latin America and the Middle East. The post-Cold War era saw migrants from Eastern Europe, and from the 1990s, asylum seekers arriving from conflict zones like Iraq, Somalia, and Afghanistan, alongside increased EU migration following Sweden's EU membership (e.g., Borevi, 2012). The large-scale refugee influx around 2015 prompted tightened immigration controls and policy changes (Borevi, 2024; Hagelund, 2020). Looking at the statistics for foreign-born, i.e. residents who were born outside of Sweden, the numbers between 1960 to 2010 changed from 4% to 15%, and reached about 20% at the end of 2023. Before the 1990s, the proportion of residents with a foreign background (having both parents born abroad) was below 10%. The proportion rose to about 19% in 2010, and continued to reach around 27% as of the end of 2023.[35]

From one perspective, Sweden can be considered a distinctive case due to its institutional background and policy history. The country's universal welfare regime is often cited as a fundamental factor in promoting equality and fairness, supported by efficient governance that fosters and sustains trust among citizens (e.g., Rothstein & Stolle, 2008). Notably, Sweden's welfare state was largely established before immigration levels significantly increased. A strong comprehensive welfare state foundation has been argued to empower societies to withstand pressures on trust and maintain support for welfare states in the face of growing diversity (Crepaz, 2008; Kumlin & Rothstein, 2010), and to facilitate more open admission policies toward forced migration (Boräng, 2015). The social democratic welfare state offers inclusive rights to immigrants, rooted in universalism and equality, with access to social protection and security typically not contingent on nationality or type of residence permit (Ahlén & Palme, 2020). Sweden's citizenship regime, characterised as individualistic and civic, is seen as conducive to reducing the salience of ethnic differences and fostering political and social tolerance among majority populations

[35] Statistics Sweden: https://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-composition/population-statistics/pong/tables-and-graphs/population-statistics—summary/swedens-population-in-summary-1960-2023/#Fotnoter (accessed on 10 December 2024)

towards ethnic minorities (Weldon, 2006). Sweden was also often recognised as a leader in multiculturalism, launching its official multiculturalism program in the 1970s to promote cultural diversity and integration in response to labour migration (Borevi, 2012). While some part of Western Europe experienced a retreat from multiculturalism during the 2000s, Sweden largely resisted this trend at the aggregate policy level (Borevi, 2012, 2013), maintaining liberal criteria for newcomers to acquire equal formal rights alongside natives. However, changes in policy rhetoric (Dahlström, 2004) and fluctuations in policy (Borevi, 2013) are not absent, and more prominently in the recent decade following the refugee crisis, there has been a gradual shift in focus from cultural diversity towards integration and immigration control (e.g., Borevi, 2024).

These favourable institutional and policy conditions, coupled with high levels of economic development, are believed to generate and sustain high levels of trust and ethnic tolerance, while also better equipping societies to address the challenges posed by increasing diversity to social and economic solidarity (e.g., Banting, 2010; Crepaz, 2008; Kesler & Bloemraad, 2010). Indeed, Swedish public attitudes towards immigration, ethnic tolerance, and trust have, on average, been comparatively high in international public opinion surveys and exhibit minimal identifiable fluctuations at the aggregate national level(e.g., Delhey & Newton, 2005; Heath & Richards, 2020; Meuleman et al., 2009; Ortiz-Ospina et al., 2024).

However, Sweden is not different from other Western European countries in witnessing increasing salience of public backlash against immigration and the electoral success of right-wing anti-immigration forces since the late 2000s (Rydgren & van der Meiden, 2016). The anti-immigrant party New Democracy won seats in national elections in 1991, and despite slower pace in gaining political influence than other European anti-immigration parties (Green-Pedersen & Krogstrup, 2008), the Sweden Democrats have been in the parliament since 2010, a time near when the SALTY survey was conducted. The slower development of anti-immigration party attributed to party strategies, rather than low public demand for anti-immigration policies (Dahlström & Esaiasson, 2013; Green-Pedersen & Krogstrup, 2008). The increasing prominence of right-wing influence, coupled with structural social and economic changes, has posed significant challenges to Sweden's welfare and migration regimes (Dahlstedt & Neergaard, 2019). At the same time, disparities between natives and immigrants, particularly non-Western immigrants, have been well-documented since the 1990s in areas such as labour market outcomes (e.g., Åslund & Skans, 2010; Dancygier & Laitin, 2014), political engagement (e.g., Dahlstedt & Hertzberg, 2007; Dancygier et al., 2015), and residential segregation (e.g., Bråmå, 2006; Müller et al., 2018). Swedish respondents tend to recognise discrimination as a significant obstacle for immigrants more strongly than the EU average (Dražanová et al., 2020). Nonetheless, evidence of discrimination, especially against individuals from Muslim-majority countries, has been observed in the labour market (e.g., Arai et al., 2016; Bursell, 2014;

Carlsson & Rooth, 2007; Rydgren, 2004), with mixed findings from field experiments regarding discrimination in public administration or political responsiveness (e.g., Adman & Jansson, 2017; Ahmed & Hammarstedt, 2020; Larsson Taghizadeh et al., 2022). Notably, Swedish respondents perceive the success of immigrant integration (both locally and nationally) rather negatively. This contrasts with other European societies, where positive evaluations of integration success often correlate with favourable perceptions of immigration's economic, cultural, and security impacts (Dražanová et al., 2020). These patterns suggest that political and public responses to immigration and increasing diversity in Sweden have been far more complex and divided than commonly assumed or predicted.

4.2 The SALTY cohort and survey

The Swedish Twin Registry (STR) is an infrastructure of broad utility mainly for epidemiological and molecular studies of twins, containing information on Swedish twins born after 1886 (Zagai et al., 2019). SALTY is among one of the studies conducted in STR targeting whole Swedish twin cohorts born between 1943-1958.[36] These birth cohorts were chosen as they belong to the active workforce and have higher participation rate than older cohorts. SALTY is a collaborative project initiated in 2007 by researchers in epidemiology, medicine, and economics, which conducted data collection on an extensive self report paper-questionnaire, saliva collection for DNA extraction, and a request to participate in an Internet assisted investigation on musical experience and other psychological performances. The first requests for participation in the SALTY study were sent out in early 2009 and the data collection was completed in the summer of 2010 when a total of 24,916 twins had been contacted, and 11,372 respondents (subject-wise response rate 46%) gave informed consent to have their data stored and analysed (Magnusson et al., 2013).

The SALTY survey includes extensive items on economic and sociopolitical preferences and behaviour (Benjamin et al., 2012), including preferences specifically on immigration related policy (four items, of which three were taken from the Swedish National Election Study), generalised trust (two items taken from the General Social Survey), prosocial behaviour, and batteries on multiple psychological traits. The SALTY cohort can also be linked to information from a range of available state registry, providing objective information as recorded in them. STR is also one of the participating cohorts in numerous GWASs and in the polygenic index repository (Becker et al., 2021), which gives STR access to polygenic indices constructed under the most unified pipeline and stringent standards. While prominent twin surveys in the US and Australia cover topics of interest for social sciences research, such as The

[36] See https://ki.se/en/research/research-infrastructure-and-environments/core-facilities-for-research/swedish-twin-registry-core-facility/swedish-twin-registry-birth-cohorts-and-studies.

Minnesota Twin Family Study (MTFS) and the Australian Twins Economic Preferences Survey (ATEPS), many cannot be linked to official records. Twin and family cohorts in the Netherlands and Norway, though linkable to state records in areas of educational, socioeconomic, and health outcomes, lack survey content comparable in scope and focus to SALTY. This unique constellation of survey data and linkable registries for the SALTY cohort makes it a valuable resource for applying genetically informed approaches to the study of sociopolitical attitudes and behaviours.

Four main characteristics of the cohort are noteworthy, and I will discuss the implications of the cohort profile further in Section 7. First, the sample primarily (over 98%) consists of individuals with a Swedish background (being born in Sweden with at least one Swedish-born parent). This means that their relationship with immigrants reflects majority-minority group dynamics. Second, compared to the general population from the same birth cohorts, the SALTY respondents have slightly higher education levels, higher income, and a greater proportion of women. Third, as mentioned in Paper 2, these respondents do not differ significantly in their attitudes towards immigration compared to other age groups, although they show less support for labour immigration, potentially due to their career stages. Additionally, the twins' political preferences, as reflected in their self-reported party choices relative to election outcomes, closely align with those of the general population (Ahlskog & Brännlund, 2022). Fourth, the sample cohort grew up during the height of social democracy and the welfare state development. A primary aim of the Swedish compulsory education reform was to promote equality of opportunity through educational expansion (Holmlund, 2007). Later on, they also lived through the economic challenges of the 1990s Swedish financial crisis. The cohort witnessed the labour migration in the 1960s, the introduction of the multiculturalism programme in the 1970s, and waves of asylum and refugee immigration from non-European regions beginning in the 1980s and 1990s. However, during their formative years (1960 to the mid-1980s), the proportion of foreign-born individuals in Sweden remained below 8%, only rising to around 15% by the time of the SALTY survey (2009–2010). Consequently, compared to younger cohorts, this group had limited exposure to or interaction with immigrants during the critical period when trust and political attitudes are shaped (Alwin & Krosnick, 1991; Sears & Funk, 1999) but witnessed rising immigration during their careers, when it became a socially and politically salient issue.

5 Summary of Papers

Paper I: Triangulating the relationship between education and attitudes towards immigration

Paper 1 examines the robust association between education and attitudes towards immigration using a methodological triangulation approach that explores both the causal effect of education and the role of genetics in this relationship. This summary also includes some discussion on connections to other studies that were not covered in the published short research article. Through three distinct natural experiments, the paper contributes to disentangling this relationship by: (1) identifying the effect of educational attainment using a discordant twin design to leverage within-twin differences in education covering a broad range of educational levels as the source of variation, and providing evidence on the extent to which twin-shared factors account for the observed strong association (Study 1); (2) comparing these findings with the effects of a Swedish education reform that primarily extended the length of compulsory schooling (Study 2); and (3) examining the role of education-related genetic predispositions in shaping the relationship and variation in immigration attitudes (Study 3).

Study 1 employs a discordant twin design, an approach not previously applied in research on education and immigration attitudes. Unlike longitudinal studies that trace within-individual changes in education during adolescence and early adulthood, it estimates the relatively long-term effects of education, including its downstream consequences as reviewed in Section 2.1. Study 1 reveals a modest but significant positive effect of education on pro-immigration attitudes. When comparing models with basic controls and municipality fixed effects to twin fixed effects models, the latter generally show a reduction in estimates to about one-third of their original size, with even larger attenuations observed for the estimates of tertiary education. Supporting the "education-as-proxy" explanation, these results indicate that the educational gradient in immigration attitudes can be partly attributed to predispositional factors shared by identical twins, likely including early familial, neighbourhood, peer influences, and genetics.

Study 2 evaluates a 1950s Swedish education reform that increased compulsory schooling to nine years, implemented in a staggered manner across municipalities. The results indicate no significant effect of the reform on general immigration attitudes, with small and imprecise estimates. This null finding may stem from the reform's limited impact on higher education levels or insufficient statistical power. However, focusing on the Norwegian education reform, Finseraas et al. (2018) also employed cohort differences in exposure to the reform within municipalities and used a sample size comparable to that of Study 2, but reported a precisely estimated null effect. It also aligns with the null (local) effect reported by Cavaille and Marshall (2019), who applied a regression discontinuity design to evaluate the same Swedish reform. In contrast to several studies reporting significant positive effects of compulsory education reforms in other European countries (Cavaille & Marshall, 2019; D'Hombres & Nunziata, 2016; Margaryan et al., 2021), these results, appear to suggest that increases in secondary education have limited impact on promoting positive immigration attitudes in Sweden and Norway, where citizens tend to hold more tolerant and inclusive views on immigration compared to other European countries.

Building on the findings of Study 1, Study 3 further explores the role of genetic predispositions for education. Using a polygenic index (PGI) for education and within-family analyses of dizygotic (DZ) twins, the study demonstrates a (local) causal effect of the education PGI on immigration attitudes. The effect size of a one-standard-deviation increase in the education PGI is comparable to that of 1-2 years of schooling. The education PGI, which is expected to partially capture residual education-related genetic differences within DZ twin pairs, slightly attenuates the effect of educational attainment. This modest attenuation does not provide strong direct evidence for genetic confounding. Several potential factors might explain this modest attenuation: the education PGI only partially captures all genetics related to education and the residual genetic confounding within DZ twins, measurement error in the PGI introduces biases, and genetic factors associated with other intermediate traits may also contribute to the genetic confounding. On the other hand, the effect of the education PGI is only partially mediated by educational attainment, suggesting that genetics related to education can influence attitudes through additional mediating pathways or traits beyond educational achievement. This finding aligns with recent studies demonstrating that the EA PGI has predictive and explanatory power for a range of cognitive and socioeconomic outcomes (e.g., Okbay et al., 2022).

Through a triangulation approach incorporating genetically informed designs, Paper 1 contributes to the discussion on the extent to which a causal interpretation of education can be applied to the educational divide in attitudes towards immigration. Additionally, it presents the first investigation into the role of genetic predispositions towards education in this relationship. Paper 1 has several limitations. First, the study on the reform's effect may suffer from limitations in statistical power, making it uncertain whether the nonsignificant effect observed truly represents a null effect. This uncertainty somewhat compromises the strength of comparisons with other studies. Second, while the discordant twin design effectively accounts for a range of confounding factors, it remains agnostic to the specific twin-shared factors that constitute self-selection mechanisms. The use of an education PGI to examine genetic predispositions represents only one attempt to characterise such mechanisms.

Finally, Paper 1 does not further disentangle the effects of education to evaluate the relative importance of the mechanisms outlined in Section 2.1. One may compare Paper 1's finding with those from discordant twin studies examining the effects of educational attainment on other political outcomes. For instance, existing research does not find that education impacts voter turnout in national elections or social trust in Sweden (Dinesen et al., 2016; Oskarsson et al., 2017).[37] These outcomes, however, are arguably less characterised by political polarisation compared to attitudes towards immigration, nor do they represent a key element from the perspective of cleavage politics. This distinction may lend stronger support to the "education-as-cleavage" explanation, which is more specific to attitudes towards immigration. The mechanisms of education carry distinct implications. For instance, the "education-as-character-shaping" explanation, encompassing value and norm internalisation, cognitive sophistication and flexibility, perspective-taking, and critical thinking, is perhaps the most desirable given its broader implications for individual and democratic development (Nussbaum, 2006). In contrast, if the "education-as-cleavage" mechanism plays a significant role, it suggests that education can also exacerbate social and political segregation within the context of current politics, contradicting the optimistically envisioned role of education (Marks et al., 2021). Rigorous tests of these mechanisms would require investigations into mechanism-specific factors, such as the internalisation of norms and values, or subjective and objective economic and occupational positions, or downstream mediators emphasised in the cleavage perspective, such as education-based social networks, identity, and communication.

Paper II: Trust, prosociality, and immigration policy views

Generalised trust is fundamental for navigating local and broader social relationships with elements of uncertainty and complexity. However, the role of generalised trust has received relatively little attention in broader discussions on immigration and diversity, where debates often revolve around how social cohesion may be undermined. Among the few addressing this gap, Crepaz (2008) argues that the initial levels of generalised trust (which he terms universal trust) are decisive in the way foreigners experience discrimination (p.106). By adopting the "trust-as-morality" perspective, he concurs that generalised trust embodies an expansive sense of extended moral community that transcends one's own racial, religious, and ethnic identity (p.132). Multiple

[37] For second-order elections in Sweden, where the norm to vote is less pronounced and participation requires more information and resources, differences in education between twins do appear to affect turnout. This could reflect a downstream effect of education, wherein it gives individuals more access to information through social networks or other sources (Ahlskog, 2020).

studies also noticed a strong and robust association between generalised trust and favourable attitudes towards immigrants and policy arrangements (e.g., Herreros & Criado, 2009; Rustenbach, 2010), mirroring the lower trust levels observed among right-wing populist party supporters (e.g., Berning & Ziller, 2017; Keefer et al., 2019). If generalised trust influences how citizens perceive immigrants and their views on how immigrants should be treated, discussions on the implications of immigration and diversity should consider this factor not only as a dependent variable but also in relation to its underlying sources and strength as the social glue.

However, existing discussions lack a clear articulation of how and to what extent generalised trust matters and a thorough consideration of confounding factors. Paper 2 addresses these limitations by examining the relationship between generalised trust and immigration policy attitudes using a discordant twin design.[38]

Theoretically, I synthesise three mechanisms through which generalised trust can explain why trust in strangers can lead to a pro-immigration stance, outlined in Section 2.2. "Generalised trust as moral value" implies an inclusive stance as a result of adhering to the principle of being trusting and holding a universal outlook of one's moral community, thus being approval for inclusive and equitable policies. "Generalised trust as cognitive sophistication" implies a less prejudicial orientation, as individuals who are trusting tend to make more informed judgements regarding trustworthiness and potential risks in social interactions, therefore they are less reliant on shortcuts such as stereotypes to evaluate immigrants and policy arrangements for immigrants. "Generalised trust as psychological security" also predicts more tolerant attitudes, but as a result of being less inclined to perceive threats from immigrants.

Furthermore, I point out that trust in strangers may to some extent be underpinned by one's prosocial tendency – being willing to increase others' benefit even at personal costs – so as to "give the benefit of the doubt" to those one does not know. As discussed in Section 2.2, trust and prosociality are related

[38]There is limited research that experimentally manipulates the level of generalised trust to examine its impact on attitudes and behaviours. A notable example is the experiment conducted by Mutz (2005) on generalised trust and E-commerce participation. In this vignette experiment, respondents' levels of generalised trust were manipulated through reading a true *Reader's Digest* story about the return rates of lost wallets worldwide. The experimental conditions varied by emphasising 1) the generally positive or 2) negative aspects of human trustworthiness in these lost-wallet experiments, 3) or receive no information treatment. However, the component of generalised trust that is manipulated in such experiment is hard to characterise and to be connected to the developmental processes that cause individual variation in generalised trust. For example, from the perspective of seeing generalised trust as a psychological trait, is informational treatment sufficient or reliable to meaningfully manipulate a trait? This is not to imply that leveraging twin or sibling differences in generalised trust is a better approach than experiments in all cases. Which approach is better (with certain purposes) is both a conceptual and methodological discussion.

but also distinct constructs.[39] Prosociality may be relevant in shaping immigration policy preferences as living alongside immigrant groups entails allocating public goods, sharing resources and common spaces across various domains. It is therefore possible that individuals who are more trusting of strangers may be more immigration-friendly not because of trust per se, but because of their underlying prosocial tendencies. In this sense, prosociality is a potential confounding factor that must be distinguished from trust in analyses.

Empirically, I use Swedish twin data on generalised trust, assessed through two standard survey questions, alongside prosociality, which is operationalised by four common prosocial behaviours: organ donation, blood donation, unpaid volunteering, and charitable contributions. These factors are examined in relation to policy preferences based on four items of various immigration and integration policies.

The main finding shows a robust relationship between generalised social trust and favourable/liberal views on immigration policies. In contrast, while all four prosociality measures are initially positively associated with the attitude index with conventional controls, the associations between prosociality and the attitude index largely diminish and becomes statistically insignificant within identical twin pairs. Moreover, the influences of trust on pro-immigration policy stances seem to be independent of prosocial tendencies. Hence, the role of being willing to trust strangers is distinct from the role of being willing to benefit others – the readiness to accept potential vulnerability is more central to explaining a generally open stance on immigration.

Across various policy items, generalised trust is most strongly associated with an open stance towards accepting labour and refugee immigration. Its relationship with more complex policy areas, such as integration and multiculturalism – specifically language tests for citizenship requirements and economic support for protecting immigrant cultures – is weak and not statistically significant. What makes people believe that most people can be trusted may not have straightforward implications on public attitudes on conditions, boundaries, and benefits of social membership.

Further analyses indicate that the association between generalised trust and a general pro-immigration stance does not appear to be compromised or contingent on 1) exposure or competition with immigrants in the same employment sector, which has been considered a factor for anti-immigration sentiments (Dancygier & Donnelly, 2013), or 2) rank-based socioeconomic status, that shows a considerable effect on policy preferences. Moreover, factors such as religiosity, political ideology, and political trust, which have all been linked to trust building and immigration attitudes, barely influence the estimates of trust

[39] Trust and prosociality can be considered similar depending on their conceptualisation and operationalisation. For instance, behavioural trust, often measured through cooperative decisions, is also recognised as a form of prosocial behaviour in economic games (e.g., Thielmann et al., 2021). Within an evolutionary framework, prosociality or prosocial behaviour is a broader construct that encompasses trust as one form (Keltner et al., 2014).

when they are included as additional controls. The standardised effect size of generalised trust is generally comparable to left-right ideological orientation and trust in politicians.

In summary, Paper 2 confirms that trust in strangers has a distinct and robust association with a generally open stance on immigration. Generalised trust appears to extend inclusiveness towards immigrants, though this inclusiveness is primarily reflected in immigration acceptance. This study has several limitations. First, the study only uses self-reported trust, and prosocial behaviours are used as proxies for prosociality which may be imprecise and could reflect dispositions beyond a tendency to act prosocially. Second, although three mechanisms were proposed to explain why generalised trust is linked to more tolerant attitudes towards immigration, which one is most relevant is not empirically tested. Third, the findings are limited to the Swedish context during 2009-2010. In the discussion section of the paper, I elaborate on considerations of the generalisability of the results, how the proposed mechanisms can guide future research into the contextual variability of trust's role, and significant changes in Sweden such as the rise of the Sweden Democrats and policy shifts following the refugee crisis.

Paper III: Local interethnic exposure, trust, and neuroticism

Paper 3 revisits the relationship between ethnic diversity and social trust and cohesion by introducing several key additions on how, to what extent, and for whom ethnic diversity influences trust and other indicators of social cohesion at the individual level. This study builds on recent work that focuses on casual interethnic exposure – unstructured exposure with visibility but does not necessarily involve actual interactions – and uses micro-contexts (such as small spatial units and next-door neighbours) to approximate exposure with observational data (Brown et al., 2021; Danckert et al., 2017; Dinesen & Sønderskov, 2015; Tolsma & van der Meer, 2017; van Leeuwen et al., 2024). The focus on casual interethnic exposure in the residential vicinity is motivated by two key considerations. First, casual intergroup exposure represents a common means through which individuals encounter people from different ethnic groups in daily life (e.g., Allport, 1954), and such superficial exposure is often sufficient to connect an individual's social context to social and political behaviours (e.g., Enos, 2016, 2017; Spater, 2022). Second, focusing on variation in casual exposure in the vicinity avoids conflating distinct processes and social configurations operating at different levels that carry varying implications.

Paper 3 adopts a similar approach to Dinesen and Sønderskov (2015), who measure ethnic diversity within an 80-m radius as a proxy for casual interethnic encounters. Their study conducted in Denmark finds that such exposure is associated with slightly lower levels of generalised trust. As reviewed earlier in Section 2.3, distinct from existing broad accounts, they propose a cue-based theory to explain this link: casual interethnic exposure provides visible cues regarding outgroup presence and size. Since individuals typically have lower trust in outgroups (e.g., Delhey et al., 2014; Romano et al., 2017), encountering more neighbours from other ethnic groups in the vicinity creates stronger negative cues about the trustworthiness of others locally. As perceptions of local contexts and local experiences factor into generalised trust (Glanville & Paxton, 2007), a perception of lower trustworthiness of local residents can inform inferences about the trustworthiness of strangers within the wider society (Dinesen et al., 2020; Dinesen & Sønderskov, 2015).

Paper 3 contributes to clarifying the role of casual exposure in two key ways. First, Paper 3 seeks to, on the one hand, assess the scope of influence of casual exposure, and on the other hand, evaluate some alternative explanations to tease out plausible mechanisms. Dinesen and Sønderskov (2015) do not explore whether other relevant indicators of social cohesion are influenced in a similar manner or to the same extent as generalised trust. This ambiguity is also reflected in broader accounts, where generalised trust is often viewed as something generated and sustained in conjunction with prosocial engagement and associational life (see Section 2.3).

Specifically, I tested two sets of alternative outcomes: (1) social engagement proxied by two measures – charity donation and voluntary participation, and tendency towards social avoidance measured by an index reflecting extraversion and novelty-seeking tendencies; and (2) outgroup negativity, proxied by an item measuring attitudes towards refugee acceptance. If experiences of diversity through interethnic exposure do not lead to increased social avoidance or reduced prosocial engagement, this would challenge the "hunker down" mechanism of Putnam (2007). It would also limit the explanatory scope of theories based on preference diversity and coordination problem, as well as the social network and control problem (Koopmans et al., 2014), both of which suggest that individuals become less socially active due to a perceived lack of social codes guiding public behaviour (van der Meer & Tolsma, 2014). If outgroup negativity is not associated with interethnic exposure, it would also undermine explanations rooted in heightened outgroup threat, as predicted by the intergroup threat theory.

Second, Paper 3 contributes by examining how personality moderate responses to casual interethnic exposure, focusing on neuroticism predisposition which is marked by sensitivity to social context and a tendency towards negative emotions. Neuroticism may affect individuals' willingness to embrace vulnerability, which relates to the psychological security perspective of trust (cf. Section 2.2), and make them more attuned to potential risks in trusting others. This can result in a heightened responsiveness to visible social contextual factors, prompting a general reluctance to trust others. I therefore hypothesise that interethnic exposure is more negatively associated with trust among those with higher neuroticism.

Using survey and register data from the SALTY cohort, Paper 3 investigates the association between casual interethnic exposure – proxied by ethnic diversity within a 125-meter radius – and diversity at larger spatial scales, alongside a range of individual outcomes. Ethnic diversity at each contextual scale is measured using three indicators: the proportion of foreign background residents, the proportion of non-Western immigrants, and an index of ethnic fragmentation. The analysis includes an extensive list of individual- and contextual-level controls in socioeconomic and demographic domains. Given the expectation of modest effect sizes for local interethnic exposure, the discordant twin design was not employed due to concerns about statistical power. Instead, the analysis controls for a list of polygenic indices (PGIs) related to social, psychological, and health traits, to address potential genetic and heritable confounding factors. To test the hypothesis regarding neuroticism predisposition, I use the polygenic index (PGI) for neuroticism. This approach enables the exploration of the genetic predisposition for trust while mitigating concerns about reverse causality when examining the moderating role of predispositional factors, as explained in Section 3.

This study yields three key findings and implications. First, I observe the main finding of a small negative association between interethnic exposure and generalised trust, consistent with Dinesen and Sønderskov (2015). Notably, local interethnic exposure shows no discernible association with social avoidance or prosocial engagement. The patterns of association across various contextual scales between contextual diversity and all alternative outcomes differ from those observed with generalised trust. These results suggest that people's mutual regard for one another and their inclination to engage in civic activities are not easily influenced by the presence of immigrants in their immediate surroundings, and is unlikely to be primarily mediated by heightened outgroup negativity. Thus, the results provide indirect support for the cue-based mechanism.

Second, the neuroticism PGI has a significant effect on self-reported generalised trust, along with PGIs for other trust-related traits such as cognitive performance, education, subjective well-being, and depression. This finding challenges the strong assertion of Van Lange (2015) that trust is predominantly shaped and updated through social interactions and experiences.

Third, the association between interethnic exposure and trust appears to be stronger among individuals with a high neuroticism PGI. While the overall relationship between local exposure and trust is modest, it may be more pronounced for those who are more sensitive to cues that signal potential vulnerability in social interactions and who are inclined to avoid such vulnerability.

In conclusion, Paper 3 demonstrates that casual interethnic exposure in residential vicinity may indeed provide cues about outgroups and influence perceptions of the trustworthiness of strangers, suggesting it plays a role in cognitive processes, particularly for individuals more susceptible to the impact of such social cues. However, this influence may not extend to diminishing engagement in civic life.

A major limitation of this paper is that variation in local ethnic exposure is not exogenous, although several steps are taken to examine the extent of bias from omitted variables and self-selection. I also provide a discussion on why economic inequality and residential segregation are not the main confounding factors in the current research setting. In addition, this study does not directly test the cue-based mechanism proposed by Dinesen and Sønderskov (2015). Further research can use experimental approaches to explore the implicit contents in those cues, to explain why ethnic outgroups are perceived to be linked with lower trustworthiness.

It is important to emphasise that the findings of this study do not conflict with the view that segregation fosters mistrust and that constructive intergroup contact is essential. Local interethnic exposure in residential areas represents just one way of experiencing diversity in daily life, but it may be a particularly common form, especially for individuals who lack access to deeper interactions with immigrants and ethnic minorities. A key future research agenda would involve examining patterns of access to different types of intergroup contact and understanding how these forms of contact interact with one another. Additionally, given the finding that neuroticism predisposition moderates individual responses to social cues, it is crucial to consider individual differences, particularly those affecting sensitivity to social contexts and interactions, when investigating self-selection and the effects of various types of intergroup contact. Finally, the effects of polygenic indices (PGIs) on trust are likely the result of numerous interactive mechanisms during developmental processes. Future research should explore contexts that may moderate the role of neuroticism and related predispositions in the development and maintenance of trust, particularly during early life stages when trust and related attitudes are more malleable.

6 Contributions and implications

In this dissertation, I have adopted a genetically informed perspective that takes genetic confounding and heterogeneity into account, to investigate three crucial questions at the intersection of immigration, diversity, and trust. Collectively, the papers demonstrate that for questions revolving around individual variation in attitudes and behaviour around these topics, if not adequately accounted for, genetic confounding can bias relationships of interest, and genetic-linked individual heterogeneity can also moderate these relationships. In the following, I summarise the key contributions from each paper, highlight their interconnections, and present the overarching conclusions and contributions of the dissertation, alongside its broader implications.

Addressing the educational divide in support for immigration, Paper 1 shows that the "education-as-proxy" view has some explanatory power, but higher formal education as such may indeed liberalise attitudes towards immigration. Thus, explanations on the causal role of education likely remain effective. This dissertation is also the first to use the PGI for education to examine the role of education-related genetic predispositions on immigration attitudes.

Paper 2 asks how generalised trust may serve as a source of attitudes towards immigration. It does so by proposing three theoretical mechanisms, distinguishing generalised trust from prosociality, and accounting for familial and twin-shared confounders. Empirically, it shows a robust link between trust and a generally open immigration policy stance, although the role of this inclusive trust appears stronger for immigrant acceptance than more complex policy areas.

Paper 3, on the other hand, sheds new light on the debates surrounding immigration-induced ethnic diversity and its impacts on social cohesion. It does so by recognising that individuals experience diversity in various ways and emphasising individual heterogeneity. Empirically, it provides indirect evidence supporting the mechanism that casual interethnic exposure may serve as a cue that leads to changes in trust in strangers, while also underscoring that trust and other aspects of social cohesion can be shaped by distinct mechanisms and should not be treated as homogeneous outcomes. It also shows that the influence of casual interethnic exposure depends on individual psychological predispositions. This highlights that responses to diversity are not uniform across individuals, a nuance often overlooked in broader discussions.

Papers 2 on the role of trust and paper 3 on the role of ethnic diversity can be related to the broader discussion on the progressive's dilemma – the perceived tension between promoting social cohesion, and embracing diversity.

This framing has received various critiques from different analytical perspectives, and many nuanced considerations have already been raised on the basis of empirical scrutiny, normative evaluations, and historical and political background (e.g., Banting & Kymlicka, 2017; Larsen, 2022). Both papers reveal further nuances. Fostering trust itself can lay the groundwork for more inclusive attitudes and tolerance, but conflicts over how immigration-led diversity should be embraced in the society are not addressed solely by making citizens believe that most people can be trusted. Moreover, the lived experiences of diversity, such as the casual interethnic exposure examined in paper 3, can affect individuals differently. From this individual level perspective, for some individuals we may not see a tension between living among diversity and continuing to be attitudinally optimistic about others and behaviourally engaged in civic activities. But it might be relevant for some individuals, e.g., those who are more self-conscious in social interactions and tend to feel uncertain, anxious, and insecure, yet are not necessarily more negative towards outgroups or reject diversity. Therefore, adding to the broad discussion on addressing societal inequality, identity and nation-building, political sources, macro social configurations to understand the relationship and challenges between social cohesion and diversity, another layer may be to acknowledge the complexity and various ways people perceive and navigate diverse contexts, in a time when the connotations of differences may be subtly present.

The findings here can also be linked to general models of attitude formation and variation. An implication is that the settled disposition model that emphasises dispositional factors and "past" conditions, and the active updating model that emphasises situational impacts (e.g., Edelmann et al., 2023; Kiley & Vaisey, 2020; Lersch, 2023), are not in dichotomy. On the one hand, conditioning on familial and genetic factors, which can be broadly conceptualised as dispositions, tend to substantially attenuate the associations examined, whether for the effect of education or the effect of trust. On the other hand, trust and attitudes towards immigration can be shaped by factors other than twin-shared socialisations and dispositions, although those specific factors tend to have modest influence after early adulthood, as expected from a "settled disposition model" of attitude formation. For example, Paper 1 shows that education lead to more positive attitudes. Paper 2 shows that the more trusting twin is more pro-immigration. And paper 3 shows that to what extent a contextual factor matters is dependent on relevant individual predispositions.

In addition to demonstrating that trust and immigration attitudes can be shaped by socially relevant factors free of genetic confounding, this dissertation underscores the pitfalls of seeking simplistic answers to whether genetics or non-genetic factors primarily drive individual variation in complex human behaviour. Classical twin modelling provides insights into the relative genetic contribution to traits, but it risks fostering a dichotomised view of genetics versus the environment. Meanwhile, scholars sometimes rely on selective studies to support their claims about whether specific traits are predominantly influenced by genetic predispositions or experiential factors, further perpetuating this oversimplified perspective.

This dissertation shows a more complicated picture by employing polygenic indices. It shows that a sociopolitical trait can be shaped by genetic predispositions linked to multiple intermediate traits. For example, Paper 3 shows that PGIs for multiple social, psychological, and health traits have effects on generalised trust. It also shows that genetic predispositions towards a specific trait can influence outcomes beyond the intermediate trait itself, as evidenced in Paper 1's findings on the education PGI and attitudes towards immigration: a majority of the effect of education PGI is not mediated by obtained education. This intricate web of relationships and mediating mechanisms challenges views with genetic essentialist and deterministic biases, which tend to portray traits as immutable, homogenous, and natural, and emphasise genetic contributions to these traits more than is justified (e.g., Dar-Nimrod & Heine, 2011). Such perspectives oversimplify and undervalue the complexity of these influences and the role of environmental and social factors. By embracing this complexity, the dissertation underscores the importance of a more integrative approach to understanding complex human behaviour such as sociopolitical attitudes and behaviour.

7 Discussion: limitations and future directions

A genetically informed perspective and approach can facilitate investigations into social influences and processes by accounting for genetic confounding and heterogeneity. However, adopting such an approach also entails certain limitations and considerations. I address two key aspects in this discussion. First, as I have predominantly focused on the Swedish context and the SALTY cohort due to the availability of family structure and genetic data, I discuss potential limitations concerning generalisability with regard to country and cohort characteristics.[40] Second, I summarise the challenges of using twin comparisons and polygenic indices in social research on complex human behaviour, and discuss ways to better address some of these limitations and challenges while leveraging their advantages. In relation to this, finally, I suggest some future directions in applying genetically informed approaches to studying individual differences in political attitudes and behaviours.

7.1 Generalisability

As discussed in Section 4, while Sweden is notable for its universal welfare state institutions, strong civic engagement, and comparatively high levels of tolerance and trust, it shares many similarities with other Northern and Western European countries, including the gradual rise of right-wing, anti-immigration parties, increasing public concerns about immigration, and ethnic segregation across various domains. Therefore, the main findings of this dissertation should not be solely confined to or uniquely applicable to the Swedish context. For example, Appendix A.5 of Paper 2 demonstrates that a positive relationship between generalised trust and immigration attitudes is consistently observed across countries in the European Social Survey. Although this bivariate association was stronger in Sweden during the early 2000s, by 2014, Sweden no longer stood out as exceptional. Similarly, the modest negative association between local interethnic exposure and trust reported in Paper 3 aligns with findings from prior Danish research (Dinesen & Sønderskov, 2015), suggesting broader applicability. Moreover, the findings from Paper 2 and 3 in fact suggest that, even in a high-trust context, individual-level mechanisms and explanations remain relevant and are not entirely overshadowed by country-level factors.

[40] Considerations about measures used are discussed in individual papers.

At the same time, the literature underscores that institutional and societal characteristics can serve as higher-level moderating factors, helping to explain why definitive conclusions about the relationship between diversity and social or economic solidarity may not universally apply across contexts (e.g., Banting & Kymlicka, 2017; Kesler & Bloemraad, 2010). Appendix A.5 of Paper 2 highlights substantial cross-country differences in the strength of the association between trust and immigration, indicating that some variation across countries and over time is to be expected. While this dissertation has primarily focused on individual- and local-level factors, explorations with appropriate methodologies and data on cross-national heterogeneities (e.g., how the role and foundations of generalised trust differ across societies (e.g., Delhey & Newton, 2003; Welzel & Delhey, 2015)), political power shifts, policy transformations, and economic and demographic developments, as well as how higher-level variations interact with local-level dynamics (e.g., Dinesen et al., 2020; Helbling et al., 2015; Hopkins, 2010), remains crucial areas for further empirical research and theory building.

Several considerations regarding cohort characteristics can further contextualise the findings related to specific inquiries pointed out in the recent literature. One notable characteristic is that the SALTY cohort grew up in a period when there were much few immigrants, which provided limited opportunities for constructive intergroup interactions and the development of social networks with immigrants, unlike younger generations. In relation to Paper 2, the finding that generalised trust developed in this environment – despite the absence of constructive intergroup interactions – still has positive effects on attitudes towards immigration, implies that intergroup interactions may not be an essential condition for fostering meaningfully "generalised" trust. In relation to Paper 3, for this cohort, casual interethnic exposure may serve as a more salient cue for identifying outgroups, alongside potential stereotypes. Psychological research underscores that the frequency of interactions influences intergroup perceptions and anxiety (MacInnis & Page-Gould, 2015), and deeper experiences of diversity are argued to foster cognitive adaptation and liberalisation (Crisp & Meleady, 2012; Hodson et al., 2018). Recent studies also highlight a general trend of human adaptation to social diversity over time (Ramos et al., 2019). Consequently, due to the lack of interactions with immigrants during childhood and early adulthood, the effects of casual interethnic exposure may manifest more prominently for this cohort later in life compared to younger cohorts, potentially representing an upper bound. Future research employing long-term longitudinal data could further examine and disentangle these temporal adaptive changes from other correlated variations (e.g., age-related changes).

Another characteristic is that the SALTY cohort is slightly more highly educated compared to the population average. Prior studies employing compulsory education reforms as an instrument consistently report significant effects of formal education despite the reforms mainly affecting the lower end of the educational distribution (D'Hombres & Nunziata, 2016; Margaryan et al., 2021), and it is noted that the effect of education reform could be stronger for the group of individuals who otherwise would not have pursued additional education. If the inclination to attain education represents a dimension of effect heterogeneity, the SALTY cohort may be less likely to exhibit effects from additional education, assuming other sample characteristics remain constant. However, to fully establish this point, careful methodological and sample comparisons are needed.

Additionally, over 98% of the SALTY respondents have a Swedish background, meaning that most individuals belong to the majority group in their relationships with culturally different immigrants and ethnic minorities. While, the responses of native majorities to immigration are both prominent and consequential, forming the focus of much of the recent literature on immigration attitudes, trust, and diversity[41], it should be highlighted that the meaning and effects of diversity can vary significantly based on group positions, such as majority versus minority status (Abascal & Baldassarri, 2015; Fouka & Tabellini, 2022; Kustov & Pardelli, 2018). This dissertation is therefore limited in addressing the perspectives of minorities.

Finally, genetic contributions to individual variation in traits are frequently observed across different contexts, as indicated by the first law of behavioural genetics (Turkheimer, 2000). Recent studies using polygenic indices for education, for example, also show their predictive power for voter turnout in the US, Sweden (Dawes et al., 2021), and Denmark (Aarøe et al., 2021). Therefore, the roles of polygenic indices for education, neuroticism, and other traits found in this dissertation are likely to be observed in other settings and samples that are typically covered in GWASs. However, as the role of genetics can vary depending on environmental and societal conditions, understanding how genetic influences differ across contexts remains a critical theoretical and empirical issue that warrant further investigation. I return to this important research agenda in the end of this section.

7.2 Challenges and promises of genetically informed approaches

The purpose of employing twin comparison and polygenic indices as genetically informed approaches in this thesis has been to leverage their unique

[41] Broadly speaking, recent literature focuses predominantly on developed economies and immigrant-receiving countries, where immigrants often differ from the host population in terms of socioeconomic background, ethnicity, language, and religion. A small portion of recent studies have highlighted other dimensions of immigration, including migration in developing contexts (e.g., Zhou, 2021), immigrants who share ethnic or linguistic similarities with host societies (e.g., Holland et al., 2024), and migration driven by factors such as war displacement, climate disasters (e.g., Arias & Blair, 2022; Helbling, 2020), or family reunification.

strengths to refine our understanding of causal relationships and sources of individual differences in attitudes towards immigration and trust. However, methodological challenges and specific considerations remain.

In twin comparison studies, despite twins sharing greater similarities than unrelated individuals, encompassing both observable and unobservable characteristics, the findings may not be directly interpreted as causal effects. As discussed in Section 3, residual unshared confounding factors, if left unaccounted for, may introduce biases (e.g., Frisell et al., 2012). Meanwhile, classical measurement error in the independent variable can lead to increased attenuation bias when using the fixed effects estimator (Ashenfelter & Krueger, 1994; Frisell et al., 2012). However, the consistent reduction of about or over 50% in the estimates from twin fixed-effects models, compared to those from naïve models, does not appear to be primarily caused by measurement error-related attenuation bias. This is also because such bias should be mitigated by the use of education levels derived from official records and employed two items for generalised trust, both of which serve to reduce noise in these measures. Moreover, if measurement error is correlated within twin pairs, the resulting attenuation bias may be smaller in twin fixed-effects models. Another potential source of bias is the sibling spillover effect or interference, where the exposure and outcome of an individual can impact those of their siblings. Interference poses a common concern for causal inference in human behaviour due to the prevalence of human interactions (Bailey et al., 2024), but investigating these effects often necessitates targeted designs. In sibling comparison designs, this bias may arise from interferences between siblings within the family (Sjölander et al., 2016). But it has also been argued that some patterns of interference do not necessarily bias the estimated effects (e.g., twins responding to co-twins' schooling symmetrically in making their schooling decisions) (e.g., Kohler et al., 2011), and that twin comparison estimates can still provide useful bounds of true effect (e.g., Amin et al., 2015).[42] Ultimately, it might be a research agenda on its own to theoretically characterise dynamics of sibling and within-family interferences, and design corresponding studies to empirically test these, e.g., leveraging exogenous variations (e.g.,, policy changes, natural experiments) that affect one sibling but not the other to identify causal spillover effects (e.g., Altmejd et al., 2021; Zang et al., 2023), or even conduct controlled experiments to observe sibling interactions and decision-making in real-time, or qualitative studies that can help unpack subjective perceptions and experiences within siblings and the family (e.g., Hamwey et al., 2019).

[42] Sjölander et al. (2016) suggests that the bias resulting from various interference patterns tends to produce a conservative estimate of the true exposure effect with conditional maximum likelihood estimation, but this is not always the case. Theoretically, one can also use sensitivity analysis that incorporate domain knowledge to examine the extent of these influences. However, we have scant evidence about the strength of effect under plausible theoretical scenarios specific to sociopolitical attitudes.

Therefore, although twin comparison offers a valuable control-by-design approach – with findings helping to refine theoretical models and empirical applications assuming, for instance, a strong causal link between education and political attitudes – it has its limitations, just like any single method. A helpful strategy to enhance research validity is to combine different methodologies each with its own contributions and limitations. Consistent results across different methods provide greater confidence in the findings, and different methods may offer complementary insights into the same phenomenon. In this context, twin comparison serves as a useful addition to methodological triangulation and evidence accumulation (Frisell, 2021; Lawlor et al., 2017; Pingault et al., 2018), particularly in cases where experimental manipulations are not feasible. However, a key challenge remains in carefully comparing the designs, considering factors such as variation in the independent variable or construct, as well as subtle differences in causal interpretation and generalisability.[43]

The main advantages and limitations of polygenic indices are discussed in Section 3 with more detailed explanations in the Appendix. In summary, a PGI is an individual-level genetic summary index that combines the weak associations between numerous measured genetic variants (SNPs) and a target trait. Compared to the candidate gene approach or variance decomposition methods based on family samples, PGIs offer greater power and flexibility for capturing genetic heterogeneity in social research. However, current PGIs contain measurement error and do not encompass all genetic variants that may be relevant to the traits.[44] The naïve associations between a PGI and a trait can also be confounded by social and environmental factors such as historical, cultural, and geographic influences, genetic nurture, and assortative mating. To account for these confounders, approaches like sibling comparison or controlling for parental genetics are recommended.

To address these limitations, ongoing advancements in large-scale databases, genotyping techniques, GWAS methodologies, and statistical frameworks for understanding and estimating polygenic gene-environment interactions (Miao et al., 2022) are expected to improve GWASs and enhance the explanatory power and research applications of PGIs across domains (Abdellaoui et al., 2023). In the meantime, the exploratory processes themselves, facilitated by

[43] See, e.g., Petersen and Lange (2020) and Sjölander et al. (2022). Focusing on the causal effect of parental schooling on children's schooling, Holmlund et al. (2011) provides a thorough investigation into differences between methods used in existing studies and their implications, including twin studies that use the difference in twin parents' education to identify effects on their children, adoption studies where genetic transmission between adoptive parents and children is assumed to be absent, and studies that use compulsory schooling laws as an instrument for parental education.

[44] A related subtle limitation, both conceptual and methodological, is that PGIs are constructed from genetic variants with sufficiently large average effects identified in GWASs. As a result, genetic variants with smaller average effects that are strongly moderated by some environmental factors may not be included in the PGI.

debates and collaborative efforts among geneticists, statisticians, and social scientists, contribute to a deeper understanding of molecular genetics and its connection to complex human behaviours (Abdellaoui et al., 2023; Visscher & Goddard, 2019; Visscher et al., 2017; Young et al., 2019). For instance, the recognition of the polygenicity of complex human traits is a significant insight that has emerged from GWASs and reflections on the poor replication records of candidate gene studies (Chabris et al., 2015).

Ethical concerns have been highlighted amidst the rise of large-scale genomic studies investigating genetics and complex human traits (See, e.g., Meyer et al., 2023). The history of behavioural genetics includes instances of misuse, such as promoting eugenic ideologies and policies, or using genetic differences to legitimise social hierarchies. One concern is that findings about genetic contributions to traits associated with social status and desirable advantages, like education and income, may be misappropriated to justify inequality and biological and genetic determinism. Such interpretations risk exacerbating stigma, placing undue blame on individuals for their disadvantages, or fostering fatalistic beliefs that genetic influences render environmental interventions futile (e.g., Martschenko, 2024; Martschenko et al., 2019). Similarly, research exploring the genetic basis of sensitive or stigmatised behaviours, such as externalising behaviours, raises worries of reinforcing stigma and discrimination (e.g., Ventresca et al., 2024).[45]

The interdisciplinary community has extensively deliberated the potential risks associated with genomic research, especially large-scale GWASs, emphasising the need for clear and responsible communication to prevent misconceptions and potential misuse. One key recommendation is to accompany studies with FAQs that provide concise, accessible summaries and address common misunderstandings (Martschenko et al., 2021; Meyer et al., 2023). In line with this recommendation, the Polygenic Index Repository (Becker et al., 2021), which is the source of the PGIs used in this dissertation, includes an FAQ that clarifies key concepts and questions. For instance, it explains that GWAS and polygenic indices (PGIs) do not identify specific genes responsible for particular outcomes and cannot predict individual outcomes.[46] Currently, a number of FAQs from large-scale genomic studies and consortiums have been compiled into the "FAQs on Genomic Studies" (FoGS). This FAQ collection is publicly

[45] In human and population genetics, ethical concerns extend to the risk of misinterpretation and misappropriation of findings on group differences. Scientists have consistently refuted the notion that human "races" are primarily biologically distinct, showing significant genetic overlap across populations and attributing contemporary genome variation to historical migration and intermixing. However, research or narratives related to population and group differences may still be unintentionally misinterpreted by readers (Sawyer & Nam, 2024) or deliberately misused by individuals and organisations with racialist or extremist ideologies (Carlson et al., 2022).

[46] The FAQ for the PGI repository is accessible on the Social Science Genetics Association Consortium's website at https://www.thessgac.org/pgi-repository.

available and aims to support the responsible communication of findings in social and behavioural genomics.[47]

With these challenges and considerations in mind, I outline a few exploratory avenues where genetically informed approaches, not limited to twin comparison and polygenic indices, can facilitate and expand investigations into how individual differences in sociopolitical attitudes and behaviour come about, extending beyond the applications and focuses discussed in the individual papers. Family is frequently regarded as a primary agent of socialisation for children, influencing their social attitudes, identity formation, and behaviour. The literature on intergenerational transmission and family socialisation has theorised and investigated how parents and children become similar and differ (e.g., Hyman, 1959; Jennings & Niemi, 1968, 2014; Sears & Brown, 2023; Westholm, 1999), as well as the implications of various family structures such as birth order and sex composition (e.g., Bratsberg et al., 2022; Healy & Malhotra, 2013). However, there are other interactive and dynamic processes within the family. Research on education related outcomes have begun to elucidate these within-family processes combining polygenic indices and family structured data. For example, focusing on siblings within the same family, Fletcher et al. (2023) reveal that parents compensate for sibling inequality within families, making siblings who differ in education PGI, more equal in educational outcomes. Houmark et al. (2024), on the other hand, find that children with higher PGIs receive more parental investment from very early childhood, suggesting that parental responses to children may amplify initial differences in cognitive skills among children, and they argue that such heterogeneity may be underestimated or misattributed to other family factors if genetic related heterogeneity is ignored. Such interactive processes between family members remain undertheorised and inadequately investigated in the political socialisation literature.

Second, it has been emphasised that genetic influence can operate through environmentally mediated and moderated pathways, and genetic influence can only be understood in a structure and context, but we still know little about whether and how the broad range of social contexts at different levels and along different dimensions (Boardman et al., 2013) interact with genetic predispositions in shaping attitudinal and behavioural differences. Residential context is just one. Along with appropriate designs and interpretations (e.g., Domingue et al., 2020; Mills et al., 2020), future studies could focus on other more pronounced and structural differences such as gender (e.g., Perry, 2016), cohort differences (e.g., Herd et al., 2019), institutional and policy reforms (e.g., Ahlskog et al., 2024; Fraemke et al., 2024) to examine how socially evolved institutions, structures, and norms difference/changes interact with genetic influences. For instance, Van Ditmars and Ksiazkiewicz (2023) use twin modelling with data from Germany to demonstrate that differences in political

[47] FoGS is accessible at https://www.thehastingscenter.org/genomic-findings-on-social-and-behavioral-outcomes-faqs/.

interest among boys are largely explained by genetic factors, while for girls, shared environmental factors play a larger role. This supports the hypothesis that girls, being less encouraged to develop political interest, experience a gendered socialisation environment that suppresses the expression of their genetic predispositions compared to boys. Gender differences in expressed political interest are sustained through a combination of genetic variation, socialisation, and the interaction between the two. Using an adoption design, Oskarsson et al. (2022) show that strong environmental cues, such as consistent parental voting behaviour in the family, weaken the biological and genetic pathways in shaping voter turnout and vice versa. Research on educational outcomes has also investigated how social and institutional transformations change the association between genetic predispositions for education and obtained education using polygenic indices (e.g., Fraemke et al., 2024; Herd et al., 2019; Pettersson, 2025; Rimfeld et al., 2018).

As discussed earlier and demonstrated in this dissertation, incorporating genetics into research is valuable even for studies primarily focused on non-genetic factors and relationships rooted in debates and gaps within the political science literature. Datasets combining genetically informed data with politically relevant variables, such as those examined in this dissertation on how individuals think about and interact with others, remain scarce, but a number of social science surveys commonly used in political studies are beginning to include genetic data. Notable examples include the German Socio-Economic Panel (SOEP) (Koellinger et al., 2023) and British cohort studies (Shireby et al., 2024). With carefully managed data access policies, these resources can allow researchers to draw on existing political science theories (e.g., socialisation, psychological dispositions (e.g., Arceneaux et al., 2024; Sears & Funk, 1999)) and integrate insights from genetics and human behaviour (e.g., Harden, 2021; Koellinger & Harden, 2018; Mills & Tropf, 2020) to facilitate a more refined and comprehensive understanding of how individuals vary under myriad social influences.

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Appendix

Additional explanations on genetically informed studies and polygenic index

Twin and family modelling in behaviour genetics

The twin modelling approach provides a framework to examine the sources of individual variation, including the component of genetics. It also faces criticism on its conceptual representation and strict assumptions. One critique is that the twin modelling and variance decomposition approach overly simplify the complex dynamic, and inseparable relationship between gene and environment (e.g., Burt & Simons, 2014). Twin models make several assumptions in order to identify key parameters, including no assortative mating, no gene-environment correlation and interaction, no gene-gene interaction, and the equal environment assumption, i.e., MZ twins share environmental influences to the same extent as DZ twins. Violating these assumptions can over or underestimate heritability and other parameters. Some of these assumptions have been critically debated (e.g., Burt & Simons, 2014; Charney & English, 2013): while some studies do not find evidence, for example, of a violation of the equal environment assumption which inflate the heritability estimate (Conley et al., 2013), others argue that the assumptions are largely untenable or even unverifiable (e.g., Beckwith & Morris, 2008). Verhulst and Hatemi (2013) use simulations to address the influence of gene-environment interplay on estimates from twin modelling, and argue that estimates from twin modelling can be viewed as an initial, baseline model, akin to correlation or simple regression. Other family and extended kinship designs are also developed, which can relax some of these assumptions or rely on different assumptions than do twin studies, and estimate more parameters (e.g., gene–environment interaction covariance, assortative mating), although at the cost of modelling complexity and other constraints (Willoughby et al., 2023). These extended family designs have been applied in research on political attitudes and behaviour, in political science (Hatemi et al., 2010) and in psychology (e.g., Hufer et al., 2020; Willoughby et al., 2021). Despite discussions regarding the potential magnitude of bias in these estimates, decades of research through twin, adoption, and family studies have consistently demonstrated nonzero, and sometimes substantial, heritability for various complex human traits (e.g., Polderman et al., 2015; Turkheimer, 2000).

For political scientists, Hatemi et al. (2010) and Medland and Hatemi (2009) provide introductions for twin modelling and the extended family design for political scientists. In the most recent comprehensive primer for behaviour genetics methods, Willoughby et al. (2023) present an overview of the advantages and limitations of these modelling approaches, and highlight the need of using multiple designs to increase the validity of findings.

By including two or more measured traits of the twin pairs, multivariate models can be extended from bivariate models to estimate genetic and environmental correlations between phenotypes. In a bivariate model, other than using information from cross-twin (MZ and DZ twins) covariance in a single trait, it also makes use of cross-twin cross-trait covariance to decompose the covariance between two traits into the three components as mentioned above, and calculate the relative proportion of covariance due to each component. These bivariate model estimates can tell us the sources that contribute to the correlation between two traits of interest, as well as the genetic correlation and environmental correlation that reflect the overlap of the genetic and environmental factors underlying the traits, respectively.

The availability of twin and family samples, combined with sociopolitical trait data obtained from these samples, has prompted research across multiple fields to utilise behaviour genetics methodologies for investigating a broad spectrum of sociopolitical traits. Comprehensive reviews on these research are available in several key collections on genetics, biology, and politics (e.g., Dawes & Weinschenk, 2020; Ksiazkiewicz & Jung, 2020; Settle & Detert, 2023).

Interpretations and limitations of polygenic index

Despite notable advancements, there are several key caveats in applying and interpreting PGIs. It is essential to keep in mind that a PGI is best interpreted as a noisy measure of the additive genetic factor associated with a target trait.

First, PGIs capture measured SNPs (where allele count are observed directly or imputed with high accuracy), but do not capture all genetic variants related to the target traits. The explanations for why current PGIs do not have satisfactory explanatory power are mainly that, complex traits such as social and behavioural outcomes are 1) highly polygenic (i.e., are influenced by many genetic variants), and could be contributed by 2) rare variants, and 3) non-additive variance[48]. Another explanation is that twin studies overestimate heritability (e.g., Young et al. (2019)). It is expected that, as the sample sizes in GWAS increase, more comprehensive common genetic variants can be identified and incorporated in PGI construction. Genotyping rare variants and identifying non-additive variance remain challenging in the investigation of genetic architectures. However, in terms of non-additive variance, theoretical work and recent research have argued that genetic variance for complex traits is predominantly additive (e.g., Hill et al., 2008; Hivert et al., 2021; Okbay et al., 2022).

[48] The portion of genetic variance in a trait that arises from interactions between alleles or genes.

The predictive power of a PGI also depends on the GWAS sample size, as SNP effect estimates become more precise with larger samples, measurement error will be reduced. For example, the PGI based on the first education GWAS (EA1) explains 3-4% of the variation in educational attainment out-of-sample (Rietveld et al., 2013), while the most recent education GWAS (EA4) explain 12-16% (Okbay et al., 2022). Currently, the predictive power of PGIs for social and behavioural outcomes is generally lower than traits such as height and BMI. And it is acknowledged and cautioned that PGIs are poor predictors and *should not be used in predicting individual social and behavioural outcomes* (e.g., Becker et al., 2021; Benjamin et al., 2024).

Second, the association between a PGI and a trait may not represent causal genetic effects. This is because a PGI likely not only captures the effect of the measured SNPs, but also captures genetic nurture and other confounding factors (Young et al., 2019) that are environmental in nature. Genetic nurture refers to situations where parental genotypes (or other family members) influence children's traits over and above genetic transmission, through the environment (e.g., parental behaviours, family resources), which in turn affect the children (Cawley et al., 2020; Wu et al., 2021). This phenomenon creates an association between a genotype and a child's trait, where the association is actually driven by environmentally mediated effects of parental genotypes. For example, Kong et al. (2018) demonstrated that a PGI for educational attainment, calculated from parental SNPs not transmitted to their children, was still significantly associated with the children's educational outcomes, even after accounting for the children's own PGI for educational attainment. Another confounding factor is population stratification. This means that at a particular SNP, the frequencies of different alleles may vary systematically across environments for social, cultural, or geographic reasons. This bias can be partially mitigated by incorporating principal components from the genetic-relatedness matrix to capture general patterns of genetic variation due to population structure. However, residual population stratification that remains unaccounted for can still introduce associations between genotypes and phenotypes, as allele frequencies may still vary systematically due to social, and environmental factors even within a group of people of similar genetic ancestry.

Another major factor is assortative mating, which has long been of interest in social science research due to its link with social inequality. Assortative mating occurs when partners select each other based on specific traits (e.g., education, BMI), and in the context of GWAS, this can lead to a situation where the association between a SNP and a trait is partly inflated by other SNPs also correlated with the trait (inflate the effect size of the SNP).

For these reasons, the naïve association between a PGI and a trait might be confounded. However, within-family analysis can mitigate these issues. Within a family, genetic inheritance from a pair of biological parents is random due to Mendelian segregation during meiosis. As a result, genetic differences between siblings, as captured by a PGI, are not correlated with shared familial influences that shape the environment (genetic nurture), or with factors like population stratification and assortative mating.[49] Consequently, within-family analysis can help estimate the (local)causal effect of a PGI (e.g., Okbay et al., 2022; Selzam et al., 2019).[50] It should be noted that, since noise in the PGI is essentially classical measurement error, the within-family estimates of PGI are subject to attenuation bias (Becker et al., 2021).

Based on the most recent GWAS for education, Okbay et al. (2022) compare the associations between education PGI and educational attainment as well as 22 health, cognitive and socioeconomic traits in between-family and within-family analysis (conditional on parental PGIs), and find that controlling for the parental education PGIs roughly halves the education PGI's association with the phenotype, suggesting a substantial amount of the associations are resulted from a mix of sources described above. In contrast, when examining PGIs for height, BMI and cognitive performance, controlling for parental PGIs has far less impact on their associations with corresponding traits.[51]

Sibling and family-based GWASs have been proposed to account for these sources of bias more fundamentally. However, currently, nearly all published GWASs are based on unrelated individuals, because datasets with genotyped family members are too small to enable well-powered sibling or family-based GWASs. The few exceptions are Howe et al. (2022) and Tan et al. (2024).

Thirdly, GWASs and PGI constructions involve samples and procedures that can differ across studies, which can affect the explanatory power of PGIs, although the essence of the idea remains the same. For example, PGI construction can vary in terms of the choice for GWAS discovery samples, criteria on which SNPs are included, and corrections for linkage disequilibrium (LD)[52] (see discussions in, for example, Becker et al. (2021) and Muslimova et al. (2023)). To partially resolve these inconsistencies and avoid problematic practices, the Polygenic Index Repository has been established with a uniform methodology, and made available to help overcome obstacles[53] faced by researchers who want to conduct GWASs and use PGIs (Becker et al., 2021). The repository contains PGIs for 47 phenotypes and is based on meta-analysis with data from 11 participating datasets (such as the UK biobank and other

[49] Comparing within siblings is equivalent to conditioning on parental genotypes, though sibling comparisons typically have less statistical power (Benjamin et al., 2024).

[50] The causal effect is local as only heterozygous parents contribute to genetic variation within family (e.g. Benjamin et al., 2024).

[51] In their additional analysis that use education PGI to study assortative mating, Okbay et al. (2022) find that the assortative mating pattern related to education is not only that people marry each other based on educational attainment, the results imply that matings are based on some factor or factors other than educational attainment (perhaps in addition to educational attainment itself) but which is correlated with the PGI for educational attainment.

[52] If an allele of one genetic variant is inherited or correlated with an allele of a nearby genetic variant within a given population, these alleles are in linkage disequilibrium.

[53] There are often administrative hurdles in accessing genetic data and GWAS summary statistics.

registries with individuals mainly of European ancestry).[54] Two studies of this dissertation employ PGIs from the repository.

Finally, because large-scale datasets of genetic material and phenotype measures predominantly come from sources where most participants are of European ancestry, eurocentric bias poses a significant challenge for GWASs (Mills et al., 2020). As a result, PGIs derived from these studies have considerably lower explanatory power for samples of non-European ancestries. This disparity is a well-recognised concern, with the worry that genetics research risks disproportionately benefiting individuals with European genetic backgrounds (Duncan et al., 2019).

To assist interested researchers to get familiar with and use the PGI Repository, the Repository provides a user guide, with more specific accounts on methodologies (and software) for PGI and principal component construction; genotyping, imputation, and phenotype definitions in Repository datasets; a list of predictive power (incremental R^2) of Repository PGIs in validation datasets. The authors also provide a list of suggestions on how to think through some of the interpretational issues when using PGIs. In addition to theoretical and technical explanations, a FAQ section about the Repository's research background, design, social and ethical implications, in a more accessible form, is appended in the supplemental material of Becker et al. (2021) and available on the Social Science Genetics Association Consortium's website at https://www.thessgac.org/pgi-repository.

Apart from the examples mentioned above, PGIs have also been used to study other forms of gene-environment interplay, as well as social processes that contribute to inequality such as assortative mating. For example, as one example for gene-environment correlation, Abdellaoui et al. (2019) identify genetically related geographical mobility that suggest gene-environment correlation. They find that individuals who are genetically predisposed to higher educational attainment in Great Britain were more likely to migrate out of lower socioeconomic status areas such as coal mining areas. Using PGI for education of a large sample of parent-offspring trios in Norway, Nivard et al. (2024) find that the non-causal component of the PGI effects on children's educational attainment are primarily explained by multi-generational process of social stratification. Sunde et al. (2024) use PGIs from co-parents in Norway and find genetic evidence of assortative mating in nine out of sixteen examined traits. For six of these traits, including educational attainment, the findings reveal greater genetic variance among offspring, which contradicts the expectation of stable assortative mating over many generations and instead suggests an ongoing increase in familial similarity for these traits.

[54]The Health and Retirement Study, Add Health study, and the Wisconsin Longitudinal Study also provide preconstructed PGIs for use by researchers who have acquired permissions.

Glossary

DNA Molecular carrying the genetic instructions to build and reproduce living organisms in the form of a double helix.

Genome The collection of DNA of an individual.

Locus A given position on the genome.

Gene A sequence of nucleotides in the DNA that codes for a molecule (e.g.,, a protein).

Genetic variant A change or difference in the DNA sequence among individuals in a population.

SNP A SNP (pronounced “snip”) is a variation at a single position in the DNA sequence where individuals in a population may have different bases (A, T, C, or G). SNPs are the most common form of genetic variation and are frequently studied in genome-wide association studies (GWAS) to identify genetic variants associated with traits and diseases.

Allele An alternative version of a given genetic variant such as an SNP.

Major allele The allele of an SNP with the highest frequency.

Minor allele The allele of an SNP with the lowest frequency.

Minor allele frequency (MAF) The frequency of the least often occurring allele at a specific locus.

Genotype The genetic makeup of an individual, often in reference to a specific set of genes or SNPs.

Genome-wide association study (GWAS) A GWAS (pronounced JEE-wahs) is a hypothesis-free approach to identify genetic variants, mostly SNPs, that are statistically associated with variations in specific outcomes. Researchers often meta-analyse data from multiple studies to gather the largest sample possible.

Summary statistics (in a GWAS) The results obtained after conducting a GWAS, including information on chromosome number, position of the SNP, SNP(rs)-identifier, MAF, effect size (odds ratio/beta), standard error, and p-value. These statistics are used, for example, to create polygenic indices.

Polygenic index An individual-level genetic summary index that combines the weak associations between numerous measured genetic variants (SNPs) and a target trait, weighted by results from GWASs.

Heritability A population measure defining the proportion of variance in a trait explained by genetic variance within a population. Narrow-sense heritability focuses on additive genetic variance, while broad-sense heritability includes both additive and non-additive genetic variance.

Complex traits Traits that are affected by many genes (polygenic) and environmental factors.

Genetic nurture Parental genetics (or other family members related to the individual) influence the environment they provide for an individual, which in turn affects the individual's outcomes.

Assortative mating The selective mating of individuals on the basis of trait similarity or social homogamy. In genetic research, this refers to a mating structure where pairs of genetically similar individuals mate with a higher probability than expected under random mating.

Population stratification The presence of multiple subpopulations (e.g.,, individuals with different ancestral backgrounds) in a study. Because allele frequencies can differ between subpopulations, population stratification can lead to false positive associations. For example, the "chopstick gene" illustrates how a SNP might be wrongly assumed to be a true association due to differences in allele frequencies among populations with differing cultural practices, such as chopstick use, rather than biological reasons.

Additive genetic effects When two or more genes contribute to a trait or when alleles of a single gene combine such that their combined effects on the phenotype equal the sum of their individual effects.

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