



**Teacher-Student Relationships and Mathematics Achievement: The Role of Socioeconomic Status and Gender in Chile from a Longitudinal and Comparative Perspective**

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### Abstract

Students' relational experiences with their teachers are central in everyday school interactions, with important consequences for students' cognitive and socioemotional outcomes. While extensive research explores strategies to enhance school climate, less is understood about the role of teacher-student relationships (TSR), particularly how they vary by student gender and socioeconomic status (SES). Notably, research exploring the differential effects of TSR on mathematics achievement for adolescent students, specifically considering gender and socioeconomic disparities, their evolution over time, and cross-national variations, remains scarce. This study explores gender and socioeconomic differences in students' perceived relationships with their teachers, their association with mathematics achievement on three measurement occasions in Chile, and their differences with Peru, Paraguay, Spain, Sweden and Denmark in 2022. Drawing on school gender culture and Hofstede's cultural values theories, we conduct a repeated cross-sectional analysis of data from the Programme for International Student Assessment (PISA) for the years 2009, 2012, and 2022. Using ordinary least square (OLS) regression models, our findings indicate that SES does not moderate the association between gender and TSR in Chile, consistent with Peru, Paraguay, Spain, Sweden, and Denmark. The gender gap in TSR widened in favour of males in PISA 2012 and 2022, with no significant intersectionality between gender and SES in TSR over time in Chile. Boys experience enhanced mathematics achievement with better TSR, especially in Paraguay, Spain, and Denmark, but not in Chile, Peru, or Sweden. In Spain and Sweden, socioeconomically advantaged students benefit more academically from positive TSR, evidenced by higher mathematics achievement, a pattern not observed in Chile, Paraguay, or Denmark. From PISA 2009 to 2022 in Chile, an intensification in the magnitude of the association between TSR and mathematics achievement was observed. The results are discussed considering the recent educational policies implemented in Chile.

*Keywords:* teacher-student relationship, mathematics achievement, gender, socioeconomic status, PISA.

The role of teachers, particularly their teaching practices, is considered a main educational factor contributing to student outcomes (Muijs et al., 2014; Sammons et al., 2016; Teddlie & Reynolds, 2000). While several facets of teaching practice are related to improved educational outcomes (Creemers & Kyriakides, 2007; Hattie, 2009), the quality of teacher-student relationships (TSR) is a key factor enabling students to achieve meaningful and lasting learning (Eccles & Roeser, 2015).

Education is, in part, a social and relational experience. Seminal works have shown how social networks of interpersonal relationships form the basis of meaningful schooling processes for students, promoting a sense of belonging, engagement, and personal growth (Coleman, 1988; Moreno, 1934), especially for children and adolescents (Morrow, 1999). In particular, the relationships fostered between educators and learners are considered essential, playing a key role in emotional and instrumental support (Havik & Westergård, 2020; Pianta et al., 2003). This dual role is critical in fostering students' development and driving their academic success throughout their educational pathways.

These associations between TSR and educational outcomes have been examined across various educational levels, from preschool through to higher education. However, their perceived quality and the magnitude of their association with educational outcomes also show variability depending on students' backgrounds (Furrer & Skinner, 2003; Maulana et al., 2014; Roorda et al., 2011). For instance, several studies show that, during adolescence, the nature of TSR affects academic achievement significantly (Hattie, 2009; Maldonado-Carreño & Votruba-Drzal, 2011; Roorda et al., 2017; Sengul et al., 2019). Moreover, the potential role of cultural context in shaping these associations, as demonstrated by variations in the impact of student perceptions of TSR on academic achievement across nations, would suggest the importance of examining each country's context to elucidate its specificities (Mikk et al., 2016).

TSR not only contribute positively to students' experiences but also have beneficial effects on teachers. Some studies have shown that positive relationships with students enhance teachers' well-being, with important implications for their teaching careers and personal lives (Brekelmans et al., 2002; Spilt et al., 2011), increasing teacher trust in students, parents, colleagues, and school principals (Van Maele & Van Houtte, 2012). This corpus of literature highlights the need for social and emotional bonding in educational contexts (Bashir et al., 2014; Van Maele & Van Houtte, 2012), where positive relationships between members of the school community benefit the school climate as a whole (Thornberg et al., 2022).

This study describes and compares the magnitude and evolution of gender and socioeconomic gaps in the quality of TSR in Chile over a 13-year period (2009-2022) using PISA data. We also examine the association between these inequalities and mathematics achievement in six countries, as measured in PISA 2022. Examining these educational outcomes is particularly key in Chile, the focal country of this study, due to its strong market orientation and privatisation in its school system (Torche, 2005), which has led to high levels of socioeconomic segregation in schools (Gutiérrez & Carrasco, 2021; Valenzuela et al., 2014; Villalobos & Valenzuela, 2012).

In addition, this study provides new and robust evidence on the social mechanisms driving gender and socioeconomic differences in the quality of TSR and their consequences on mathematic achievement. The study's repeated cross-sectional design, which includes three occasions of country-level measurement from PISA 2009 to PISA 2022 describing recent trends in Chile<sup>1</sup>, and the comparative analysis with PISA 2022 data among adolescent secondary students, represents substantial advances over previous research in this field mainly focused in high-developed economies and primary education schools.

### **Understanding Teacher-Student Relationships in Education**

The quality of TSR is a relational construct, which presents inherent challenges in defining it due to its composite nature derived from the interaction between student and teacher behaviour. Relationships are broadly defined by more prolonged and comprehensive patterns of engagement, but interactions can occasionally be short and based on information, reinforcement, and modelling exchanges (Kilday & Ryan, 2022; Pianta et al., 2003). These dyadic relationships are based on the dynamics of these interactions, primarily within schools but also taking place in pedagogical activities outside the classroom. Attachment and motivation theory has greatly enriched the understanding of these classroom interactions, which provides a better understanding of these underlying contextual and psychological mechanisms.

### **Attachment and Motivation Theory**

Following attachment theory applied to education settings, given that young children in early childhood education often relate to their teachers in a way that is similar to the parent-child dynamic, they may rely on teachers to help them learn to cope in a classroom setting (Berman-Young, 2014). Thus, teachers can act as attachment figures for children,

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<sup>1</sup> We use PISA 2009, 2012, and 2022 data as these are the datasets with the relevant scales for this study in Chile.

providing them with a secure base to bond in schooling processes (Pianta, 1994; Pianta et al., 2003).

Meaningful interactions between students and their teachers, which in attachment theory terms are the initial attachment experiences, shape perceptions of their educational process and may influence later relational dynamics with their educators and their adaptation to the school context (Berman-Young, 2014). Numerous studies show that these students' perceptions of the teacher's affection and attention can provide a solid basis for further students' educational outcomes (Pianta, 1999; Roorda et al., 2011, 2017). Moreover, attachment theory typically focuses on the role of positive aspects, like friendliness, closeness, and support to negative elements, such as conflict in TSR and how they shape educational experiences (Wubbels et al., 2016).

While attachment theory focuses on the development of students' adaptation in school contexts, motivation theory is concerned with explaining goal-directed behaviour (Furrer & Skinner, 2003). Motivation is conceptualised as emerging from individuals' interactions within varying environmental contexts rather than being solely an intrinsic property (Urduan & Schoenfelder, 2006). According to this perspective, motivation is inherently situational, susceptible to enhancement or inhibition by social context.

Motivational research in education, therefore, focuses on examining the extent to which teacher behaviours facilitate a supportive environment capable of fostering student motivation and subsequent learning outcomes (Klem & Connell, 2004; Urduan & Schoenfelder, 2006). Thus, the main contribution of the motivational theory is that TSR includes not only emotional support and attention but also emphasises the interpersonal dimensions of learning, such as the structure and instructional support provided by teachers to foster an environment conducive to learning (Davis, 2003; Shan et al., 2014).

This field has been nurtured by a rich conceptual framework embraced by empirical research, attempting to integrate the concepts developed by both theoretical and multi-methods perspectives. Recent empirical studies frequently assess these teacher-student dyadic relationships both qualitatively and quantitatively, considering elements like the feedback provided during learning and instruction processes (Black & Radovic, 2018), gender unbalances in the frequency in which a teacher interacts with a specific student (Ortega et al., 2021), and a growing literature of recent longitudinal studies (Hajovsky et al., 2023; Horn et al., 2021). While this body of scholarship has provided an influential foundation for the field, the emphasis is primarily on early childhood education and Western countries from the global North. One way to enrich the field is therefore to examine other educational stages of student development and in diverse cultural contexts.

## **Teacher-Student Relationships in Secondary Education**

Although the importance of good TSR in promoting educational outcomes is well documented, most existing research focuses predominantly on early childhood and primary education. This has left a gap in understanding the potential benefits of student-teacher interactions during adolescence, particularly within secondary education (Prewett et al., 2019). The limited attention to this stage can be attributed to differences in secondary education from other educational stages. Indeed, secondary students, unlike younger students, interact with multiple teachers in various subjects, resulting in less interaction time with each teacher.

Moreover, there is a prevailing notion that adolescent students, being more independent and peer-oriented, may benefit less from relationships with teachers than younger pupils (Ellis et al., 1981; Lamet et al., 2014). Added to the fact that, during adolescence, more aspects are going on at school and outside that compete for youths' attention, and it may be complex to attribute the role of good TSRs alone in explaining educational outcomes. This study aims to address this gap by investigating students' perceptions of the quality of TSR among secondary school adolescents, thus contributing to a more comprehensive understanding of relational dimensions in school contexts for this age group.

Secondary school teachers continue to exert a positive influence on a variety of student educational outcomes. Several studies highlight their role as role models, acting as a significant other in guiding students' future educational choices (Dulce-Salcedo et al., 2022; Sevilla et al., 2023) and in strengthening teacher-student counselling (Tatar & Bekerman, 2009). Consequently, secondary education presents an opportune period to analyse students' perceptions of their relationships with teachers.

This seemingly contradictory evidence, on the one hand, the alleged diminished relevance of teachers to adolescents and, on the other, their acknowledged importance as role models, warrant an understanding of the role that the quality of these relationships plays in educational outcomes. This study, therefore, aims to analyse the general nature of TSR in secondary education, rather than focusing on subject-specific teacher interactions, thus contributing to a general understanding of their relevance for adolescents' educational development.

### **Teacher-Student Relationships, Student Gender and Socioeconomic Status**

The quality of TSR varies considerably according to student attributes. These differences, in fact, are linked to student and teacher characteristics, such as gender and socioeconomic status, predisposing disadvantaged students to a higher risk of both social

and educational marginalisation (Bernstein-Yamashiro & Noam, 2013). Moreover, the influence these relationships exert on educational outcomes is not evenly distributed across different demographic groups of students.

This section synthesises and critically examines the main theoretical perspectives identified together with empirical studies that account for gender and socioeconomic disparities in the quality of TSR. It then discusses the main explanations for their subsequent consequences on mathematics achievement.

### **The Association Between Gender and Teacher-Student Relationships**

A substantial body of research has systematically explored the association between student gender and TSR. A meta-analysis reveals an empirical tradition of studies that suggests the long-standing prevalence of gender imbalances in teacher-student interactions (Jones & Dindia, 2004). Current studies found that girls tend to perceive these relationships more positively than boys (Retali et al., 2018). Furthermore, from the teachers' perspective, when evaluating their relationships with students, teachers tend to report closer relationships with girls and more conflict-laden interactions with boys (Horn et al., 2021; Koepke & Harkins, 2008). Recent longitudinal research shows that girls consistently receive higher closeness and lower conflict in their interactions with their teachers and a more stable trajectory in maintaining this high closeness over time compared to their male peers (Hajovsky et al., 2023).

Potential explanations of these gender differences are prevailing gender stereotypes, which often categorise girls as obedient, focused, and dependable and might influence teachers to feel a stronger bond with them (Horn et al., 2021). On the other hand, the stereotypical belief that boys are more likely to be disruptive and less attentive could lead to teachers feeling less connected with their male students (Heyder et al., 2021; Van Houtte, 2023).

Research also suggests that these gender differences in the quality of TSR may vary according to the mechanism of teacher-student gender matching. Female teachers tend to evaluate female pupils more positively, in terms of closeness and dependence, compared to male pupils (Ewin, 2009; Quaglia et al., 2013) and report better teacher-pupil relationships than male teachers, although both genders generally experience more conflict episodes with boys than with girls (Spilt, Koomen, et al., 2012). Spilt, Hughes, et al. (2012) further suggest that teacher-student gender matching may be significant only for female students, possibly because female teachers and girls are stereotypically socialised to cultivate caring relationships, compared with male teachers and students.

Other studies have had mixed findings on whether the quality of TSR varies according to teachers' career stage, experience and qualifications. Some authors argue that they do not differ at different career stages (Brekelmans et al., 2002), while others suggest better-qualified teachers may create more conducive learning environments (Fauth et al., 2019; O'Connor & McCartney, 2007), potentially leading to improved student-teacher relationships.

Variations in the impact of TSR have been observed across school subjects. For example, elementary school boys who report closer relationships with teachers may exhibit better reading outcomes, while girls' mathematics achievement may be positively associated with stable and close relationships with teachers in the US (Valiente et al., 2019). This might suggest that support in stereotypically male- and female-dominated school subjects, i.e. mathematics and language respectively, could play a protective role for both genders and increase students' confidence in these areas.

Similarly, when examining systematic classroom observation studies in stereotypically masculinised subjects such as mathematics, studies indicate that girls often experience less frequent teacher engagement, receive less individualised attention, are asked less pedagogically challenging questions and show lower levels of spontaneous participation in class discussions in primary and secondary mathematics classrooms in Chile, the United States and Canada (Becker, 1981; Duffy et al., 2001; Jones & Dindia, 2004; Ortega et al., 2021). However, contrasting findings have also emerged, indicating that both boys and girls, despite reported differences in teacher-student closeness and conflict, may not demonstrate significant variations in mathematics and language achievement in US elementary schools (Hajovsky et al., 2017).

Both bodies of literature reflect a remarkable divergence in their findings regarding gender disparities in this domain, which underlines the complexity of teacher-student interactions and their varied manifestations in different school subjects, and according to the methodological strategies applied. This raises important questions about the consistency and generalisability of these findings. While the positive association between TSR and academic outcomes in specific subjects underscores the potential benefits of fostering supportive interactions, this lack of consistent results invites examination of cross-country variations, with the aim of considering educational contexts at the country level.

### **The Association Between Socioeconomic Status and Teacher-Student Relationships**

Large-scale educational assessments define SES as a broad indicator that encompasses income, educational attainment and subjective perceptions of social and occupational status, primarily associated with the opportunities and privileges that

individuals possess in societies (Organisation for Economic Co-operation and Development [OECD], 2023). Avvisati (2020) identifies three methodologies that predominate for operationalising SES in the education field. The first, the materialist approach, links educational outcomes to economic indicators such as income and wealth, often setting specific thresholds such as the poverty line or entitlement to free school meals. The second, gradient approaches, focus on relative position by ranking individuals according to SES, potentially incorporating subjective measures such as self-perceived status. The third, social class models, which emphasise society's power and privilege structures by using ordinal measures to explore social stratification.

This study chooses to employ the PISA approach to conceptualising socioeconomic status (SES), which is inspired by the materialist and gradient approach. Despite criticisms, such as PISA's reliance on a composite measure based on indicators like educational attainment, income and subjective occupational status, which some authors argue might be more useful as stand-alone indicators rather than summarised in a one-dimensional construct (Avvisati, 2020; O'Connell, 2019), this composite measure developed by PISA is widely used for its practical utility in education policy.

The critique also extends to its limited reflection of the intricate power dynamics inherent in socioeconomic stratification, diverging from the nuanced class structures posited by theories of social stratification. However, the use of a composite measure such as PISA's socio-economic status avoids estimation problems that commonly arise from the correlated nature of its individual components (Avvisati, 2020). Furthermore, using the PISA approach, this study takes advantage of its international comparability and standardisation, favouring the interpretation of socioeconomic gaps in educational outcomes.

Various theoretical traditions have contributed to understanding socioeconomic patterns in the quality of the TSR. From a sociological perspective, the traditions of social capital, stratification theory and social network perspectives posit that the interpersonal networks established by students with their educators and peers constitute a reciprocal phenomenon of agency and social structure (Archer, 1999). Such networks are not merely individual or dyadic ties but are related to aspects of social trust, prestige, social and institutional support, access to resources, and information exchange. These aspects, theorised by the seminal works of Bourdieu and Passeron ([1970] 2000) and Coleman (1988), are integral to understanding how these relationships can significantly impact educational outcomes and the broader process of social integration, viewing them as embedded within a larger socio-economic context that shapes educational trajectories.

Early empirical work by Rist (1970) identified that teachers engaged more positively with students from higher SES backgrounds in primary education in the US. Recent studies on the influence of SES and cultural capital, often measured by household possessions or parental education level indicators, also show socioeconomic patterns in classroom interactions. Specifically, these studies, focused on aspects like teacher-student feedback, show that while the socioeconomic differences in TSR are evident, the magnitude of its impact can vary significantly across educational systems (Eryilmaz & Sandoval-Hernández, 2021; Sortkaer, 2019). In addition, from teacher perceptions, Hajovsky and colleagues (2023) point out that children from higher SES families tend to be rated more favourably by teachers, in terms of closeness with their teachers. Moreover, these children also receive lower ratings of conflict in their interactions with teachers and, importantly, exhibit a smaller growth in conflict ratings over time. This body of work highlights the persistent influence of socioeconomic factors on the quality of school interactions. Notably, while these factors may cause difficulties for pupils from more disadvantaged socioeconomic backgrounds, positive teacher-pupil relationships may act as a protective factor for their educational outcomes, buffering the adverse effects of socioeconomic disadvantage (Liu et al., 2023).

Some suggest that the observed disparities in teacher-student interactions by SES may lie in differential access to cultural capital among students. Students from socioeconomically advantaged backgrounds tend to be endowed with greater objectified and embodied cultural capital (Eryilmaz & Sandoval-Hernández, 2021; Sortkaer, 2019), such as a greater number of books and a history of academic success. This greater cultural capital is likely to reinforce their active participation in classroom activities and discussions, reflecting a dynamic that is already prevalent in their family interactions (Valdés, 2022), a privilege that is less available to their socioeconomically disadvantaged counterparts.

In addition, teachers may unconsciously identify pupils from more affluent families, for example, with social markers such as signs of economic resources at home, and perceive them as more able (Eryilmaz & Sandoval-Hernández, 2021; Raudenská, 2022). These perceptions may inadvertently influence teachers' attitudes, leading them to give more attention and support to these pupils (Wildhagen, 2009), as they are perceived as easier to teach compared with children from low socioeconomic backgrounds, who tend to form more dependent relationships with their teachers (Schneider et al., 2024). However, it is essential to note that some education systems often implement compensatory education programmes to address these inequalities. These programmes are designed to enable teachers to devote more time and support to socially disadvantaged pupils (Eryilmaz & Sandoval-Hernández, 2021).

Insights from studies employing theoretical perspectives on gendered school culture may offer a potential avenue for understanding these social mechanisms. This deeply rooted sociological tradition posits a cultural explanation for the formation of social relations within schools, emphasising the influence of gender norms and stereotypes. For example, a study in Belgian secondary schools suggests that peer influence, especially among adolescent boys to conform to traditional gender norms, leads to a higher prevalence of classroom disruptive behaviour in the classroom towards their teachers and peers. This is mainly due to the belief in reinforcing their construction of a stereotypical male identity (Van Houtte, 2023).

Building upon gendered school culture and drawing from notions of gender and socioeconomic intersectionality in quantitative research (Codioli McMaster & Cook, 2019; Scott & Siltanen, 2017; Strand, 2023), we hypothesise that the intersection of gender and SES may further exacerbate disparities in TSR quality. Specifically, boys from disadvantaged socioeconomic backgrounds may face additional barriers to forming positive relationships with their teachers, while girls from higher socioeconomic backgrounds may experience more favourable interactions.

### **Gender, Teacher-Student Relationships, and Academic Achievement**

The differential effects of TSR on academic achievement by student gender remain an important area of inquiry. Existing research suggests that conflictual relationships with teachers may hinder girls' progress in mathematics, compared to boys with similar relationships or girls with non-conflictual relationships in US elementary and primary schools (McCormick & O'Connor, 2015; Spilt, Hughes, et al., 2012).

McCormick and O'Connor (2015) found, in an American longitudinal study using random sampling and hierarchical linear models, that the mathematics achievement levels and trajectories of female middle-school students are more negatively affected, and grow less, than those of their male peers, despite both showing similar levels of conflict in their relationship with their teachers. This suggests that the differential nature of TSR, as modulated by students' gender and SES, can lead to disparate outcomes, potentially exacerbating existing inequalities through divergent affective development with their teachers. Consequently, these disparities may contribute to a widening gap across various interpersonal educational outcomes (Eryilmaz & Sandoval-Hernández, 2021; Raudenská, 2022; Sortkaer, 2019), highlighting the potential role of teacher-student interaction quality in educational settings.

### ***Peer Influence Explanations***

School gender culture theory also offers a potential explanation for this phenomenon. This body of research points out that both individual and social interaction mechanisms shape the gaps in academic and emotional educational outcomes. On the one hand, peer influence to conform to traditional gender norms, specifically among adolescent boys, tends to construct a gender identity around the discourse that real boys do not strive academically (Heyder & Kessels, 2017; Van Houtte, 2023), maintaining socially deviant behaviours towards their teachers to increase their popularity among male peers as a way to avoid questioning their masculinity (Heyder et al., 2021). Consequently, studies suggest that hard work in terms of academics and behaving appropriately is perceived as feminine (Heyder & Kessels, 2017), though not academic achievement per se.

This social pressure mechanism of conforming to gendered behaviours, in turn, works to the detriment of boys by hindering their mathematics achievement, especially among working-class adolescents who tend to follow their male peers to a greater extent (Heyder et al., 2021; Van Houtte, 2023, 2024). This is not without consequence for adolescent girls, as they are the ones who most frequently report experiences of school burnout as a consequence of working hard and meeting such gendered expectations in their school relational dynamics (Van Houtte, 2024).

### ***Early Socialisation Processes in Families***

Other explanations for gender differences in TSR and their subsequent impact on academic performance focus on early socialisation processes. The role of families in shaping early socialisation is important in understanding the transmission of gender stereotypes and roles within the school environment (Bigler et al., 2013; Chestnut et al., 2021; Gunderson et al., 2012).

Differential parental involvement and gender expectations may influence how students interact with their teachers, potentially leading to gender-specific relational patterns. Consequently, despite the established consensus on the positive effect of strong TSR on academic achievement (see meta-analysis by Roorda et al., 2011), their differential effects based on gender remain an area of ongoing research and debate.

### ***Teachers as Role Models***

Despite the peer relational dynamics and family influence, some empirical studies highlight the protective role that teachers as role models may play for socioeconomically disadvantaged students. These studies indicate that close student-teacher relationships significantly improve all students' reading and mathematics achievement, especially those from low socioeconomic backgrounds (Liu et al., 2023; Olsen & Huang, 2022), suggesting a protective role among disadvantaged students.

This is also true not only at the student level. Indeed, school SES has been reported to be positively related to mathematics achievement (Xuan et al., 2019), being partially mediated by students' perceptions of the mathematics teacher-student relationship. This highlights that the quality of the teacher-student relationship can significantly influence individual students' mathematics achievement, demonstrating that improving these relationships is especially important in low-SES schools.

### ***Why Focusing on Gender Differences in Mathematics Achievement?***

Over the last two decades, gender differences in mathematics achievement have shown mixed trends, narrowing, closing or even reversing in favour of female students in many Western and other developed countries (for a meta-analysis, see Else-Quest et al., 2010). Despite these advancements towards gender equity, persistent gender gaps in mathematics achievement remain in numerous countries (Inter American Development Bank et al., 2024; OECD, 2023).

The magnitude of the gender gap in mathematics achievement in Latin America and the Caribbean is heterogeneous, often favouring boys but with significant variation across countries (Gelber et al., 2016). Chile is a notable outlier, ranking among the highest OECD countries in terms of the gender gap, with boys consistently outperforming girls and the disparity increasing over time. PISA 2022 data confirms this trend, placing Chile third out of 81 countries, with a wider gap than in 2019 (OECD, 2023). This widening gap is largely attributed to the declining performance of girls compared to boys (Inter American Development Bank et al., 2024). Further evidence from Trends in International Mathematics and Science Study (TIMSS) 2019 indicates that Chile ranks high in the mathematics gender gap favoring boys in both 4th and 8th grades (Mullis et al., 2019).

The persistent and significant gender gap in Chile's performance in mathematics over the years highlights an area of concern, which is why we focus this study on mathematics. This study seeks to understand why this gap might persist for 15-year-olds, as evidence suggests that it increases as students progress in their education (Gelber et al., 2016; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021). Understanding their possible moderators, such as TSR, is relevant for developing educational interventions aimed at promoting gender equality in mathematics education, especially given the sustainable development goals that refer to the quality of education and gender equity (UNESCO, 2021, 2022).

## **High-Order Explanations of Country-Level Differences in Teacher-Student Relationships**

Hofstede's (1980) theory of cultural dimensions is widely applied in the fields of education and psychology as a framework for explaining cultural differences in socio-emotional outcomes. This theory suggests that cultural values, particularly the spectrum between individualistic and collectivistic orientations, shape interpersonal relationships (Hofstede, 1980; Pianta et al., 2003). In individualistic cultures, behaviour is primarily driven by personal goals and independence from social groups, whereas collectivistic cultures emphasise conformity to group norms and interpersonal interdependence as a form of social cohesion (Minkov & Kaasa, 2022; Triandis, 2018).

These cultural orientations could be significantly associated with interpersonal relationships within school contexts. Consequently, there is growing interest in examining cross-cultural variations in the moderating role of national cultural values on educational outcomes. While a growing body of empirical literature explores their relevance in explaining socioemotional educational outcomes (Bonneville-Roussy et al., 2019; Chen et al., 2019; Imada, 2012), the potential moderating role of cultural values on the quality of TSR in schools remains underexplored.

Building upon previous comparative studies, we hypothesise that the quality of TSR may be more important in collectivistic cultures and less pronounced effects in countries characterised by individualistic value orientations (Chen et al., 2019, 2024; Yang et al., 2013). We propose a comparative analysis, with a focus on Chile, of how TSR differentially affect mathematics achievement in a diverse set of countries, focusing specifically on the moderating effects of gender and SES. Western countries participating in PISA 2022 were selected that showed different scores on the profile of individualistic and collectivistic value orientations according to the latest data from The Culture Factor (2023), as defined by Hofstede's cultural dimensions theory. This approach allows us to maintain a degree of cultural and regional similarity for comparative purposes while ensuring heterogeneity in individualism/collectivistic scores. Furthermore, we included countries whose educational models are frequently cited as aspirational benchmarks for the Chilean education system, typically characterised by advanced economies and comparable economies and population sizes.

The selected countries for this study include Chile, Peru, Paraguay, Spain, Sweden, and Denmark. Peru and Paraguay were chosen because of their regional, cultural and linguistic proximity to Chile, which facilitates comparative analyses in a geographically and culturally relevant way. In addition, these two countries offer some degree of heterogeneity

in the individualism value orientations subscale scores at the country level, despite exhibiting significantly lower scores than Chile. Spain was included due to its cultural and linguistic proximity, historical ties, and similar score on the individualism values scale with Chile. Finally, Sweden and Denmark were selected because of their high individualistic value orientations, high-performing educational systems, and significant progress in gender and socioeconomic equity.

### **The Chilean Educational System Context**

The Chilean school system is characterised by a strong market orientation and a high degree of privatisation, factors that have contributed to significant levels of socioeconomic segregation between schools (Mizala & Torche, 2012, 2017; Valenzuela et al., 2014). This section provides an overview of the consequential socioeconomic segregation, gender-equality orientation, and ongoing challenges in Chile's education system in school climate policies.

### ***Socioeconomic Segregation and School Vouchers***

Chile presents an interesting case study of an education system founded on a universal school voucher system implemented in the early 1980s under a dictatorial regime. This system provided a fixed per-pupil subsidy to both public and private schools, enabling families to freely choose among them irrespective of their residential location (Bellei & Munoz, 2023; Mizala & Torche, 2017). However, schools retained the discretion to accept or reject students, even when vacancies were available. This has encouraged private voucher schools to select socioeconomically advantaged students, resulting in minimal improvements in educational outcomes (Elacqua et al., 2015; Zubizarreta et al., 2014). Conversely, proponents argue that the system has effectively addressed social demands for educational access within the context of a developing country (Bellei & Munoz, 2023). They also argue that a voucher-based school system would increase the freedom of families to choose schools for their children, especially those from disadvantaged families, and the quality of education by creating an educational market based on competition between schools (Hsieh & Urquiola, 2006; Mizala & Torche, 2012).

In parallel, from 1987 to the present, a national standardised census-level assessment (Sistema de Medición de la Calidad de la Educación, SIMCE) measures the academic performance in mathematics, language and science of second, fourth, sixth, eighth, tenth and eleventh graders, in addition to other indicators of the school context. Since the mid-1990s, school rankings have been produced and made public to facilitate school parental choice (Bellei & Munoz, 2023), and their scores have been used for high-

stakes decisions as part of the education accountability system, such as closing schools that show low academic performance<sup>2</sup>.

### ***From School Voucher-Fuelled Segregation to Attempts to Inclusion-Driven Equity***

Subsequent to the transition to democratic governments in 1990, a series of educational reforms have been enacted to mitigate these socioeconomic inequalities. These reforms encompassed the 2008 Preferential School Subsidy (SEP) reform, which adjusted the school voucher model from a flat-rate to a means-tested system, thus increasing financial support for economically disadvantaged students and schools with high concentrations of such students (Mizala & Torche, 2017). In 2015, the Inclusion Law was implemented, regulating student selection practices, expanding the preferential voucher to middle-class students, and prohibiting for-profit schools from receiving state funding (Bellei & Munoz, 2023). The most ambitious effort to date to counter the strong market orientation of the Chilean education system is the ongoing New Public Education reform (2017). This reform seeks to replace the existing municipal education administration with a national network of 70 local education services directly linked to the Ministry of Education. Taken together, these measures represent a significant policy effort with a redistributive approach to the Chilean school choice system, aimed at reducing socio-economic segregation and strengthening the state's role in guaranteeing quality access to school education.

Despite educational policy efforts to mitigate socioeconomic disparities, these inequalities have profoundly affected social cohesion in Chilean society. Chile indeed ranks as the third least socially diverse country among 62 nations in terms of social diversity within schools (Valenzuela & Allende, 2023). This segregation, as Molina (2021, 2023) discusses, has far-reaching implications beyond academic achievement, shaping classroom environments, student-teacher relations, students' connectedness to school, and the social and political integration of young people into their local communities.

### ***The Paradox of Progress: Gender Equality Among Youth Students and Chilean Society***

While gender norms refer to the socially accepted rules about roles and behaviours related to masculine and feminine, individuals' perceptions or endorsement of gender norms are what constitute gender attitudes within a specific culture (Kågesten et al., 2016; Varela et al., 2023). They are key to shaping a gendered school culture that promotes or excludes certain patterns of peer socialisation and can shape learning environments and

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<sup>2</sup> Nevertheless, this measure has been suspended since the COVID-19 pandemic, with an ongoing legislative debate in the Chilean Chamber of Senators and Deputies on whether to repeal or maintain this measure.

gender stereotypes in, for example, career path choices (Blazquez et al., 2024; Bordón et al., 2020; Van Houtte, 2024).

Adolescent students in countries with lower economic affluence and more collectivist cultures often exhibit more traditional attitudes toward family values and gender roles (Gibbons et al., 1991), and they tend to show less support for gender equality, particularly adolescents from Latin American countries (Sandoval-Hernández & Carrasco, 2020). However, Chile distinguishes itself by having a notably higher proportion of adolescent students advocating for equal rights between men and women compared to other South American countries (López-Hornickel & Sandoval-Hernández, 2023).

Despite this overall trend among Chilean youth, significant gender disparities persist in various facets of Chilean society. These inequalities manifest in areas such as choice of college major, labour markets, political participation, and business organisations. For example, there is a broad consensus that women tend to apply less to STEM disciplines at the undergraduate level (Blazquez et al., 2024; Bordón et al., 2020; Herskovic & Silva, 2022). This may be having consequences for labour markets by producing gender segregation in occupations, with women disproportionately represented in care-oriented roles (Semenza et al., 2021). Thus, it is possible that this gender segregation partially explains the gender wage gap (Sánchez et al., 2022), which has been complex to address in the absence of inclusive labour market policies in Chile (Ugarte et al., 2015), such as co-parenting and care work in families in general. Furthermore, women's representation as elected parliamentarians remains significantly unbalanced (Gamboa & López, 2019), in addition to differences in participation in high-managerial positions (Améstica-Rivas et al., 2020; Kuschel & Salvaj, 2018), highlighting the current challenges in achieving gender equality.

### ***Chile's Policy Framework Towards a Positive School Coexistence***

Chilean education policy has made significant progress in improving school coexistence by continuously updating its regulatory framework in recent years, recognising the fundamental role of fostering positive relationships between teachers and students. The National Policy on School Coexistence (2015-2018) represents a shift from normative regulation to a participatory, inclusive and democratic approach (Chilean Ministry of Education, 2002, 2015). The policy emphasises a rights-based framework and gender equity, with the aim of creating an educational environment that is responsive to the diverse needs of students. In addition, the Framework for Good Teaching focuses pedagogical practices on students' personal and social development, promoting a positive classroom climate and integrating social-emotional skills.

With regard to the school curriculum, a cross-cutting learning objective focuses on personal, social, coexistence and citizenship development, supported by relevant resources for teachers. Moreover, the Framework for Good School Leadership and Management sets standards that emphasise school climate, coexistence and community well-being for school principals. Together, these policies promote a supportive school environment that promotes socio-emotional development and fosters positive relationships between teachers and students, ultimately creating a climate conducive to learning.

We hypothesise that this updated policy framework has the potential to reduce the gender gap in the quality of TSR over time (2009-2022). By addressing and mitigating differential treatment of students based on gender, these sets of policies could lead to more equitable mathematics achievement outcomes. Specifically, school principals and teachers would be better equipped to provide gender-sensitive support and encouragement to all students, fostering a more inclusive and supportive learning environment. This, in turn, could lead to improved academic performance and reduced gender disparities in mathematics achievement.

### **Research Questions**

The following research questions guide our study:

- To what extent does student SES moderate the association between student gender and the quality of student-teacher relationships in PISA 2022 in Chile, Peru, Paraguay, Spain, Sweden and Denmark?
- To what extent is the quality of TSR differentially affected by students' gender and SES in PISA 2009, 2012, and 2022 in Chile?

We then focus on the moderating role of gender and SES, and their differential effects by TSR, on mathematics achievement, considering cross-national differences and variations over time for the case of Chile.

- How do students' gender and SES shape the association between TSR and mathematics achievement in PISA 2022 in Chile, Peru, Paraguay, Spain, Sweden, and Denmark?
- What is the role of students' gender and SES in the association between TSR and mathematics achievement across PISA 2009, 2012, and 2022 in Chile?

### **Methods**

A repeated cross-sectional, observational, quantitative, and correlational study design is proposed to examine the differential effects of student gender and SES on the association between TSR and mathematics achievement in Chile.

## Data

We use data from the OECD's Programme for International Student Assessment (PISA), a large-scale educational assessment study of 15-year-old secondary school students in OECD and non-OECD participating countries. This large-scale assessment aims to measure performance in mathematics, science and reading, as well as other educational outcomes, and provides countries with comparable data over time to evaluate their education systems.

First, we use cross-sectional data from PISA 2022 to comparatively analyse Chile, Peru, Paraguay, Spain, Sweden and Denmark with respect to differential effects by gender and SES in TSR on mathematics achievement. Then, to focus longitudinally on the Chilean case, we merge cross-sectional data from PISA 2009, 2012 and 2022 at the student level to analyse gender and socioeconomic gaps in TSR and mathematics performance over time. We excluded PISA 2006, 2015, and 2018 from our analysis as these assessments did not include the teacher-student relationship scale in the student questionnaire. In addition, PISA 2000 and 2003 are not considered as Chile's participation in PISA began in 2006.

The analytical sample of Chile comprises 19,013 unique students across three time points: 5,669 students in 200 schools in 2009, 6,856 students in 221 schools in 2012, and 6,488 students in 220 schools in 2022. Complete case analysis was applied considering our variables of interest, resulting in the exclusion of 104, 2,371, and 842 students, and the exclusion of 1 school each in PISA 2009, PISA 2012, and PISA 2022, respectively.<sup>3</sup> Descriptive statistics of the relevant variables in this study, as Table 1 shows, suggest that, in overall, the analytical sample has a consistent average age of students, a slight improvement in students' socio-economic status, and slight variations in mathematics achievement scores over time.

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<sup>3</sup> In PISA 2009, of the initial 5,669 students, 89 were excluded for missing student SES data and a further 15 for missing data on the teacher-student relationship scale, leaving a final sample of 5,565. In PISA 2012, the initial sample of 6,856 was reduced by 102 for missing SES data and 2,269 for missing teacher-student relationship data, resulting in a final sample of 4,485. For PISA 2022, the initial sample of 6,488 students was reduced to 5,646 after excluding 307 for missing SES data and 535 for missing teacher-student relationship scale data.

**Table 1**

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Regarding the analytical samples of Paraguay, Peru, Spain, Denmark, and Sweden in PISA 2022, they initially comprised 5,084, 6,968, 30,800, 6,200, and 6,072 students, respectively, with corresponding 281, 336, 966, 347, and 262 schools. After applying list-wise deletion for the variables of interest, the analytical samples were reduced to 4,555,

6,778, 29,436, 5,647, and 5,794 students, with 274, 336, 965, 342, and 261 schools for Paraguay, Peru, Spain, Denmark, and Sweden, respectively.<sup>4</sup>

## Measures

### *Dependent Variable*

**Mathematics Achievement.** The dependent variable of our study is the mathematics test scores. Mathematics test scores are based on the PISA mathematics assessment framework, which operationalises mathematical literacy as the ability of students to think mathematically and to create, apply, and interpret mathematical concepts to solve problems in several real-world situations (OECD, 2023). PISA scores are scaled to fit approximately normal distributions, with a mean of 500 points and a standard deviation of 100 points.

### *Independent Variables*

**Gender.** A dichotomous variable indicating the student's gender as either (1) male or (2) female. PISA data categorise this attribute under a binary conception of gender. However, it is adhered to by using the term gender instead of sex to emphasise that the differences observed between male and female students are not biologically based but socioculturally based.

**Student SES.** A continuous variable based on the composite measure of the PISA Economic, Social, and Cultural Status (ESCS) index, which accounts for the financial, social, cultural, and human capital resources of students' families (Avvisati, 2020). The composite index consists of indicators of home possessions, highest parental education level and occupational status. ESCS scores are calculated as the average of the three indicators, with each indicator score and the composite ESCS score normalised ( $M = 0$ ,  $SD = 1$ ) across OECD countries (OECD, 2023). We also derived SES quintiles from ESCS scores for our descriptive analysis.

**TSR Scale.** A continuous variable based on student ratings consisting of a 4-point Likert-type battery of items ranging from (1) strongly disagree to (4) strongly agree.

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<sup>4</sup> In Paraguay, the initial sample of 5,084 students was reduced by 62 for missing SES data and 467 for missing teacher-student relationship scale data, resulting in a final sample of 4,555. In Peru, the initial sample of 6,968 students was reduced by 45 for missing SES data and 145 for missing teacher-student relationship scale data, leaving a final sample of 6,778. In Spain, the initial sample of 30,800 students was reduced by 1,152 for missing SES data and 212 for missing teacher-student relationship scale data, resulting in a final sample of 29,436. In Denmark, the initial sample of 6,200 students was reduced by 292 for missing SES data and 261 for missing teacher-student relationship scale data, leaving a final sample of 5,647. In Sweden, the initial sample of 6,072 students was reduced by 188 for missing SES data and 90 for missing teacher-student relationship scale data, resulting in a final sample of 5,794.

As shown in Table 2, in PISA 2012 and PISA 2019, students rated five items, while in PISA 2022 it consisted of eight items. Students answer this set of items and measure their attitudes towards their secondary school teachers in general and do not focus on a specific subject teacher. PISA 2009 and PISA 2012 use similar item wording, while PISA 2022 uses different item wording. Although the specific items changed in PISA 2022, this set of items was chosen because conceptually the theoretical construct being assessed is the same. However, the limitation that it is not possible to interpret absolute change between measurement occasions from the scores on this scale is acknowledged. Nevertheless, this methodological choice allows us to determine how the association between the quality of TSR and the proposed covariates changes only for each measurement occasion.

**Table 2**

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This scale is developed by PISA whose scores were constructed with the generalised partial credit model (Muraki, 1992) by weighted probability estimation (WLE). In PISA 2022, the assessment of the teacher-student relationship scale employed a within-construct matrix sampling design (OECD, 2023). Combining the strengths of multi-form and single-form questionnaire designs, this approach involved administering a randomised subset of five items per construct to each student. This methodological strategy ensures equitable item distribution across countries and the entire sample, enabling a broader assessment of each construct while maintaining a consistent student cognitive load with previous cycles (OECD, 2023). Furthermore, by presenting only five items out of eight per questionnaire, this design reduces the cognitive load on students (OECD, 2023). We treated this variable as continuous and used its WLE scores in our analyses.

To ensure the construct validity of the scale of the teacher-student relationship included in PISA 2022 across countries, this scale, as reported in OECD (2023), demonstrated acceptable psychometric properties across its items (see Table A1 in Appendix). The items showed varied levels of discrimination ( $\alpha$  ranging from 0.22 to 1.66) and difficulty ( $\beta$  ranging from -1.78 to 0.54), indicating diverse item characteristics in measuring the construct. Items assessing positive teacher behaviours generally had higher discrimination parameters, while negatively worded items exhibited lower discrimination. Step parameters indicated thresholds for response categories, with variability across items, reflecting the scale's capacity to capture different aspects of teacher-student interactions. Concerning scale reliability, as reported by OECD (2023), a minimum Cronbach's alpha of 0.60 was required to incorporate country-level and within-country language group scale scores into the PISA data. Given the psychometric official report and multi-form questionnaire design conducted by the OECD for PISA 2022, we did not perform our own factor analysis or reliability analysis on this dataset.

However, for PISA 2009 and 2012, which utilised a single-form student questionnaire, we conducted exploratory and confirmatory factor analyses to assess the validity and reliability of the theoretical construct underlying the teacher-student relationship scale. Our exploratory factor analyses, supplemented by parallel analysis shown in Figure A1, suggested a unidimensional factor model for both years. Confirmatory factor analyses further supported this unidimensional model in both PISA 2009 and 2012, demonstrating good fit indexes (RMSEA = [.059, .064]; CFI = .987; TLI = [.973, .974]), factor loadings ranging from .654 to .848, and an appropriate McDonald's  $\omega$  internal consistency reliability ranging from .853 to .879, as Table 3 shows. We opted to treat this variable as continuous and use its factor scores in our analyses.

**Table 3**

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using the lavaan 0.6-18 R package. All factor loadings are standardised and statistically significant at  $p < .001$

### **Analytical Approach**

Along with descriptive analysis of our variables of interest, a series of ordinary least squares (OLS) linear regression models were estimated, given the normal distribution of the teacher-student relationship scale. Models of increasing complexity were fitted, starting with an empty model to estimate students' scores on the quality of their relationship with teachers. Then, as shown in (1), the predicted scores in the quality of TSR score  $y_i$  by student  $i$  were specified as a linear model predicted by *Female* in Model 1.

$$y_i = \alpha + \beta_1 Female_1 + \varepsilon_i \quad (1)$$

Then, as shown in (2), Model 2 adds the effect of *Student SES*.

$$y_i = \alpha + \beta_1 Female_1 + \beta_2 StudentSES_2 + \varepsilon_i \quad (2)$$

Then, as depicted in (3), in Model 3 the moderating effect of *Female* on the association between *Student SES* and *TSR* scale was assessed. This is, whether gender acts as a differential effect on *TSR* scale depending on levels of *SES*.

$$y_i = \alpha + \beta_1 Female_1 + \beta_2 StudentSES_2 + \beta_{12} Female_1 * \beta_2 StudentSES_2 + \varepsilon_i \quad (3)$$

Similarly, we then fit a series of models to determine whether *Mathematics Achievement* scores  $y_i$  are associated with the *TSR* scale. Moreover, we estimate interaction effects to study if, in particular, male or female students, as well as socioeconomically

advantaged or disadvantaged students, are differentially benefited from good TSR to improve their mathematics test scores. To present it more succinctly, in (4) we show only the full model, which includes the main effects of *Female*, *Student SES*, and *TSR* scale, predicting *Mathematics Achievement*, plus interaction effects between *Female* with *Student SES*, *Female* and *TSR*, and *Student SES* with *TSR*.

$$\begin{aligned}
 y_i = & \alpha + \beta_1 \text{Female}_1 + \beta_2 \text{Student SES}_2 + \beta_3 \text{Teacher Student Relationships}_3 \\
 & + \beta_{12} \text{Female}_1 * \text{Student SES}_2 + \beta_{13} \text{Female}_1 * \\
 & * \text{Teacher Student Relationships}_3 + \beta_{23} \text{Student SES}_2 \\
 & * \text{Teacher Student Relationships}_3 + \varepsilon_i
 \end{aligned}
 \tag{4}$$

We modelled this set of regression models separately for the three measurement occasions in the case of Chile, while for Peru, Paraguay, Denmark and Sweden, it was modelled only for the PISA 2022 data. The models were fitted in R 4.4.0 using the *Rrepest* package to apply student weights to obtain unbiased parameter estimates, considering the complex sampling design of PISA data, and replicate weights to obtain unbiased standard errors. Data processing and visualisation were performed using the *tidyverse* package.

## Results

### Gender and Socioeconomic Disparities in Teacher-Student Relationships

This results section focuses on the comparative analysis of Chile, Paraguay, Peru, Spain, Denmark and Sweden in PISA 2022. First, we describe the association of students' gender and SES with the TSR scale. Second, we present the results of the association between the TSR scale, and its differential effects by gender and SES, with mathematics achievement across countries in PISA 2022.

As shown in Table 4, our results from Model 1 show that the association between student gender and TSR varied across countries. In Chile, being female was significantly associated with lower relationship quality ( $B = -0.07, p < .05$ ), while in Paraguay and Spain, the opposite was true, with female students reporting significantly higher quality relationships ( $B = 0.09, p < .01$  and  $B = 0.06, p < .01$ , respectively). However, in Peru, Denmark, and Sweden, no significant gender differences were observed.

When accounting for student SES in Model 2, we found that the association between student gender and TSR remained robust, with the same directionality and statistical significance across countries. In Peru, Spain, Denmark, and Sweden, a significant positive association was found between SES and reported teacher-student relationship quality. Conversely, in Paraguay, a striking negative association between SES and the quality of TSR

was found, suggesting that low SES students tend to report better TSR than socioeconomically advantaged students.

Results from Model 3 in Chile, Paraguay, Peru, Spain and Sweden show that the interaction between student gender and SES is not significantly associated with the quality of TSR, except in Denmark. In the case of Denmark, there was a significant positive interaction, indicating that the positive association of SES with TSR was slightly stronger for female students than for their male peers.

Despite the fact that the inclusion of SES in the models slightly improved the proportion of explained variance ( $R^2$ ) compared to the models without SES, the explanatory power is generally very low in all countries, ranging from 0.1% to 1.2% of the variance of the teacher-student relations scale. This suggests that, although SES plays a moderating role, particularly in Denmark, it explains only a very small part of the variance in TSR. Therefore, other factors not included in these models contribute to explaining TSR.

**Table 4**

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### **Gender and Socioeconomic Gaps in Teacher-Student Relations in Chile over Time**

Having considered the international picture earlier, this section focuses on Chile. We present our longitudinal descriptive results on the estimated gender and socioeconomic gaps in the TSR scale and mathematics achievement between PISA 2009 and PISA 2022.

As Table 5 shows, in 2009, boys reported a slightly negative perception of the TSR (TSR) of -0.03 standard deviation units, while girls reported a slightly positive TSR of 0.02 points, implying a gender gap of -0.05 points. This means boys tend to have a somewhat worse perception of their relationship with teachers than girls. Interestingly, the trend is reversed in 2012 and 2022. That is, in 2012, the average for boys was 0.04 standard deviation units, while the average for girls was -0.04. Then, in 2022, the average TSR of boys slightly decreases to 0.02 standard deviation units and that of girls to -0.05. Thus, the gender gap remained positive at 0.08 and 0.07 in 2012 and 2022 respectively, suggesting that boys tend to have more positive perceptions of their relationship with their teachers than girls, although the overall gender gap tends to be small over time (i.e. no more than 0.10 standard deviation units).

In mathematics, boys have consistently outperformed girls in all three PISA cycles. As Table 4 shows, in 2009, boys scored on average 432 points compared to 411 points for girls, resulting in a gender gap of 21 points. In 2012, the average score of boys increased slightly to 436 points, while the average score of girls remained relatively stable at 410 points, widening the gender gap by 26 points to the detriment of girls. Finally, in 2022, both boys' and girls' mathematics scores decreased. The average for boys was 427, and for girls, 409, reducing the gender gap to 18 points. Despite the decrease in scores, the gender gap persists, and its slight narrowing in 2022 is mainly explained by a decline of 11 points for boys rather than an improvement in girls' performance in mathematics on this occasion. This means there is still room for progress, both for boys and especially for girls, whose performance in mathematics has stagnated.

**Table 5**

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In 2009, as shown in Table 6, students in the lowest socioeconomic quintile (Q1) reported a slightly positive TSR value of 0.02 standard deviation units, while those in the highest quintile (Q4) reported a slightly negative TSR value of -0.03 standard deviation units. This results in a socioeconomic gap of 0.05 points, indicating that students of lower SES had a slightly better perception of their relationship with teachers than their peers of higher SES. In 2012, both Q1 and Q4 students reported an improvement in TSR scores, with Q1 students reporting an average improvement of 0.03 standard deviation units and Q4 students reporting an average improvement of 0.01 standard deviation units. The socioeconomic gap narrowed to 0.02 points, suggesting a slight convergence in TSR perceptions between the two groups. By 2022, the average TSR of Q1 students remained stable at 0.03 standard deviation units, while the average TSR of Q4 students increased significantly to 0.15 standard deviation units. This change resulted in a negative socioeconomic gap of -0.12 points, indicating that students of higher SES now perceive better TSR than their peers of lower SES.

In mathematics, students in the highest socioeconomic quintile have consistently outperformed those in the lowest quintile over the three PISA cycles in mathematics achievement. In 2009, Q1 students scored on average 379 points compared to 487 points for Q4 students, resulting in a socioeconomic gap of -108 points, to the detriment of disadvantaged students. In 2012, the average mathematics score for Q1 students decreased slightly to 378 points, while the average score for Q4 students increased to 508 points, increasing the socioeconomic gap to -130 points. This indicates a widening gap in mathematics achievement in favour of students of higher SES. By 2022, both Q1 and Q4 students, showed changes in their mathematics scores. The average score of Q1 students increased to 389 points, while the average score of Q4 students decreased to 480 points.

As a result, the socioeconomic gap narrowed to -91 points. Interestingly, this reduction in the socioeconomic gap is mainly due to the improvement in the scores of Q1 students and the decrease in the scores of Q4 students.

**Table 6**

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### **The Association Between Student Attributes and Teacher-Student Relationships in Chile over Time**

This section presents the results from our regression models predicting the quality of TSR over time. As Table A2 shows, the estimated coefficients for our main predictors and the interaction between gender and student SES are presented.

As shown in Figure 1, in PISA 2009, the results indicate no statistically significant effects on the quality of TSR. The coefficient for being female is positive but not statistically significant ( $B = 0.04$ ,  $\beta = .02$ ), suggesting that gender is not associated with the quality of TSR for that occasion of measurement. Similarly, the effect of student SES is not statistically significant ( $B = -0.01$ ,  $\beta = -.01$ ), and the interaction between female gender and student SES is also not significant ( $B = -0.02$ ,  $\beta = -.02$ ). The model explains a very small proportion of variance in the quality of TSR, with an  $R^2$  of 0.001.

However, PISA 2012 data shows a notable shift, as our previous descriptive analysis suggested. The effect of being female becomes negative and statistically significant ( $B = -0.09$ ,  $\beta = -0.05$ ,  $p < .05$ ), indicating that female students experienced a slight but significant decrease in the quality of TSR compared to their male peers. The student SES effect continues to be non-significant ( $B = -0.01$ ,  $\beta = -.01$ ), as does the interaction between gender and SES ( $B = -0.02$ ,  $\beta = -0.02$ ). Despite the significant finding for gender, the overall model again explains only a very small proportion of the variance in teacher-student relationship quality, with an  $R^2$  of 0.002.

For PISA 2022, we found that being female has a significant negative association with the teacher-student relationship scale, similar to the findings from PISA 2012 ( $B = -0.07$ ,  $\beta = -.03$ ,  $p < .05$ ). This reinforces the previously observed slight but negative association. Once again, student SES did not show a significant effect ( $B = 0.01$ ,  $\beta = .01$ ), and the interaction term between gender and student SES also remains non-significant ( $B = 0.01$ ,  $\beta = .01$ ). The model still explains only a small proportion of the variance, with an  $R^2$  of 0.001.

**Figure 1**

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Note. B coefficients and 95% confidence intervals are shown. Results are also available in Table A2, Appendix.

### **The Differential Effects of Teacher-Student Relationships in Math Achievement Across Countries**

This section presents our results on the moderating role of TSR in the association between gender and SES with mathematics achievement in PISA 2022 for Chile, Peru, Paraguay, Spain, Denmark and Sweden.

Our results consistently highlight a negative statistically significant gender gap in mathematics achievement across Chile, Peru, Paraguay, Spain, Denmark, and Sweden, with female students underperforming male students (between  $p < .01$  and  $p < .001$ )

across all models, except for Paraguay in Model 3 (see Table 7). The magnitude of this effect, however, is low and slightly varied across countries in Model 1, ranging from  $\beta = -.04$  in Sweden to  $\beta = -.11$  in Chile.

In Model 2, incorporating TSR as a predictor did not substantially alter the effects of gender and SES on mathematics achievement across the six countries examined. Gender and SES effects remained consistent with Model 1, indicating a persistent gender gap to the detriment of girls and a positive association between SES and mathematics performance. A positive TSR was significantly associated with higher mathematics achievement in all countries ( $p < .001$ ), with the strongest effect observed in Denmark ( $\beta = .19$ ), whilst Peru showed the weakest TSR effect among the countries analysed, increasing mathematics achievement by 0.05 standard deviation units ( $p < .01$ ). The inclusion of TSR slightly increased the explained variance ( $R^2$ ) in all countries, from 0.4% in Peru to 3.2% in Denmark. In particular, Peru and Sweden had the highest total explained variance (18.3% and 17.3%, respectively), suggesting that TSR plays a more important role in these countries than in others.

**Table 7**

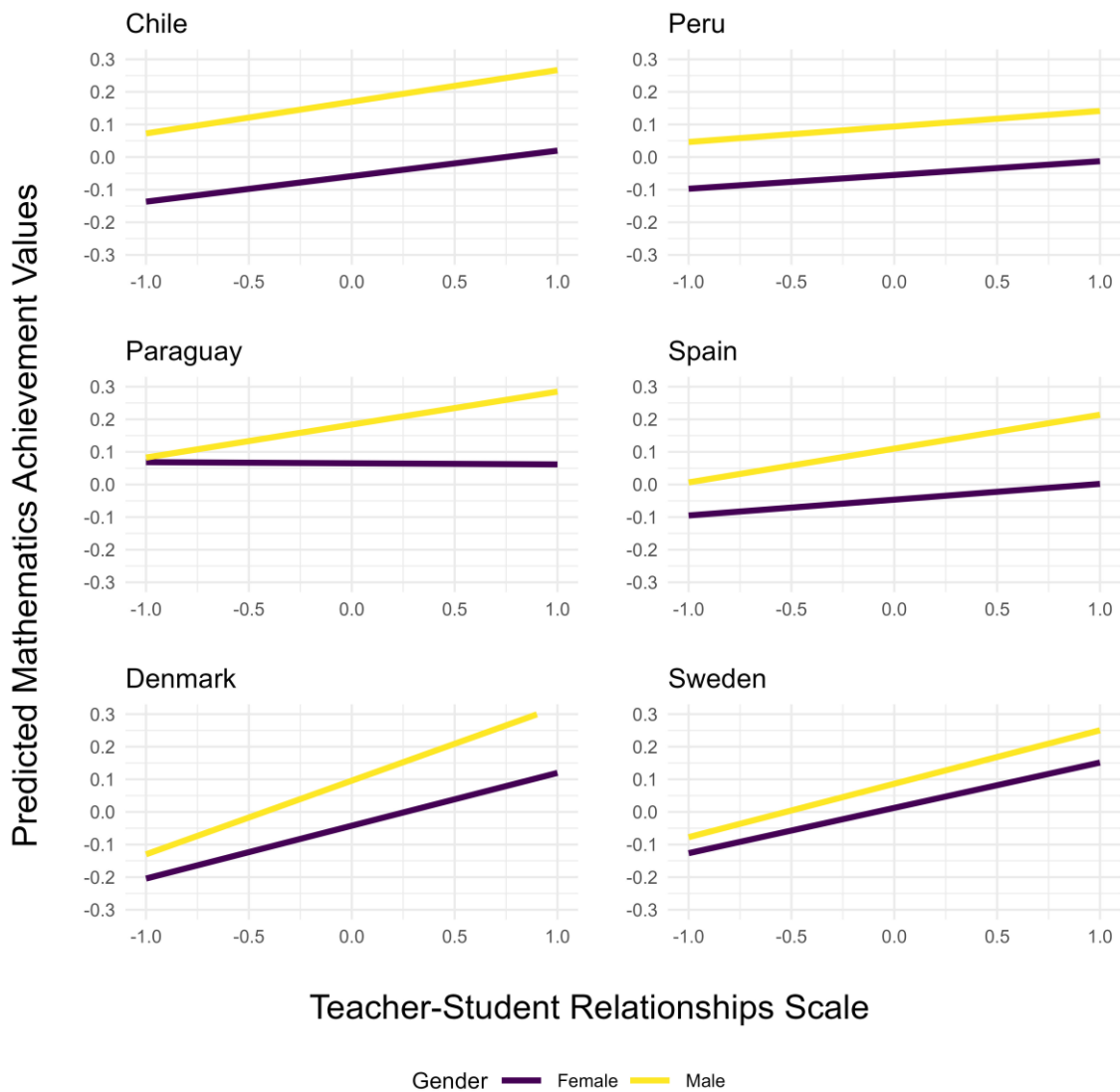
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Crucial for our aims, results from Model 3 (Table 7), which incorporates interaction terms, reveal nuances in the interaction of gender, SES and TSR on mathematics performance across the six countries. While the main effects of gender, SES, and TSR remained consistent with previous models, the interaction terms highlighted significant differences in how these factors operate in specific contexts. Specifically, a negative interaction between gender and TSR emerged as a significant pattern in Paraguay, Spain, Denmark, and Sweden, indicating that the positive effect of TSR on mathematics achievement is less pronounced for female students compared to male students, as shown in Figure 2. This suggests that gender may moderate the influence of TSR on academic outcomes, potentially reflecting differential teacher-student interactions or gendered learning environments.

**Figure 2**

*Predicted Mathematics Achievement Values by TSR, Gender, and Country*

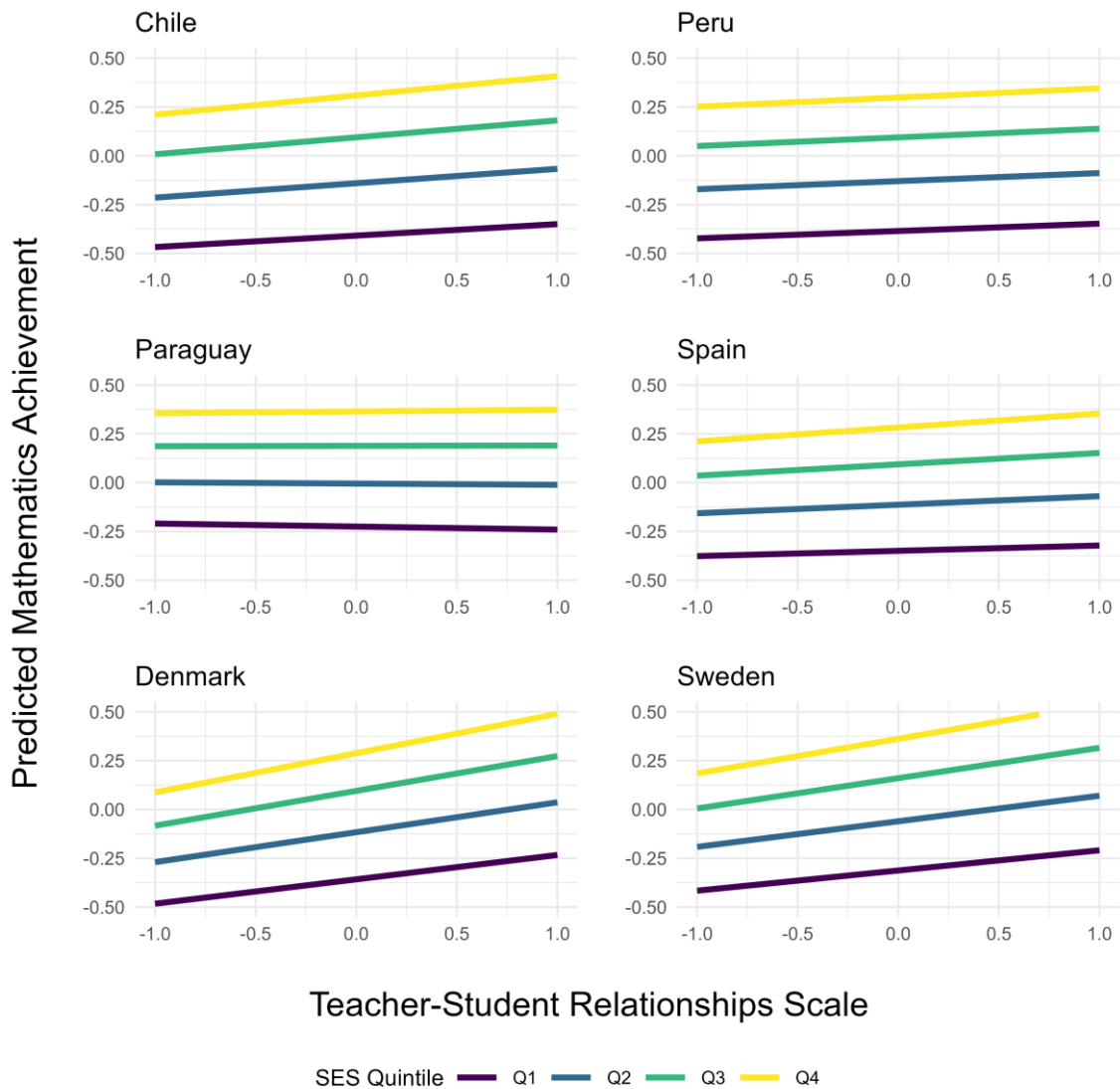


Note, Scores for both predicted mathematics achievement and TSR are shown in Z-scores. Predicted values are based on Model 3, Table 7.

Moreover, a positive interaction between SES and TSR was significant in Spain and Sweden, suggesting that the beneficial effect of TSR is amplified for students from higher socioeconomic backgrounds, as Figure 3 suggests. The variance explained by mathematics achievement increased marginally in Model 3 compared to Model 2. Thus, in Model 3, the proportion of mathematics achievement variance explained by its predictors remained relatively modest, ranging from 14.3% in Chile and Paraguay to 18.4% in Peru.

**Figure 3**

*Predicted Mathematics Achievement Values by TSR, SES Quintiles, and Country*



*Note.* Scores for both predicted mathematics achievement and TSR are shown in Z-scores. Predicted values are based on Model 3, Table 7. Student SES was categorised as quintiles.

### **Exploring the Implications of Teacher-Student Relationships in Math Achievement in Chile over Time**

The following section outlines our models for estimating mathematics achievement based on different predictors. As depicted in Table A3, we observed a consistent trend across the three measurement occasions.

As depicted in Figure 4, in PISA 2009, being female is found to be negatively and significantly associated with mathematics achievement ( $B = -20.91, p < .001$ ), indicating

that female students scored lower than male students, even though it is a small effect size ( $\beta = -.13$ ). Student SES is positively and significantly linked to mathematics achievement ( $p < .001$ ), which means that for each unit of increase in student SES, mathematics scores increase by 31.11 points in PISA mathematics, which is considered a moderate effect size ( $\beta = .45$ ).

The TSR scale shows a small, positive, and significant effect ( $B = 4.82, \beta = .06, p < .05$ ), highlighting that better TSR are linked to higher mathematics achievement. However, interaction terms between female and student SES ( $B = 1.27, \beta = .01$ ), female and TSR scale ( $B = 2.02, \beta = .02$ ), and student SES and TSR scale ( $B = -0.39, \beta = -.01$ ) are not statistically significant, suggesting that these attributes do not have differential effects on mathematics achievement. The model accounts for 22.8% of the variance in mathematics achievement, which is considered a moderate effect size.

PISA 2012 data also highlights a negative effect of being female on mathematics achievement, which is slightly more pronounced than PISA 2009 ( $B = -24.08, \beta = -.14, p < .001$ ). Student SES continues to have a medium and positive effect ( $B = 33.07, \beta = .48, p < .001$ ), reinforcing the predominant role of socioeconomic disparities in students' mathematics achievement. The TSR scale, however, does not show a significant effect ( $B = -1.07, \beta = -.01$ ). Interaction terms also remain non-significant: female and student SES ( $B = -0.30, \beta = -.01$ ), female and TSR scale ( $B = 2.05, \beta = .02$ ), and student SES and TSR scale ( $B = 1.56, \beta = .03$ ). The model accounts for 24.8% of the variance in mathematics achievement, which is quite similar to the estimated model for PISA 2009 data.

Results from PISA 2022 models reveal that being a female student continues to have a negative effect on mathematics achievement, although this impact has been slightly reduced than the previous PISA cycles modelled ( $B = -16.17, \beta = -.10, p < .001$ ). Moreover, students' SES maintains a significant, moderate ( $\beta = .35$ ), and positive relationship with mathematics achievement ( $B = 27.40, p < .001$ ), although with a smaller effect size than in previous years. Notably, TSR scale shows a significant positive effect ( $B = 7.22, \beta = .10, p < .001$ ), indicating that, as in PISA 2009, the better the teacher-student relationship, the higher the mathematics performance, and this effect is also slightly stronger than in previous PISA cycles. However, there were no significant moderating effects found between female students and student SES ( $B = 0.34, \beta = .01$ ), female students and the TSR scale ( $B = -0.55, \beta = -.01$ ), and student SES and the TSR scale ( $B = 1.65, \beta = .02$ ), all of which remain non-significant. It is also noteworthy that this model explains a lower proportion of variance compared to previous models in 2009 and 2012, accounting for 14.3% of the variance in mathematics achievement.

**Figure 4**

The figure originally presented here cannot be made freely available via ORA because of copyright.  
The figure was sourced at <https://worldpopulationreview.com/country-rankings/pisa-scores-by-country>

*Note.* B coefficients and 95% confidence intervals are shown. Estimates are shown in PISA scores scaled to fit approximately normal distributions ( $M = 500$  and  $SD = 100$ ). Results are also available in Table A3, Appendix.

## Discussion and Conclusion

This study analysed gender and socioeconomic inequalities in the quality of TSR, examining their further differential associations with mathematics achievement across six countries using PISA 2009, 2012, and 2022 data. With a specific focus on Chile and drawing on motivational and attachment theory perspectives, this research explores how these educational outcomes are linked to gender differences and socioeconomic segregation within the education system. Thus, we aimed to contribute to the state-of-the-art research that scarcely identifies patterns for studying cross-cultural differences in TSR and their relevance for mathematics achievement, for which we propose the theory of cultural dimensions to study this diversity.

Regarding our first research question, which refers to the moderating role of socioeconomic status in the association between student gender and student-teacher relationships in PISA 2022, our results indicate that SES does not moderate this association in Chile, which was also consistent with our results from Peru, Paraguay, Spain, Sweden and Denmark.

Notwithstanding, our findings suggest a significant gender gap in the quality of TSR to the detriment of girls in Chile, which is in line with previous studies (Jones & Dindia, 2004; McCormick & O'Connor, 2015; Ortega et al., 2021). In addition, SES was positively related to the quality of TSR in Peru, Spain, Denmark and Sweden, which means that socioeconomically advantaged students tend to report better relationships with their teachers. This result expands on the findings of Hajovsky et al. (2017, 2023), who also found this pattern of association, but using teachers' reports in pre-primary and primary classrooms. Surprisingly, the opposite is true for Paraguay, which differs from the findings of these previous studies, in that students from lower socioeconomic backgrounds report better quality TSR. In Chile, no statistically significant association was found between SES and the quality of TSR.

As concerns our second research question that refers to the trend over time of the quality of TSR, according to gender and SES, in Chile, our results indicate that the gender gap tended to widen in favour of males in PISA 2012 and PISA 2022. We find no significant socioeconomic advantage or intersectionality between gender and SES in teacher-student relations over time for Chile. The persistence of gender disparities in teacher-student relations suggests that education policies focusing on school coexistence may not have been sufficiently implemented or may have been implemented unevenly across schools. It is also possible that their guiding frameworks are not meaningfully adapted or updated

to address different pedagogical challenges in the face of diverse teaching and learning contexts, contributing to the ongoing existence of these differences.

Examining the role of TSR across the six countries under study, our findings support the positive association between these relationships and mathematics achievement. This association is particularly pronounced in Denmark and Sweden compared to the Spanish-speaking countries. While this finding contrasts with prior research suggesting a stronger salience of TSR in collectivist societies (Chen et al., 2019, 2024; Yang et al., 2013), a plausible explanation, as proposed by Chen et al. (2024), lies in the specific variations of individualistic and collectivistic values orientations within Western and Eastern cultural contexts. Our results, therefore, imply a potential interplay between cultural context and the role of TSR on mathematics achievement in Western countries. Specifically, the quality of TSR may be a more relevant factor in enhancing mathematics achievement in Western countries characterised by individualistic values and higher levels of economic development, compared to Western countries situated in the Global South.

Regarding our third research question on the moderating role of gender and SES in the relationship between TSR and mathematics achievement, our findings contribute to the growing body of evidence highlighting the protective role of high-quality TSR on gender differences in mathematics achievement, which has been primarily explored in US elementary education (Hajovsky et al., 2017; Valiente et al., 2019). Notably, our study consistently reveals that adolescent boys, in comparison to girls, tend to experience enhanced mathematics achievement when they report better relationships with their teachers. This association is particularly evident in Paraguay, Spain, and Denmark, while our findings do not substantiate this hypothesis in Chile, Peru, or Sweden.

Furthermore, in Spain and Sweden, we find that students from socioeconomically advantaged backgrounds seem to benefit more academically from positive TSR, as evidenced by their higher mathematics performance in our results. This pattern is not observed in Chile, Paraguay or Denmark. It is therefore plausible that a double educational disadvantage exists in Spain and Sweden, where the prevailing socioeconomic gap is exacerbated by disparities in the quality of TSR. This finding aligns with existing literature emphasising that teachers often establish a more intimate relationship with students from higher socioeconomic backgrounds (Eryilmaz & Sandoval-Hernández, 2021; Raudenská, 2022), as these students tend to be perceived as more receptive to instruction (Schneider et al., 2024). Our study extends this body of research as these studies use teachers' reports, while our study incorporates students' perceptions

of their relationships with teachers. However, again, we found no clear pattern between the continuum of countries with collectivistic and individualistic value orientations. Such educational contexts did not promote differential increases in mathematics achievement, although these contexts theorised cultural valuing of meaningful social relations.

Finally, focusing on the fourth research question regarding the longitudinal trend of the moderating role of TSR on mathematics achievement in Chile, our results show that there is no differential effect of SES and gender on this association across the three PISA assessments. However, our analysis reveals a consistent and persistent trend across time, wherein female adolescents in Chile tend to underperform their male peers in mathematics. Similarly, the socioeconomic advantage in mathematics achievement remained largely stable between PISA 2009 and 2012, with a minor attenuation in the strength of this association observed in PISA 2022. Finally, a slight intensification in the association between the quality of TSR and mathematics performance was noted between PISA 2009 and PISA 2022.

The observed weakening of the strength of the association between SES and mathematics achievement, together with an increase in the strength of the association between TSR and mathematics achievement in Chile, could potentially be placed in the context of the recent educational reforms discussed above, which aim to reduce socioeconomic inequalities and improve school climate. Chile's transition from a flat-fee education system to a means-tested voucher system, as well as the 2015 Inclusion Law, represent significant efforts to reduce socioeconomic segregation by increasing financial support for economically disadvantaged students and regulating arbitrary student selection practices.

In addition, initiatives such as the National School Coexistence Policy and the Framework for Good Teaching have highlighted the importance of fostering positive teacher-pupil relationships, which may contribute to the greater importance of teacher-pupil relationships in predicting student outcomes. Taken together, these policies aim to promote inclusive and supportive learning environments, which may explain the greater dominance of teacher-pupil relationships in mathematics achievement and the slight weakening of individual SES effects over time. However, our results cannot be interpreted as causal associations, nor how these educational policies cause longitudinal co-evolution in terms of reducing these educational inequalities. Moreover, the persistent gender gap in mathematics achievement shows the need to address educational inequalities from a gender perspective in Chile.

It is important to recognise the limitations of this study. Firstly, the items used to measure the teacher-student relations scale broadly capture adolescent students' perceptions of their teachers. This means that students' ratings do not refer to a specific teacher, such as one defined by subject, qualification level or gender, but rather aim to measure students' general attitudes towards their secondary teachers. This limitation is important because it precludes the study of dyadic teacher-student interactions (e.g. gender matching), an area of considerable interest in recent research because of its insights into classroom relational processes.

Second, although the PISA data allow for the study of TSR at the secondary level, the scale is conceptually shortened. Indeed, it does not distinguish between different relevant dimensions of the underlying theoretical construct, such as closeness, conflict and dependence, which have been extensively assessed in the field. Consequently, it was not possible to assess whether the quality of TSR differed by student gender for each dimension, a critical issue according to previous research (Šumatić et al., 2023). Despite these limitations, this study contributes to the theoretical understanding of TSR in a general sense, rather than by specific dimensions, among secondary school students, a population that has received less attention in this growing body of literature.

Furthermore, although our analyses provide a detailed description of the empirical patterns and examine their consistency with the existing literature, thereby advancing the sociological understanding of how gender and socioeconomic inequalities are intertwined in education, they cannot determine the causality of the mechanisms linking students' socioeconomic background and gender to the quality of TSR and their impact on mathematics achievement. Finally, it is important to note that the teacher-student relations scale underwent a slight reformulation when comparing PISA 2009 and 2012 with PISA 2022, which restricts these results from inferring conclusions of absolute change between measurement occasions.

A number of educational policy implications can be drawn from the findings of this study. First, educational interventions aimed at improving the overall classroom climate could significantly improve the quality of teacher-student interactions. Strategies should focus on updating teacher education and training frameworks to align with sound pedagogical criteria. Thus, implementing classroom management strategies that promote the participation, emotional and relational well-being of all students can help prevent relational exclusion (Ortega et al., 2021, 2024), particularly for socioeconomically disadvantaged children. Such interventions would ensure a more inclusive and supportive classroom environment, promoting better educational outcomes for all students.

Second, the design and evaluation of educational interventions that involve the whole school community, throughout the students' life course, is central to addressing socioeconomic and gender gaps in mathematics. Thus, awareness-raising campaigns and activities should begin in early childhood and continue through secondary school, with an emphasis on involving parents and guardians in addressing gender and socioeconomic inclusion issues. These interventions should actively discourage social stereotypes in curricula and teaching resources, with the aim of promoting education that is sensitive to gender and socioeconomic segregation. As several studies suggest, special attention should be paid to groups most vulnerable to traditional gender attitudes, such as adolescent' male working-class students (Morris, 2008; Van Houtte, 2024). By fostering an inclusive educational environment, these interventions can help mitigate the impact of gender stereotypes and promote equitable educational opportunities for all students.

Our study also opens several promising avenues for future research, both in Chile and internationally, that could elucidate the factors that explain socioeconomic and gender gaps in the quality of TSR and mathematics achievement. In particular, future research could examine the role of cultural gender norms instilled by other influential figures in students' lives, such as parents, siblings or peers, who may act as role models or via peer influence. Consequently, different gender expectations about academic performance, transmitted through these channels, may contribute to the observed differences in mathematics achievement, or to the relative importance of establishing good relationships between teachers and students.

In addition, the study of country characteristics could provide valuable structural insights. For example, the educational opportunities structure at the system level, as reflected in indicators such as the Human Development Index (HDI) or the Gender Inequality Index (GII), may help to explain variations in educational outcomes studied between countries. Thus, comparative studies that include different national contexts, as well as the evolution over time of these indicators, could provide a broader notion of the factors contributing to the educational disparities analysed in this study, and how to address them effectively, both at student, school and country level.

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## Appendix

### Figure A1

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The figure was sourced at <https://worldpopulationreview.com/country-rankings/pisa-scores-by-country>

*Note.* Parallel analysis and exploratory factor analyses (EFA) were conducted in the *psych* R package on a polychoric correlation matrix and WLMSV estimator. Varimax rotation was applied.

**Table A1**

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The figure was sourced at [https://www.oecd.org/en/publications/pisa-2022-results-volume-i\\_53f23881-en/full-report.html](https://www.oecd.org/en/publications/pisa-2022-results-volume-i_53f23881-en/full-report.html)

**Table A2**

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**Table A3**

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