Gender and mathematics: pathways to mathematically intensive fields of study in Australia

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Declaration

This thesis is my own original work, except where otherwise indicated and cited accordingly.

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Abstract

Women in Australia have gone from being under-represented to being over-represented in university education, but they are still far less likely than men to engage in mathematically intensive science fields including engineering, information technology and the physical sciences. With a rapid growth of employment opportunities in these fields, women need quantitative skills to become competitive in technologically and science-oriented niches of the labour market. The persisting gender gap in mathematically intensive fields is important also because it may reinforce the stereotypical belief that males are naturally more talented in mathematics, abstract thinking and technical problem solving. The prevalence of such a belief drives adolescents to aspire to gender-typical occupations and thus reproduces gender inequality. Given this, there is an urgent need to systematically examine the extent to which socialisation influences and educational experiences in adolescence affect the participation in advanced high school mathematics and mathematically intensive university qualifications. The key question to consider is why engagement in advanced mathematics and cognate disciplines remains so strongly segregated by gender.

This thesis offers a comprehensive examination of this issue in Australia by drawing on the theories of gender stratification and educational psychology. The scope of this examination is broader than any other Australian study of this issue to date. I adopt a life course perspective to study the impact of teenage educational experiences and occupational expectations on the gender differences in later pursuits of advanced mathematics subjects in Year 12 and mathematically intensive fields at university. To achieve this, I use multilevel logistic regression models to analyse the data from the 2003 cohort of the Longitudinal Survey of Australian Youth. The data comprise a

nationally representative sample of adolescents who turned 15 around 2003 and entered the labour market in the following decade.

Occupational expectations are crucial in explaining why boys are considerably more likely than girls to enrol in advanced mathematics subjects in Year 12. These expectations, however, are less influential than the combined effect of self-assessed mathematical competence of students and their achievement in mathematics. The gender gap in Year 12 advanced mathematics enrolment would disappear completely should we succeed in generating the same levels of self-assessed mathematical competence and in fostering similar levels of early achievement in mathematics across both genders. To achieve gender parity in the choice of a mathematically intensive university major, we would also have to persuade teenagers of both genders to aspire to similar careers and have similar confidence in their mathematical abilities.

Apart from individual micro-social characteristics of students, single-sex schooling enhances the participation of girls in advanced high school mathematics and related fields of study at university. The advantage of all-girls education is evident in these analyses even after considering the pre-existing differences between single-sex and coeducational schools in school resources, teacher quality and the policy of selectivity in student admissions. These results suggest that all-girls secondary education provides an environment that somewhat counters gender stereotypes and fosters mathematically intensive studies, not only in high school but also at university.

Contents

List of tables

List of figures

Chapter 1

Introduction

1.1 Research problem

While women in Australia and overseas have been steadily increasing their participation in tertiary education, men and women around the globe tend to concentrate in different fields of study and employment (Charles and Bradley 2009; Charles and Grusky 2004). In line with this trend, Australian education continues to be strongly segregated by gender (Bell 2010; Marginson et al. 2013). In the 1990s and early 2000s, there were more male than female enrolments in the highest level of school mathematics that involves calculus (Forgasz 2006; Fullarton and Ainley 2000). Recent research has also shown that women continue to be under-represented in mathematically intensive science fields including engineering, information technology and the physical sciences at the post-secondary level (Sikora 2014b; Sikora 2015). Given this, however, previous studies have rarely examined, using nationally representative samples of Australian students, the extent to which early educational experiences influence the decisions of adolescent boys and girls to engage in advanced high school mathematics and related fields of tertiary education.

The understanding of factors that facilitate participation in advanced mathematics and cognate disciplines is more than desirable because the under-representation of females in these disciplines has long-lasting and possibly unfavourable consequences for both individuals and society. Firstly, subject choice has a direct bearing on the occupational trajectories of men and women. Since the beginning of the twenty-first century, employment opportunities in mathematically intensive fields have dramatically increased (ABS 2014a). These mathematically oriented and many other

professional occupations tend to require strong quantitative skills. Therefore, females' under-representation in advanced mathematics in secondary school and related fields of study at university may not only hinder them from taking up opportunities in the thriving industries (Graduate Careers Australia 2014) but it may also contribute to the pay gap between men and women (Brown and Corcoran 1997; Gerber and Cheung 2008; Mitra 2002; Paglin and Rufolo 1990). Across the world in the fields where women are often over-represented, such as teacher training, education and humanities, young workers carry a wage penalty (OECD 2014). Hence, less gender segregation in fields of study may result in a step forward towards gender equality in the occupational sphere (Smyth and Steinmetz 2008; Xie and Shauman 2003).

Secondly, gender segregation in fields of study may reinforce the beliefs in innate gender differences, including the view that males are better at mathematics, abstract thinking and technical problem solving. Such beliefs, when widely shared across society, steer adolescents towards aspiring to gender-typical occupations (Charles and Bradley 2009; OECD 2006). Stereotypes supported by such beliefs may in turn affect adolescent confidence and interest in particular fields of education and career (McMahon and Patton 1997). When girls and young women, particularly those who are talented in mathematics, avoid advanced high school mathematics and related disciplines because they perceive that those subjects are not appropriate for their gender, their talents are under-utilised and their individual potentials are wasted.

Thirdly, the loss of individual talents and potentials is a problem for society that has a great demand for skilled workers with quantitative skills. In Australia, the mathematically intensive sciences constitute about 11 per cent of economic activity directly and the industry continues to grow (Australian Academy of Science 2015). Nevertheless, in a recent survey conducted by the Australian Industry Group, a majority of businesses pointed out that they encountered difficulty recruiting employees with

mathematics and science skills (Australian Industry Group 2013). Meanwhile, enrolments in advanced high school mathematics and related fields of tertiary study keep declining (Barrington and Brown 2014; Office of the Chief Scientist 2012). To increase the participation of young people, particularly girls and young women, in mathematics and related fields at the secondary and tertiary levels, the Australian Mathematical Science Institute and the BHP Billiton Foundation launched Choose Maths, a five-year national program, in 2015. In the same year, the Australian Academy of Science started running the Science in Australia Gender Equity (SAGE) Pilot, another national program aiming to promote gender equity and gender diversity in mathematics and science, in partnership with the Academy of Technology and Engineering. In summary, the governments, academics and industry experts are aware of the continuing decline of young people's participation in advanced mathematics at the secondary and tertiary levels, in the context of the persisting gender gap, and they are attempting to reverse the trend.

Although advanced mathematics subjects in Year 12 are not the necessary prerequisites for the admission to mathematically intensive programs at university, they act as a critical filter of intentions to study and engagement with those degree programs (Ainley, Kos and Nicholas 2008; Varsavsky 2010). Nevertheless, many students, especially girls, choose not to study advanced mathematics even though their schools offer relevant subjects. Therefore, the questions that require answers are how and why gender continues to act as a catalyst for the engagement with or withdrawal from mathematically intensive fields.

This thesis aims to account for, from a life course perspective, a comprehensive range of mutually reinforcing factors that facilitate or hinder engagement in advanced mathematics and related disciplines in Australia. The life course perspective emphasises the crucial influence of the sociocultural environment on human development. It argues

that individuals' behaviour and developmental processes are shaped by social structures and cultural norms across life stages (Elder 1998; Giele and Elder 1998). Specifically, individuals' choices are subject to the opportunities and constraints of social structure and culture over the life course (Elder 1998). By applying the life course perspective to this thesis, the decisions of adolescent boys and girls to pursue advanced mathematics and related fields of study are seen as contingent on the social structure and cultural norms, particularly in relation to gender beliefs and stereotypes, which affect young people from the day they were born.

A comprehensive analysis of the factors that affect students' engagement in advanced mathematics and related disciplines calls for high quality data that do not only represent the entire cohort of young Australians but also account for the dynamics of their educational experiences and occupational expectations. To this end, I use data from the 2003 cohort of the nationally representative Longitudinal Survey of Australian Youth (LSAY) (NCVER 2011). This cohort reached age 15 around 2003 and entered the labour market in the decade that followed. Commencing my observations of youth from the time when they were age 15 and describing their occupational expectations and self-assessed mathematical competence at that time, I next account for the gender gap in advanced mathematics enrolment in Year 12. Following that, I analyse factors that facilitate the choice of a mathematically intensive major at university along the gender divide. Because student preferences and specialisations may change during post-compulsory education, my objective is to provide a life course account of historically and institutionally situated individual choices which have led recent Australian students to specialise in or stray from advanced mathematics and cognate disciplines.

1.2 Advantages of a stratification approach to explaining gender segregation in mathematics education

The educational and psychological literature rarely conceptualises gender segregation in mathematics education as a form of social inequality. It tends to focus on gender differences in school achievement in the early stages of life and to regard such differences as the major cause of women's under-representation in mathematics and related fields at later stages of their educational careers (see, for example, Else-Quest, Hyde and Linn 2010; Lubinski and Benbow 1992; Wai et al. 2010). However, gender differences in mathematics achievement have narrowed considerably over the last few decades (Baker and LeTendre 2005). In fact, recent studies in social stratification and psychology have shown that such gender differences account for only a small share of gender segregation in mathematics and related disciplines (Ceci and Williams 2010a; Ceci and Williams 2010b; Charles and Bradley 2009; Riegle-Crumb et al. 2012).

As gender continues to differentiate participation in mathematics and cognate fields strongly, even after achievement differences have been taken into account, perceiving gender as a form of social inequality offers illuminating insights into the causes behind gender segregation in mathematics education. Psychological research often draws on Eccles's expectancy value theory of achievement-related choices (hereafter: expectancy value theory) to understand how males and females make gendered educational and occupational choices (Eccles 2011). Although the expectancy value theory stems from psychological research, it recognises the social and cultural influences on facilitating gendered choices over the life course (Schoon and Eccles 2014).

In stratification research, gender inequalities are regarded as having a vertical and a horizontal dimension (Figure 1.1; Charles and Bradley 2002; Charles and Grusky

2004; also see Jonsson 1999). The vertical dimension refers to the hierarchical differences between males and females in access to education, in the level of education attained, as well as in occupational status, authority and pay (Blau, Brinton and Grusky 2006). This form of gender inequality has been significantly bridged in Australia where women have been benefiting from the feminist movement and the relatively egalitarian welfare policies since the 1970s (Aspalter 2003). The gender gap in education has reversed with Australian women now outnumbering men in tertiary education (Marks, McMillan and Ainley 2004; Marks and McMillan 2007). By contrast, horizontal segregation in Australian education persists. The prime example of that is the dominance of men in mathematically intensive areas and women in life science courses which encompass significant biology, health and environment-related contents and other fields of study, such as education, the humanities and the social sciences (Fullarton and Ainley 2000; Sikora 2014b). As discussed in the previous section, horizontal segregation in education is detrimental not only to individuals but also to society.

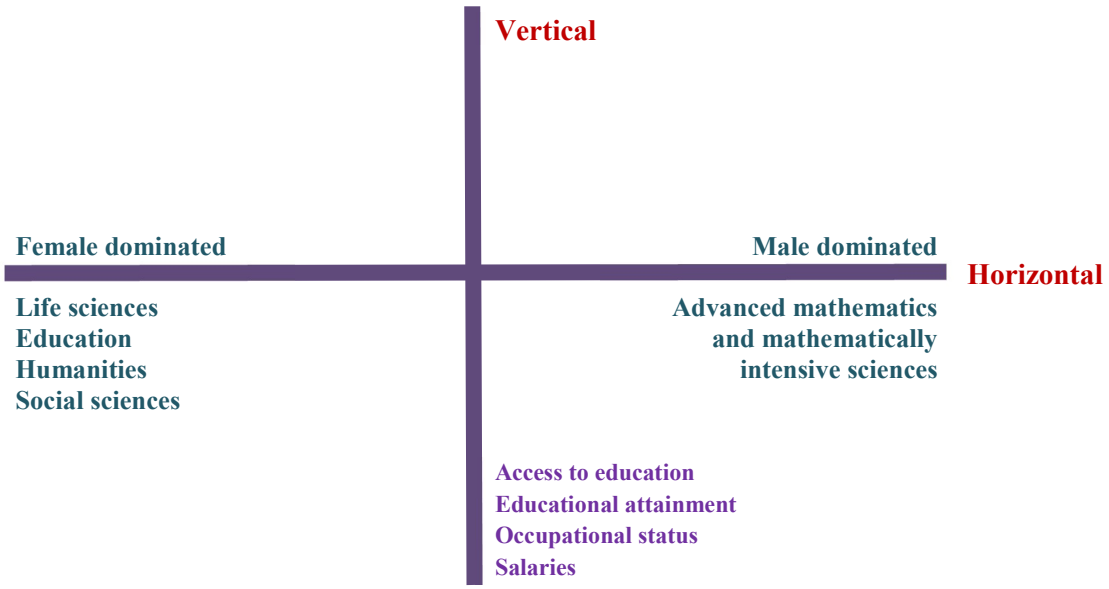

Figure 1.1 Vertical and horizontal dimensions of gender inequalities

Note: Based on Charles and Bradley (2002), Charles and Grusky (2004), and Jonsson (1999).

Through incorporating a stratification approach to gender essentialism into the expectancy value theory, I focus on how social structures, cultural norms and individual characteristics interact to affect individual decisions and experiences over the life course of students. In turn, the importance of individual characteristics that affect students' engagement in mathematically intensive fields can and should be understood only in the context of these cultural and structural factors. The gender essentialist hypothesis proposes that men and women develop their individual identities under the influence of widely shared cultural beliefs about innate gender differences (Charles and Grusky 2004). Recent cross-national research based on the gender essentialist hypothesis has demonstrated how gender interacts with other social structures and cultural norms to shape educational and occupational choices. Specifically, gender segregation in fields of study persists and appears to be stronger in advanced industrial countries, including Australia (Charles and Bradley 2009; Sikora and Pokropek 2012a).[1] Many advanced industrial countries have comprehensive education systems, which provide a wide range of curricular options in tertiary education, that encourage students to specialise in fields they are interested in. Meanwhile, the large service sectors in these countries offer abundant employment options that allow young men and women to pursue gender-typed vocational goals that conform to their traditional gender roles. Therefore, rather than being seen as an issue of gender inequality, gender-typed educational choices are generally viewed as manifestations of the widely shared cultural belief that men and women are inherently and fundamentally 'equal but different' (Charles and Bradley 2002). As such the choices are not seen as a matter that needs intervention, but rather as a desirable individual choice differentiation.

[1] To be recognised as an advanced industrial country by Charles and Bradley (2009), a country must have been an active member in the Organisation for Economic Co-operation and Development (OECD) for more than 20 years, and have a much higher per capita gross domestic product (GDP) than any other developing and transitional countries.

While the gender essentialist hypothesis focuses on the highly diversified curricula in tertiary education, I argue that a comprehensive system in secondary education that provides a wide range of subjects for students to choose from also facilitates gender segregation in mathematics and related disciplines. Research in the United States has shown that students who fail to study advanced mathematics in high school are highly unlikely to pursue mathematically intensive fields of study at the tertiary level (Correll 2001). Even though advanced mathematics is not required in many Australian university courses, including those in science, it provides students with the best start in mathematically intensive fields (Ainley, Kos and Nicholas 2008; Fullarton et al. 2003). In Australia, Years 11 and 12 students are able to study different levels of mathematics or even opt out of the subject. However, adolescent boys and girls do not participate in each level of mathematics equally. In the 1990s and the early 2000s, Australian girls were less likely than boys to study advanced mathematics in Year 12 (Forgasz 2006; Fullarton and Ainley 2000). Thus, gender differences in the selection of advanced high school mathematics suggest that gender segregation in tertiary mathematically intensive fields occurs earlier in the life cycle. In line with this claim, Australian studies show that a majority of students start considering whether to embark on education and a career in quantitative and science fields already during childhood and adolescence (Jones, Porter and Young 1996; Tytler et al. 2008).

Previous Australian studies of the gender gap in advanced high school mathematics enrolment often analysed samples from specific cities and regions (see, for example, Lamb 1996; Lamb 1997; Watt 2006). Therefore, studies based on nationally representative samples have been rare. Even though some related research adopted samples from the national data, they seldom examined the subsequent engagement in mathematics-related tertiary education of Australian youth (Forgasz 2006; Fullarton and Ainley 2000; Fullarton et al. 2003). Therefore, in this thesis, I explain from a life course

perspective using nationwide data how early educational experiences and occupational expectations shape the choice of advanced mathematics in Year 12 and related disciplines at university.

Longitudinal survey data are well suited to conducting a life course analysis. Widely shared gender stereotypes, gender socialisation in the family and the school environment are the crucial factors that affect students' decisions to engage in specific fields of study (see, for example, Legewie and DiPrete 2014a; Morgan, Gelbgiser and Weeden 2013). However, most longitudinal studies that provide evidence for the salience of these factors focus on the American context and they rarely explore how other institutional arrangements may have an impact on gender segregation in fields of study (Gerber and Cheung 2008; Xie and Shauman 2003). The 2003 cohort of LSAY, also known as Y03, which began with the Programme for International Student Assessment (PISA) 2003 of the Organisation for Economic Co-operation and Development (OECD), is an excellent data source on adolescent choices that may lead to engagement in mathematically intensive studies at university in a non-American setting. Y03 comes from the only PISA wave that focused on mathematics and its data collection has been completed up to now.

1.3 Early socialisation influences from the family

Researchers in sociology, education and psychology have long been interested in two essential clusters of factors which affect gendered interest in mathematics and related disciplines: family background and school experiences. The expectancy value theory suggests that gender socialisation in the family may separate boys and girls into different educational pathways at an early age (Eccles 2011). Although Correll (2001) claims that differences in family structure and socioeconomic status do not contribute to gender segregation in mathematics and cognate fields in the United States, studies in

other countries have reached contrary conclusions. In Australia and the Netherlands, the gender gap in mathematics course-taking is different across socioeconomic groups (Lamb 1996; Lamb 1997; Van Langen, Rekers-Mombarg and Dekkers 2006). In the late 1980s, Australian girls in families of higher socioeconomic status were less likely than boys in families of the same status to study advanced mathematics, but they were more likely to pursue advanced mathematics than boys in families of lower socioeconomic status (Lamb 1996; Lamb 1997). It is plausible to assume that socialisation practices in low-status families may be strongly gender-typed, whereas socialisation practices in high-status families may be more egalitarian. Thus far, however, no systematic investigation of this phenomenon has been conducted in Australia with the use of nationally representative data. Therefore, using nationally representative samples from the Y03 cohort, I examine whether the gender gaps in advanced high school mathematics enrolment and in mathematically oriented university studies vary with the family's socioeconomic status.

Parental employment in science may bring an additional advantage to enhancing students' engagement in mathematics and related fields of study (Dabney, Chakraverty and Tai 2013; Dryler 1998; Sikora and Pokropek 2012b). Recent Australian studies demonstrate that students are more likely to participate in the physical science disciplines in the last year of secondary school and university education if their parents were employed in science (Sikora 2014b; Sikora 2015). These studies, however, do not identify whether students are more likely to be influenced by their fathers or mothers. According to the gender socialisation hypothesis (Marks 2008a; Marks 2008b), boys are more likely than girls to perceive their fathers as role models while girls are more inclined than boys to see their mothers as role models. I extend this line of reasoning and examine whether parents' employment in science stimulates the same-sex children's engagement in advanced mathematics and related disciplines in Australia.

1.4 Gender-typed occupational expectations during adolescence

The expectancy value theory proposes that socialisation processes in the family, school and society, as well as students' masculine and feminine identities, shape students' occupational expectations (Eccles 2011). These expectations also reflect the students' perceived opportunities and constraints, and the widely shared occupational gender stereotypes as described by the gender essentialist hypothesis. During childhood, boys and girls develop different occupational orientations and form gender-differentiated career expectations (McMahon and Patton 1997; Tai et al. 2006). In Australia and the United States, gender differences in occupational expectations channel young men and women to different educational pathways (Legewie and DiPrete 2014b; Morgan, Gelbgiser and Weeden 2013; Sikora 2014b). Up to now, however, the Australian research on how adolescents' occupational expectations affect their engagement in advanced mathematics in high school and related fields of study at university has received less than adequate attention. Therefore, in this thesis, I examine whether aspiring to a mathematically intensive career increases the chance of choosing advanced mathematics in Year 12 for male and female students. Then I continue this line of investigation and consider how important such a career expectation is to the chances of men and women engaging in mathematically oriented fields of study at university.

1.5 The impact of the school environment

Beyond familial influences, the educational system and school environment also play a crucial role in shaping adolescents' educational and occupational choices (Legewie and DiPrete 2014a; Sikora 2014a). Previous studies have concluded that gender differences in subject choice are related to the following factors: the extent of differentiation in educational and school systems, the extent that students are given

freedom in subject choice, methods of assessment and gender-segregated schooling (Yazilitas et al. 2013). Among different features of the Australian school system, I pay attention to gender-segregated schooling in my analysis. This is due not only to the long history of such schooling in Australia, but also to the ongoing worldwide debate on the extent to which single-sex schooling counteracts gender stereotypes (Signorella, Hayes and Li 2013; Smithers and Robinson 2006). Although the proponents of single-sex education argue that it promotes students' engagement in gender-atypical disciplines, many existing studies are criticised for confounding the advantage of single-sex schooling with the pre-existing differences between single-sex and coeducational schools (Halpern et al. 2011; Signorella, Hayes and Li 2013; Smyth 2010). Such differences may appear in the socioeconomic status of the student population, teacher quality and selective admission policies. The Australian research that takes similar school characteristics into account has shown that in the late 1990s and mid-2000s, students in single-sex schools were just as likely as students in coeducational schools to study physical science subjects in Year 12 (Ainley and Daly 2002; Sikora 2014a). However, whether this pattern holds also when one considers advanced mathematics courses is a matter that needs empirical investigation of the type undertaken in this thesis.

To avoid confounding the effects of single-sex schooling with the advantages of private and selective schools, in this thesis I consider the pre-existing differences between single-sex and coeducational schools with respect to the school sector, selective admission policies and teacher quality. With an emphasis on single-sex schooling, I explore how different school environments may act as an institutional factor that leads boys and girls to pursue specific fields of study. Specifically, I examine whether attending a single-sex school fosters the choice of advanced mathematics in Year 12 and a mathematically intensive major at university.

1.6 Outline of the thesis

Based on the expectancy value theory from educational psychology, I extend the model with a stratification approach to gender essentialism. Chapter 2 begins with the theory of gender essentialism that suggests how specific cultural forces and structural features of the tertiary education system and the labour market in Australia organise males and females into different science fields. The same chapter then reviews prior research in Australia and other countries that demonstrates from a life course perspective how early educational experiences, occupational expectations, socialisation influences from the family and the school environment facilitate the gendered choices of advanced mathematics and related disciplines in secondary and tertiary education. As suggested by the theory of gender essentialism, comprehensive education systems offer highly diversified curricula and encourage students to participate in the disciplines they are interested in, while legitimising opting out of fields of study that students find unappealing. In turn, such systems provide female students plenty of opportunities to choose other fields of study than mathematics and related disciplines. Therefore, in Chapter 3, I discuss why Australia is an internationally important case study of gender segregation in mathematically intensive education. I also discuss how Australian students' access to advanced mathematics and related disciplines may reflect their own socioeconomic backgrounds and those of the schools they attend. I describe the recent trend in students' enrolment in senior secondary school mathematics and whether there are more girls than boys who opt out of school mathematics. In addition, I provide a descriptive overview of Australia's contemporary educational system with an emphasis on the mathematics and science curricula in senior secondary school. In Chapter 4, not only do I introduce the LSAY data, but I also discuss its advantages for this research project and the methods of data analysis for this thesis.

From Chapter 5, I shift the attention of this thesis to presenting the empirical results of adolescent pathways to mathematically intensive fields in Australia based on a life course perspective. Chapter 5 demonstrates how boys and girls in Australia differ in their engagement in advanced mathematics in Year 12. The chapter examines how gender interacts with the family's socioeconomic status, occupational expectations and self-confidence in mathematics to influence students' decisions to study advanced mathematics. Chapter 6 studies how young men and women differ in their choices of mathematically intensive university studies. That chapter considers how the interaction among gender, family's socioeconomic status, occupational expectations, self-confidence in mathematics and subject choice in Year 12 affects students' chances of choosing a mathematically oriented degree program. In Chapter 7, I focus attention on single-sex education and examine its impact on students' engagement in advanced mathematics in Year 12 and related disciplines in university education. In Chapter 8, I summarise my findings and discuss the theoretical and policy implications.

Chapter 2

Explaining the under-representation of females in advanced mathematics and related disciplines: a life course approach

In the last three decades, Berryman's (1983) introduction of the 'leaky pipeline' argument has been widely employed to explain the under-representation of women in science (Blickenstaff 2005; Xie and Shauman 2003). According to the logic of this argument, at different educational stages women have a higher chance of 'leaking' from the mathematically intensive 'pipeline' than men. Already in high school, women have a lower propensity than men to engage in advanced mathematics and related subjects. This pattern is also evident in women's tendency to select and complete tertiary education in mathematically intensive fields and in their tendency to work in mathematically intensive fields after attaining a relevant tertiary qualification. The choice of a field of study in tertiary education is the most critical stage because once young people commence tertiary training, women are as likely to stay in their fields of study as men until graduation (Xie and Shauman 2003). Despite the many features the 'leaky pipeline' argument offers, it does not directly consider how the sociocultural environment interacts with individual characteristics to contribute to the leakage of females from the mathematically intensive pipeline. Therefore, other theories must be called upon to understand why females' participation in mathematically intensive fields still falls short of the desired levels.

In the previous chapter, I situated the analysis undertaken in this thesis within the stratification approach to gender essentialism (Charles and Bradley 2009; Correll 2001; Xie and Shauman 2003) and within the expectancy value theory (Eccles 2011). The expectancy value theory emphasises psychological processes within the context of

social and cultural influences that shape the gendered educational and occupational choices of males and females. In this thesis, I attempt to provide a comprehensive life course account of why and how the under-representation of females in mathematics persists over educational careers of youth and, by implication, may persist from generation to generation. My account blends the gender stratification perspectives with the psychological framework to emphasise the primacy of cultural factors and institutional settings that enable or hinder the operation of individual level processes (Figure 2.1). With this framework, I argue that social structures, cultural norms and individual characteristics interact over the life course of students and contribute to gender differences in their occupational expectations and educational choices with respect to mathematics.

In this chapter, I begin by reviewing the gender essentialist hypothesis (Charles and Bradley 2009), which is a social stratification approach that focuses on the global prevalence of cultural norms that facilitate gender segregation in mathematically intensive fields of study (section 2.1). With the goal of reviewing gendered attitudes to mathematics in psychological studies, in the next section I switch my attention to the subjective task values emphasised by the expectancy value theory and discuss their contributions to students' engagement in mathematically intensive fields of study (section 2.2). Then I explain the conceptualisation of gender identities in my research and discuss how identity formation and enactment are manifested in adolescent decisions to pursue or shun mathematics (section 2.3). The nearly uniform gender polarisation of subjective task values of various mathematics-related goals suggests that strong cultural underpinnings are reinforced through the socialisation processes within the family and in the school environment.

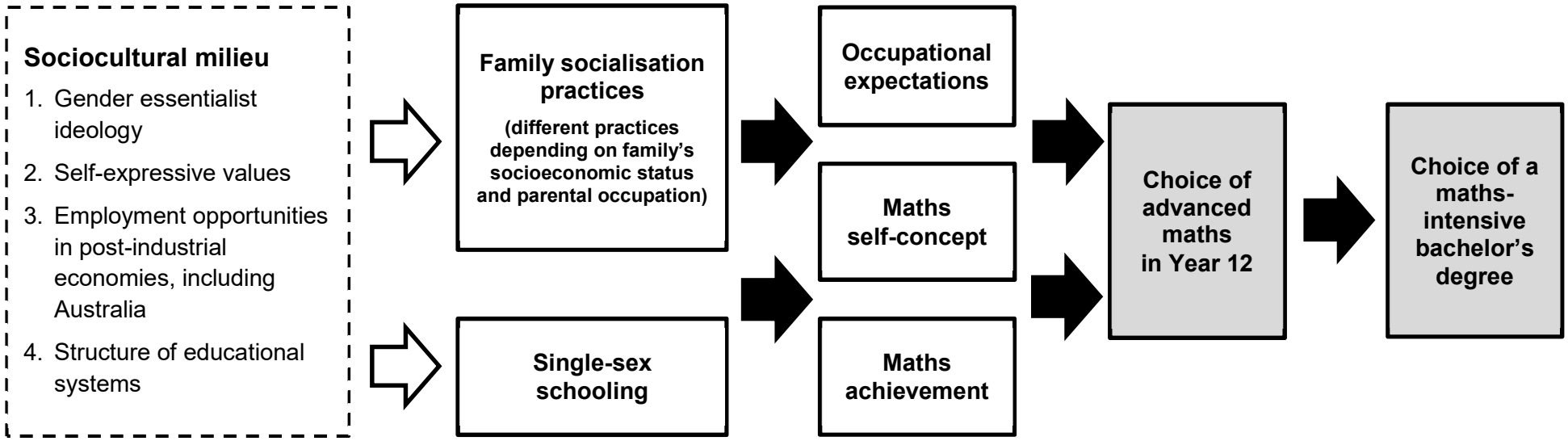

Figure 2.1 Theoretical framework of my thesis

Note: I adapt this conceptual diagram from the expectancy value theory and integrate it with a stratification approach to gender essentialism to illustrate the factors that affect a student's choice of advanced mathematics in Year 12 and of a mathematically intensive field of study at university. Boxes with solid lines contain the variables I include in my empirical analysis. Although I have not got the variables in boxes with dashed lines and do not model the causal relationships indicated by the white arrow, I discuss the contributions of these factors and the causal relationships based on prior research and theories.

Source: Charles and Bradley (2002; 2009); Charles and Grusky (2004); Correll (2001); Eccles (2011); Kerckhoff (1976; 1995; 2001); Schoon and Eccles (2014); Sikora (2014a; 2014b; 2015); Sikora and Pokropek (2012b); Smyth and Steinmetz (2008); Xie and Shauman (2003)

Therefore, in sections 2.4 to 2.9, I focus on the aspects of my theoretical framework that shape the empirical part of my analysis and inform my research questions answered with the analysis of LSAY data. I discuss the sociological and psychological theories that emphasise the variables I include in my empirical analysis.

My starting point here is socialisation practices in the family that can have the form of direct efforts of parents to instil particular attitudes towards mathematics and science in their children (section 2.4). Alternatively, socialisation may take a subtler form where children come to gain knowledge and develop attitudes towards their parental professions, without any direct effort of their parents, just by being around them as they grow up. Socialisation within the family, within the school and through other channels is one set of processes that shape occupational expectations, which is my next focal point in the discussion in this chapter (section 2.5). Vocational inclinations in turn are closely related to students' self-assessment of mathematical abilities (section 2.6), academic achievement in mathematics (section 2.7) and subject choice in high school (section 2.8). These factors converge to channel boys and girls into specific educational specialisations. Yet they do not operate in a social vacuum. Therefore, in section 2.9, I discuss how selected features of school environments, in particular single-sex schooling, may have the potential to bridge the gap in students' engagement in mathematics at both secondary and tertiary levels.

Although this thesis endeavours to study gender segregation in Australian mathematics education, I review not only Australian research but also the relevant studies from other advanced industrial countries. This is because the gender segregation patterns in affluent economies with strong democratic values and comprehensive education systems are likely to be similar as suggested by the gender essentialist

hypothesis (Charles and Bradley 2009).[2] I finish by summarising my theoretical discussion in section 2.10 and listing my research questions in section 2.11.

2.1 Stratification theory of gender essentialism

As we enter the twenty-first century, a consensus seems to prevail among academics and policymakers that males and females make their educational and vocational decisions rationally based on the perceived opportunities and constraints, but the rationality of this behaviour is conditioned by cultural beliefs and normative social practices (Barone 2011). It is hard to deny that cultural coordinates vary from place to place. Nevertheless, in a largely globalised and interconnected world one must note, as the gender essentialist hypothesis points out, the symbiotic operation of two cultural forces and two types of institutional settings. The two cultural forces are the ideology of gender essentialism and the post-industrial emphasis on the primacy of self-realisation. The structural institutional forces that operate in symbiosis with these cultural trends are a comprehensive structure of contemporary educational systems in which students are encouraged to select specialisations in line with their personal interests and strengths, and service-oriented employment opportunities in the professions increasingly available in post-industrial economies. Culturalists, including Charles and Bradley (2009) as well as Barone (2011), argue that understanding how these forces operate in unison is fundamental for an understanding of why gender segregation persists in fields of study.

The first cultural force, namely, the gender essentialist ideology involves the widely shared cultural beliefs and stereotypes that men and women are fundamentally and inherently different by nature (Charles and Bradley 2002; Charles and Bradley 2009; England 2010). These stereotypes, subtly communicated and omnipresent, seep

[2] I explain in detail in section 2.1 why gender segregation patterns in mathematics education in advanced industrial countries are likely to be similar.

into the minds of young people to facilitate an acceptance of the belief that women are naturally good at inter-human communication and care while men excel at abstract problem solving and in technology. Children internalise such gendered beliefs, including the belief that it is only natural to expect males to surpass females in mathematics. Such internalisation happens through socialisation, even against parental efforts to instil gender-neutral values in their children and is likely to manifest itself in gender-differentiated expectations and preferences (Blau, Brinton and Grusky 2006; Charles and Grusky 2004). Mathematically intensive fields are generally perceived as being more appropriate for men because more men currently work in these fields and many people believe that they enter such employment due to natural abilities that women simply do not have (Ceci and Williams 2010b). Such assumptions are often taken for granted and never critically considered.

The second cultural force is the primacy of self-expressive values, that is, the cultural emphasis on individual self-expression and self-realisation (Charles and Bradley 2009). Mathematical and technical work is often depicted as abstract, rigid, tedious and offering few opportunities for interacting with other humans and allowing for an emphatic creativity or the expression of individual personalities into the work process (Faulkner 2007; Osborne, Simon and Collins 2003). Thus the popular perception of mathematical fields is that they are less likely than other work to be perceived as enjoyable and self-expressive (Charles et al. 2014). Previous studies in the United States have demonstrated that students who value people-oriented jobs and working with other people rarely aspired to and entered male-dominated professions, including mathematics (Cech 2013; Eccles 2007; Eccles and Wang 2016). As female students tend to rate their level of people orientation higher than their male peers, the implications of these perceptions should not be underestimated.

In post-industrial societies career choice motivations have less to do with material incentives than with the perceived compatibility of a future career with the identity and personal preferences of an individual (Charles and Bradley 2009). This kind of motivation for career choices might be more applicable to young women than young men. In the 1980s, American girls were more likely than boys to value the importance of self-expression and social interaction at work, and they were more likely to pursue fields of study that offered ample opportunities for social interaction rather than mathematics and related science (Frehill 1997). Similarly, in Germany, high school graduates who entered college in 2010 had a lower chance of choosing a mathematically intensive degree if they showed higher interest in careers that involved helping and caring for others (Ochsenfeld 2016). Motivating career choices by good fit with individual identity, that is 'this job is me while that job is not me' type of reasoning is prevalent in post-industrialist societies among youth of both genders. Yet, the socialised propensity of girls to embrace even more readily this self-expressive approach to career choices may be seen as an additional element that contributes to the gender gap.

The gender essentialist hypothesis also suggests that, in addition to the two cultural forces, the structural features of the educational system and the labour market in Australia contribute to gender segregation in fields of study (Charles and Bradley 2002; Charles and Bradley 2009). Australia has a comprehensive education system that offers a wide variety of curricular options in tertiary education and in the last two years of secondary education encourages students to pursue only fields of study they are good at and interested in. The penalties associated with low numeracy skills in the local labour markets might not be enough to offset this trend because the service economy in Australia generates abundant job opportunities that involve human-centred services and professional work, which are culturally constructed as feminine. The examples of such work are music education, dance and visual arts therapy, social work and nursing. When

the gender essentialist ideology and the system of self-expressive values converge, as is arguably the case in Australia, the expected consequence is that females will be less likely to pursue mathematically intensive fields when cultural stereotypes that link these fields to self-expression and inter-human interactions are absent. Instead, abundant female-labelled opportunities exist in areas other than mathematics in education and the labour market. These opportunities attract young women's attention also because they are already dominated by other women.

In summary, cultural trends dominant in post-industrial societies, such as Australia, would not be as prevalent as they now appear in different structural conditions (Charles and Bradley 2009). However, the individualism of modern comprehensive education and the expansion of female-labelled skilled service employment create conditions in which individual processes can readily lead to self-sorting of adolescents into different educational specialisations.

2.2 Expectancy value theory: how gender shapes subjective values toward mathematically intensive fields

The stratification theory of gender essentialism argues that gendered choices of advanced mathematics and cognate disciplines are shaped by social structures and cultural forces over the life course. The expectancy value theory, which stems from psychology, focuses on explaining how gender socialisation influences educational and occupational choices mainly through its impact on individuals' expectations for success and subjective task values (Eccles 2011).

Based on her prominent expectancy value theory, Eccles (2011) argues that one of the two main reasons why young women are less likely to engage in advanced mathematics and related disciplines is that they tend to place less subjective task values on those mathematics-related fields than they place on other fields of study and possible

career options. According to Eccles (2011), subjective task value is a domain-specific construct that varies across fields of study and employment. It comprises four components: attainment value, interest-enjoyment value, utility value and perceived cost. Attainment value refers to the personally perceived importance of doing well in a task, and it is closely related to one's perception of how well the task fits in with personal and social identities, including gender identities. Interest-enjoyment value refers to the personal interest in and enjoyment of engaging in a task. Utility value refers to the personally perceived usefulness of a task in achieving one's short- and long-term goals and attaining rewards. Finally, perceived cost refers to the anticipated effort and loss required for undertaking a task. Students who place high subjective task values on mathematics and related science fields tend to show interest in those fields, believe that it is important for them to perform well in those fields, and perceive that those fields are useful for their future.

Gender differences in the subjective task values towards mathematics and science are prevalent. Among the highly competent Australian students in mathematics and science, boys tend to show higher interest in the mathematically intensive science subject, physics, whereas girls tend to declare higher interest in the life science subject, human biology (Buccheri, Gürber and Brühwiler 2011). In the 1990s, among Years 8 and 9 students in two Australian cities, Sydney and Wollongong, boys were more likely than girls to value the importance of mathematics and science for the future (Jones and Young 1995).

The expectancy value theory points out that gender differences in subjective task values are important mediators of gender differences in educational and occupational choices (Eccles 2011). In the longitudinal studies of the educational choices and occupational aspirations in Australia, Canada and the United States, gender differences in students' aspirations for mathematically intensive careers and their engagement in

related fields of study were found to be partially mediated by gender differences in the subjective task values attached to these fields (Eccles 2007; Watt et al. 2012).

The subjective task values students place on mathematically intensive fields has a greater impact on their decisions to pursue related fields than other general values and life goals. Using American student data from the early 1970s to 2000s, Mann and DiPrete (2013) found that students' concerns about work–family compatibility, values toward the importance of money and success, and values toward the importance of helping others only explained a small fraction of gender disparities in undergraduate major choice. They also showed that male students did not notably differ from female students in those general life goals and values.

Although the expectancy value theory and the gender essentialist hypothesis offer explanations for the under-representation of females in advanced mathematics and related fields of study, they have different emphases and they can complement one another. The expectancy value theory provides a strong foundation for understanding at the micro level how males and females make gendered educational and occupational choices due to gender-specific socialisation and differential goals, motivations and subjective task values, over the life course (Eccles 2011). Even though the expectancy value theory addresses the influence of the sociocultural milieu, including the gender role stereotypes and cultural stereotypes, it provides little explanation for the cross-national variations in gendered choice patterns at the institutional and macro levels (Yazilitas et al. 2013). Unlike the expectancy value theory, the gender essentialist hypothesis does not speak to the differential psychological dimensions that lead to gendered educational and occupational choices. Instead, the gender essentialist hypothesis focuses on explaining how the structural features of a comprehensive education system and a post-industrial economy provide an excellent environment for the gender essentialist ideology and self-expressive values to prevail, and thus facilitate

gendered choices of mathematics education. In the present thesis, the gender essentialist hypothesis complements the expectancy value theory by offering the theoretical framework necessary for understanding why specific characteristics of an advanced industrial country, such as Australia, offer favourable conditions for promoting gendered choices of mathematically intensive fields of study.

2.3 Gender identities: why engaging in mathematically intensive fields is regarded as equivalent to 'doing masculinity'

Socialisation affects students' perceptions of mathematically intensive fields and the gender roles expected of the students, and in turn, shapes their gender identities. In sociology, gender identity refers to 'the degree to which a person perceives the self to be masculine or feminine, given what it means to be masculine or feminine in a given society' (Vantieghem, Vermeersch and Van Houtte 2014, p. 363). Masculine and feminine identity constructions develop in response to the widely shared cultural beliefs that men and women are different (Ridgeway and Smith-Lovin 1999). The concept of gender identity connects with the sociological concept of 'doing gender' (West and Zimmerman 1987). In everyday behaviour and social interactions, individuals 'do gender'; that is, '[create] differences between girls and boys and women and men, differences that are not natural, essential, or biological.' (p. 137) In other words, individuals become males or females and affirm their gender identities by engaging in culturally prescribed tasks and holding congruent beliefs. Importantly, they derive a sense of satisfaction and fulfilment from 'doing gender'.

Previous studies have used mathematics as an example through the lens of feminist sociology to argue that males dominate mathematics because to engage in the subject is a means of 'doing masculinity' and becoming truly male (Mendick 2005b). As mathematics is widely regarded as masculine, it becomes incompatible with

females' performances of popular femininity (Archer et al. 2013). When males 'do masculinity', they undertake activities that are socially regarded as appropriate for males and demarcate their distance from femininity. Mendick (2003) interviewed young people who studied mathematics in post-compulsory secondary education in England and found that some teenage boys construed mathematics as a means of proving their masculine abilities to their peers and future employers. In doing so they perceived mathematics as abstract, difficult, and indispensable for high-status occupations. Mendick (2005a) further affirms that females must negotiate this cultural boundary which makes it harder for them to engage and remain engaged, as well as to feel competent and comfortable. Therefore, it is much easier for females to shy away from mathematics and reaffirm their cultural femininity (Mendick 2006).

The expectancy value theory also describes the relationship between gender identity and educational choices. If a student has a masculine identity and perceives that it is important to engage in fields of study and careers that align with their masculine identity, this student may place high subjective task values on mathematically intensive fields because such fields are generally regarded as masculine (Eccles 2011). As discussed in the previous section, having high subjective task values in mathematically oriented fields increases one's chance of pursuing those fields of study and career.

Other psychological studies have also conceptualised femininity and masculinity on a continuum of attributes that everybody possesses to some extent; for example, a German study has demonstrated that adolescent girls and boys who liked physics were perceived by their peers as more masculine and less feminine (Kessels 2005). The same study has also found that girls who excelled in physics felt unpopular with boys. Mathematically intensive fields are generally not constructed as people-oriented and nurturing, and therefore they have an uneasy and ambiguous relationship with the socially expected caring role of women (Charles and Bradley 2009; Charles et al. 2014).

If adolescent girls believe that being feminine is crucial to their identities, the avoidance of mathematics to affirm femininity may be an attractive behavioural option for them (Brown, Brown and Bibby 2008). These findings are not only consistent with the expectancy value theory but are also in line with the sociological concept of 'doing gender'.

2.4 Early socialisation influences from the family

Although gender differences in field of study choices are shaped by multifarious influences (Eccles 1994), both psychological and sociological research agree that the role of family might be particularly worth attention because parents are the primary and one of the most influential socialising agents in childhood and adolescence (Eccles 1993; Xie and Shauman 2003). Early studies in psychology have demonstrated that gender-specific socialisation practices in the family differentiate the decisions of boys and girls to engage in advanced mathematics and related disciplines (Eccles 2011). Specifically, parents may overrate boys' mathematical competence even when there are no gender differences in mathematics performance (Tiedemann 2000). Regarding mathematics learning, parents may have higher expectations for boys and tend to believe that it is more crucial for boys to pursue high-level mathematics subjects at school (Eccles and Jacobs 1986; Eccles, Jacobs and Harold 1990). When these gender-specific socialisation practices exist in the family, girls are aware of the lower expectations from their parents, particularly their mothers, and adjust their attitudes and aspirations with regard to mathematics learning accordingly (Eccles and Jacobs 1986; Jacobs and Eccles 1992). Consistent with the findings of these psychological studies, recent stratification research has also found that parents may be more likely to encourage their sons than their daughters to study advanced mathematics and mathematically oriented science subjects in high school (Gabay-Egozi, Shavit and Yaish 2015). Gender-specific socialisation practices do not only channel boys and girls

into different disciplines in high school, but they also have a long-lasting impact on the educational decisions of young men and women in tertiary education (Camp et al. 2009).

Gender socialisation practices may be more traditional in families of low socioeconomic status than in high-status ones, and therefore their impact on students' educational choices may vary with the family's socioeconomic status. In a family of high socioeconomic status, parents tend to be highly educated and engage in professional or managerial occupations. By contrast, in a family of low socioeconomic status, parents do not have tertiary qualifications and they tend to be employed in non-professional jobs. Early stratification research has concluded that young men and women are more likely to engage in gender-atypical fields of study if their parents are highly educated and employed in professional or executive occupations (Dryler 1998; Leppel, Williams and Waldauer 2001; Støren and Arnesen 2007). This is because these parents tend to have gender egalitarian views and behaviours that enhance their children's interest and engagement in gender-atypical areas. Based on this line of reasoning, the gender gap in the choice of advanced mathematics and related disciplines in Australia is possibly smaller among students from families of high socioeconomic status.

Early stratification studies in Australia have provided some evidence that supports the above claim. Based on a sample of students from four public secondary schools located in the metropolitan area of Melbourne in Australia in the late 1980s, Lamb (1996; 1997) found that girls from families of high socioeconomic status had a lower chance of studying advanced mathematics than boys from families of the same socioeconomic status. However, these girls were more likely than boys from lower-status families to pursue advanced mathematics. In other words, high socioeconomic status partially offsets the girls' disadvantage in advanced mathematics enrolment. The

results of Lamb's studies were based on data from a non-representative sample and an indicator of family's socioeconomic status measured solely by the father's occupation. To examine whether Lamb's findings still hold in a younger and larger cohort of Australian youth, we need a nationally representative sample and a broader measure of the family's socioeconomic status.

Other than the socioeconomic status of the family, parents' employment in science and gender-atypical careers may bring an additional advantage to increasing their children's chances of engaging in advanced mathematics and related fields of study through two likely mechanisms. First, students may look on their parents as their role models and follow their occupations, thus choosing a related field of study and career. In order to identify someone as a role model, young people need to have the opportunity to develop personal connections and emotional closeness with that person (Archer et al. 2010; Buck et al. 2008). Therefore, parents have a high chance of being recognised as role models, assuming that they spend time with their children. As suggested by the gender socialisation hypothesis, children may be more likely to regard the parent of the same sex as their role model (Marks 2008a; Sikora and Pokropek 2012b). Second, parents' active involvement in children's education may include passing on expertise and skills used in their occupations to their children (Chakraverty and Tai 2013; Ma 2009), but its effectiveness depends on whether parents believe that certain subject domains and occupations are more important to a particular gender (Bieri Buschor et al. 2014). As discussed earlier in this section, parents may overrate sons' ability in mathematics, and believe that mathematics and science are less interesting and more difficult for daughters (Tenenbaum and Leaper 2003; Tiedemann 2000). If parents work in mathematics and science, they may have a higher propensity to encourage their sons than their daughters to engage in those fields. Further, if parents show clear support and acknowledgement of children's interest and engagement in gender-atypical

education and activities, boys and girls will be more likely to persist in the gender-atypical educational pathway and ultimately choose a gender-atypical field of study and career (Bieri Buschor et al. 2014).

Stratification studies of students' occupational expectations are consistent with the basic tenets of the gender socialisation hypothesis (Marks 2008a; Marks 2008b). In a sample of British adolescents born around the early 1980s, boys tended to aspire to male-dominated careers if their fathers had the same type of occupations, whereas girls tended to expect gender-atypical careers if their mothers were engaged in male-dominated fields (Polavieja and Platt 2014). In the mid-2000s, relevant paternal employment increased Australian boys' chances of aspiring to careers in the physical sciences while relevant maternal employment enhanced Australian girls' chances of aspiring to careers in the life sciences (Sikora and Pokropek 2012b).

Recent stratification research in Australia has also demonstrated that parental employment in either physical science or life science fields may increase their children's engagement in the physical sciences. Studies using the 2006 cohort of LSAY show that parental employment in science increases a student's chance of choosing physical science and life science subjects in Year 12 and pursuing a bachelor's degree in physical science (Sikora 2014b; Sikora 2015). Thus far, the Australian studies have not examined whether maternal and paternal employment in science stimulates the same-sex children's engagement in advanced mathematics in high school and related fields of study at university. The present study attempts to fill in this gap.

2.5 Gender-typed occupational expectations

The expectancy value theory argues that socialisation practices in the family and subjective task values have some indirect influence on students' decisions to pursue mathematically intensive fields through their significance for the development of

students' occupational expectations (Eccles 2011). These expectations reflect students' perceptions of stereotypes regarding mathematics and the gender roles expected of them, as well as opportunities and constraints, which are shaped by socialisation that takes place in the family, school and society.

Boys and girls develop different occupational orientations during childhood that considerably influence their later occupational decisions (McMahon and Patton 1997; Tai et al. 2006). In Australia and many countries, boys are more likely to plan their careers in computing, engineering and mathematics, whereas girls are more likely to expect careers in biology, agriculture and health (Jerrim and Schoon 2014; Sikora and Pokropek 2012a). The occupational expectations of young people are likely to change during adolescence and early adulthood (Rindfuss, Cooksey and Sutterlin 1999). Despite that, an early American study showed that in the long run adolescent boys were more likely than girls to persist in expecting science and engineering careers (Mau 2003).

In spite of the clear distinction, much of the stratification literature overlooked the role of adolescents' science-related career expectations until recent years. One of the exceptions from the American stratification studies is that of Morgan, Gelbgiser and Weeden (2013) who found that gender-differentiated occupational expectations in Year 12 explained a large portion of the gender gap in choosing a science field of study. Another exception is Legewie and DiPrete (2014b) who showed that the gender gap in planning a science career in Year 8 predicted the gender gaps in the Year 12 intentions to study science and the attainment of a bachelor's degree in science in the United States. In addition, science-related career expectations partially explain gender segregation in science education. In Australia, recent stratification studies have found that 15-year-old students who aspire to a physical science career are more likely to engage in relevant subjects in Year 12 and related fields in post-secondary education

(Sikora 2014b; Sikora 2015). Although the general patterns of occupational expectations are known, studies in Australia before this thesis have rarely addressed the question of how early occupational expectations of boys and girls affect their decisions to pursue advanced mathematics in Year 12. The present study examines this question.

2.6 Gender-biased self-assessment of mathematical abilities and career-related tasks

Apart from gender-differentiated subjective task values in mathematics and related disciplines, Eccles (2011) suggests that another important reason that young women have a lower chance of pursuing the mathematically intensive sciences is that they feel less competent in mathematics and related areas. Due to the gender essentialist ideology, gender socialisation and gender differences in the subjective task values attached to mathematically intensive fields, males tend to rate their mathematical abilities higher than do females (Eccles 2011; Schoon and Eccles 2014). The stereotypical belief that mathematics and related sciences are masculine and more appropriate for males may enhance the confidence of males while increasing females' anxiety (Niederle and Vesterlund 2010; Spencer, Steele and Quinn 1999; Steele 1997). Females who strongly believe in this stereotype tend to avoid mathematics and related disciplines (Nosek and Smyth 2011).

Psychology scholars often regard one's perception of their abilities or competencies in mathematics as mathematics self-concept (Marsh 1986; Marsh 1990). It is known that the gender gap in self-concept persists among high school students even when boys and girls perform equally well in the subject (Wilkins 2004). When girls underestimate their talents in mathematics, they are more likely than boys to reduce their efforts to pursue mathematically intensive fields. In the late 1990s, girls in north metropolitan Sydney, Australia, were less likely to choose advanced high school

mathematics partly because they had lower self-concept in mathematics than boys (Watt 2006). Another Australian study using the 2003 cohort of LSAY data has also demonstrated that girls are less likely than boys to enrol in more complex mathematics subjects in Years 11 and 12 partially because they have lower self-concept in mathematics (Guo et al. 2015). A German study which used data from the 2000s demonstrated that male advantage in mathematics self-concept in high school contributed to the under-representation of women in mathematically intensive tertiary education (Parker et al. 2014). The same study also found that mathematics self-concept was the strongest predictor of having a long-term career aspiration and a university major in the mathematically intensive sciences, whereas mathematics achievement at school was less relevant (Parker et al. 2014). These findings imply that mathematics self-concept, rather than achievement, is the factor that filters out females from mathematically intensive fields at various stages of education.[3]

Mathematics self-concept has a closely related construct, mathematics self-efficacy, but they are conceptually and empirically distinguishable from each other (Ferla, Valcke and Cai 2009; Lee 2009). While mathematics self-concept is domain-specific, mathematics self-efficacy is task-specific and it represents one's perceived capabilities to successfully perform a designated task in mathematics or solve specific mathematics problems (Bong and Skaalvik 2003; Pajares 1996; Pajares 2005; Wigfield and Eccles 2000). Compared to mathematics self-efficacy, mathematics self-concept is a stronger predictor of motivational variables, such as anxiety and interest in mathematics (Ferla, Valcke and Cai 2009). Similar to mathematics self-concept, gender differences in mathematics self-efficacy exist and early psychological research has also

[3] A considerable amount of psychological research has documented the positive and reciprocal relationship between students' mathematics self-concept and achievement. Strong mathematics achievement raises students' self-concept in the subject; however, the corollary is also true whereby high self-concept generates improvements in mathematics achievement (for example, Huang 2011; Marsh, Byrne and Yeung 1999; Marsh and Craven 2006; Seaton et al. 2014).

demonstrated that they facilitate gendered choices of mathematically intensive fields of study (Bussey and Bandura 1999). Mathematics self-concept measures one's perceived abilities in mathematics in general, rather than one's perceived capabilities to perform specific tasks in mathematics. Therefore, in the study of gendered participation in mathematically intensive disciplines, mathematics self-concept is a more comprehensive measure of overall mathematical abilities than mathematics self-efficacy.

Stratification research covers gender-biased self-assessment not only of mathematical abilities but also of career-relevant tasks and professional role confidence (Cech et al. 2011; Correll 2001). In the case of mathematically intensive fields of study and careers, females have lower self-assessment of mathematical task competence compared to males. Under the influence of this lower self-assessment, females are less likely than males to engage in advanced mathematics in secondary school and related fields of study in tertiary education (Correll 2001). Not only does gender-biased self-assessment exist in career-relevant tasks and skills, but it also prevails in professional role confidence which Cech and her colleagues (2011) define as faith in the 'ability to fulfil the expected roles, competencies, and identity features of a successful member of their profession.' (p. 642) They examined the experiences of a sample of American engineering students in the 2000s and found that women tended to have less professional role confidence than men. This lower level of confidence in women increased their attrition rates from engineering programs and industries. To sum up, this stratification literature fully accounts for the social-psychological factors that lead to the under-representation of females in advanced mathematics and related fields of study.

2.7 Gender differences in mathematics performance

Early stratification studies have argued that girls are less likely to take part in mathematically intensive fields because they outperform boys in verbal skills but fall behind boys in mathematics at school (Jonsson 1999; Van De Werfhorst, Sullivan and Cheung 2003). Similarly, some psychological studies focus on gender differences in school achievement in the early stages of life and regard such differences as the major cause of women's under-representation in mathematics and science at later stages of their educational careers (see, for example, Else-Quest, Hyde and Linn 2010; Lubinski and Benbow 1992; Wai et al. 2010).

Nevertheless, over the last few decades, male advantage in mathematics has narrowed substantially around the globe – a trend which has also been witnessed in Australia (Baker and Jones 1993; Baker and LeTendre 2005). Reviews of previous studies conducted from the 1980s to the 2000s and primarily originating from the United States point out that males surpass females in mathematical and spatial ability, but this does not explain the under-representation of women in mathematically intensive fields (Ceci and Williams 2010a; Ceci and Williams 2010b). A recent stratification study from the United States that used data from three nationally representative cohorts of high school and tertiary students in the 1980s, 1990s and 2000s led to similar conclusions (Riegle-Crumb et al. 2012). It found that the separate advantages boys and girls enjoyed in mathematics versus verbal achievement explained very little of the variation in the lesser likelihood of women engaging with tertiary mathematically intensive studies.

In addition to a lack of evidence in empirical analysis, viewing gender differences in mathematics achievement as a major cause of gendered study choice overlooks the contributions of other individual and sociocultural factors. Such

individual factors include family socialisation practices, self-assessment of mathematical abilities, as well as vocational interests and aspirations, as argued by the expectancy value theory (Eccles 2011). These individual characteristics are also shaped by cultural beliefs and normative social practices over a student's life course.

2.8 Life course perspective: advanced mathematics and related course-taking in secondary education

Students who pursue mathematically intensive tertiary studies tend to have taken relevant subjects in high school (Correll 2001). In line with this argument, in Australia students who are engaged in mathematically intensive tertiary fields of study tend to take physical science subjects in conjunction with advanced mathematics in Year 12 (Lamb and Ball 1999). Consistent with the gender segregation patterns in tertiary fields of study, boys are more likely than girls to study advanced mathematics and physical science subjects in Year 12 (Fullarton and Ainley 2000; Rennie 2010).

Thus far stratification studies have produced different findings regarding the extent to which relevant subject choice in secondary education facilitates the engagement of men and women in mathematics-related tertiary studies. During the late 2000s, young Australians, particularly women, were more likely to pursue post-secondary education in the physical sciences if they studied a relevant subject in Year 12 (Sikora 2014b). Using the American student data from the 1980s, Ethington and Woffle (1988) found that the number of mathematics and science courses girls selected in high school increased their likelihood of pursuing tertiary studies in the mathematically intensive sciences. On the contrary, using the same data, Frehill (1997) demonstrated that increasing the number of mathematics and science courses girls studied in high school would only lead to a trivial growth in the proportion of women choosing engineering.

Previous educational studies in Australia provide evidence that students who choose advanced mathematics in the final years of secondary school have a greater chance of performing well in their first-year university mathematics and science courses (Nicholas et al. 2015; Rylands and Coady 2009). These students are also more likely to take mathematics courses in later years of university education and complete a mathematics major (Varsavsky 2010). However, these studies did not consider other key factors in the life course of students, such as early occupational expectations and mathematics self-concept. As I discussed in sections 2.5 and 2.6, aspiring to a mathematically intensive career and having high self-concept in mathematics may increase a student's chance of choosing related subjects in Year 12. In turn, these subject choices may enhance a student's propensity to engage in mathematics-related fields in tertiary education. Therefore, this literature highlights the need to understand from a life course perspective how each of these factors, early occupational expectations, mathematics self-concept and subject choice in high school, contributes to the gendered choices of mathematically intensive university studies.

2.9 The impact of the school environment – stratification theories

The allocation model of status attainment argues that the educational and occupational attainment of a student is constrained by social structure (Kerckhoff 1976). According to this model, the institutional arrangements of educational systems and schools sort students into different educational trajectories and outcomes (Kerckhoff 1995; Kerckhoff 2001). The institutional arrangements of educational systems and schools also channel young people into separate fields of study and occupation based on their genders (Charles and Bradley 2002; Smyth and Steinmetz 2008). Other than the family of origin, recent stratification studies have pointed out that the school environment has an equally important impact on adolescents' educational and occupational choices (Legewie and DiPrete 2014a; Sikora 2014a). In the late 1980s in

Melbourne, Australia, the gender gap in advanced mathematics enrolment tended to be smaller in schools that have implemented more liberal policies (Lamb 1996). Examples of such policies include offering a wide variety of elective subjects, using non-graded assessment, adopting student-centred approaches in teaching and abandoning selective admission.

Teachers and peers also influence the decisions of adolescent boys and girls to pursue advanced mathematics and related disciplines. At school, teachers are inclined to overrate boys' mathematical competence and to have higher expectations for boys in mathematics education (Li 1999). When girls are aware of the gender bias in their teachers' perceptions of their mathematical competence and expectations, they may adjust their attitudes and expectations regarding mathematics education correspondingly. With respect to advanced mathematics course-taking in high school, a stratification study from the United States which used student data from the 1990s has demonstrated that girls' decisions to select advanced mathematics were more likely than those of boys to be influenced by the performance of the same-sex peers around them (Riegle-Crumb, Farkas and Muller 2006). Nevertheless, as I discuss below, the influence of teachers and peers on students' engagement in advanced mathematics and related fields of study in coeducational schools may be different from that in single-sex schools.

Among various characteristics of the Australian school system, I devote most of my attention to single-sex schooling due to the worldwide debate on the extent to which single-sex schooling counteracts gender stereotypes and promotes engagement in advanced mathematics and related science disciplines (Signorella, Hayes and Li 2013; Smithers and Robinson 2006). In a range of international settings, proponents of single-sex schools argue that these schools promote gender equality by providing a learning environment that encourages boys and girls to participate in gender-atypical fields

(Salomone 2003; Smithers and Robinson 2006). In all-girls schools, there are more women teaching traditionally male-dominated subjects, such as mathematics and physical science subjects. These women can serve as role models for girls (Catsambis 2005; Mallam 1993). The absence of boys in all-girls schools may reduce the pressure for girls to view the mathematically intensive sciences as masculine and to conform to traditional gender role expectations (Catsambis 2005; Cherney and Campbell 2011; Vockell and Lobonc 1981). This environment may boost girls' confidence in their mathematical abilities (Foon 1988). On the contrary, girls in coeducational schools may have difficulty in overcoming traditional gender stereotyping in learning mathematics and pursuing the mathematically intensive sciences (Salomone 2003). Similarly, all-boys schools may ease the pressure for boys to comply with traditional gender role expectations and enhance their interest in traditionally less male-dominated domains (Foon 1988; James and Richards 2003; Salomone 2003).

Studies in Australia and Britain show evidence for elevating students' achievement and engagement in gender-atypical subjects. Based on a sample of students from 16 non-government schools in Melbourne in the 1980s, boys in all-boys schools were more likely to prefer English than girls in all-girls schools and boys in coeducational schools (Foon 1988). Among the same group of schools, girls in all-girls schools had a higher chance of preferring science and performing well in mathematics and science than girls in coeducational schools. When a cohort of British students born in 1958 turned 16, girls had higher self-concept in English, and boys in mathematics and science, but the gender gaps in those self-concepts were smaller among those who went to single-sex schools (Sullivan 2009).

Not all single-sex schools enjoy the same range of resources and such variations may lead to different academic outcomes. Class observations in two all-girls schools in Brisbane, Australia, showed that mathematics learning was constructed differently

based on the socioeconomic status of the school (Atweh and Cooper 1995). In the observed class of the high socioeconomic school, mathematics was regarded as preparing students for university entry. By contrast, in the observed class of the low socioeconomic school, mathematics was perceived as fulfilling daily life activities. Therefore, the effect of attending a single-sex school on raising students' performance and engagement in mathematics and related disciplines may depend on the school's socioeconomic status.

Existing studies comparing students' engagement in advanced mathematics and related fields of study between single-sex and coeducational schools arrived at mixed conclusions. Spielhofer and his colleagues (2004) found that in the mid-1990s in England, boys and girls in single-sex schools had a higher chance of enrolling in advanced mathematics than their same-sex peers in coeducational schools. During the late 1990s and mid-2000s in Australia, students in single-sex schools were as likely as their peers in coeducational schools to enrol in physical science subjects in Year 12 (Ainley and Daly 2002; Sikora 2014a). Among a sample of British students born in 1958, male and female students who attended single-sex schools were more likely to pursue gender-atypical subject areas in secondary and post-secondary education (Sullivan, Joshi and Leonard 2010). Between the 1970s and the 1990s in the United States, boys who attended all-boys schools did not only show higher interest in the humanities than their same-sex peers who attended coeducational schools, but they were also more likely to engage in similar fields in post-secondary education and employment (James and Richards 2003). Likewise, another American study shows that men who attended all-boys schools in the 1990s were more likely to gain university qualifications in gender-neutral fields than men who attended coeducational schools (Karpiak et al. 2007). Other American studies find that although women who attended all-girls schools in the 1980s and 1990s were more likely to declare gender-neutral

fields of study, they were just as likely as their same-sex peers who attended coeducational schools to complete a degree in those fields (Karpiak et al. 2007; Thompson 2003). In Northern Ireland, boys and girls who attended coeducational schools in the 1990s had a higher chance of studying academic science subjects in pre-university education than their peers in single-sex schools (McEwen, Knipe and Gallagher 1997). In summary, the inconsistent findings imply that the effectiveness of single-sex schooling in counteracting gender stereotypes in mathematics and science education depends on historical and local contexts (Kim and Law 2012; Law and Kim 2011; Sikora 2014a), as well as some methodological issues which will be discussed in detail in Chapter 4.

2.10 Summary

On the whole, this discussion of the literature highlights the need to go beyond the 'leaky pipeline' argument in theorising why females are under-represented in advanced mathematics and related disciplines. While the 'leaky pipeline' argument indicates that females may feel inclined to never take up mathematics in the first place or be more likely to opt out of advanced mathematics and related fields of study at subsequent stages of education, other theories offer a more nuanced account of the individual and sociocultural factors that operate over a life course to foster gender segregation in mathematics.

In the above discussion, I proposed theories from the fields of social stratification and psychology, namely the gender essentialist hypothesis and the expectancy value theory, as essential for the understanding of gendered study choices at the secondary and tertiary levels. According to these theories, students' decisions to engage in advanced mathematics and relevant fields of study are shaped not only by psychological factors but also by the widely shared gender-stereotypical beliefs and

social structures that constrain individual choices throughout the life course of young people. Stratification scholars do not attribute the under-representation of females in mathematics and related disciplines merely to gender differences in mathematics achievement. Such differences have become less important or entirely trivial over the last few decades in many countries, including Australia, and they can only explain a small part of the low rates of female participation in advanced mathematics. Instead, the stratification approach to gender essentialism offers a more convincing explanation at the institutional and macro levels. In this approach, students are seen as internalising the widely shared gender-stereotypical beliefs through socialisation in the family, peer groups, school and society. In developed countries, such as Australia, students are encouraged to choose the fields of study they enjoy from a wide range of curricular options. Meanwhile, the large service sector offers plentiful employment opportunities in fields that are female-labelled and do not require high levels of numeracy. Female students may be more likely to pursue those potentially self-expressive and feminine career opportunities and find it easier and more congenial than their male peers to avoid mathematically intensive fields.

The expectancy value theory complements stratification theories in explaining how gender-stereotypical beliefs affect students' engagement and persistence in advanced mathematics and related disciplines over the life course. At the micro level not only do gender-stereotypical beliefs affect the development of one's gender identity, but they can also shape a student's perception of their academic abilities, subjective task values in mathematics, and educational and occupational expectations. At the macro level, these beliefs form widespread and pervading cultures.

My review of the expectancy value theory, the gender essentialist hypothesis and other stratification theories has led me to organise my empirical analysis in the following manner. First and foremost, it is essential to adopt a life course perspective.

Therefore, I begin from examining the individual factors that contribute to gendered participation in advanced mathematics at the secondary level (Chapter 5) and then follow up with the analysis of the extent to which experiences and motivations in secondary school affect what happens in tertiary education (Chapter 6). Specifically, in Chapter 5, I analyse subject choices in the last year of secondary schooling. I consider how gender socialisation practices in the family and its socioeconomic status compare to the school experiences and students' individual motivations as determinants of which students end up in advanced mathematics classes in Year 12. My analysis is based on both stratification research and the expectancy value theory. Recent stratification studies have provided evidence supporting the gender socialisation hypothesis that students' occupational expectations are not only gendered but are also more likely to be influenced by parents of the same sex than parents of the opposite sex. I examine this possibility in my data. I extend this literature by examining whether maternal and paternal employment in science increases the chances of the same-sex children's enrolment in advanced high school mathematics. Finally, I consider the role of adolescent occupational expectations in the propensity to enrol in these classes.

In Chapter 6, I switch my attention to the next stage of education, that is university, but my focus remains primarily on the determinants that stem from secondary school experiences, motivations and the influences in parental homes while students were in their late teens. This focus on the degree to which early experiences reflect in specialisation choices made in tertiary education is the key element of my life course approach. I consider systematically how much earlier gender socialisation practices in the family, adolescent expectations, mathematics self-concept and study choices in Year 12 determine field of study at university. Throughout my analysis, I assess the relative importance of each of these factors because policy implications of this analysis will be more concrete if such a hierarchy of importance can be established.

The life course perspective and the allocation model of status attainment suggest that a student's subject choice is constrained by the structure of the educational system and of the school environment over students' educational careers. Therefore, in Chapter 7, I turn my attention to the effects of the school environment on the gendered participation in advanced mathematics in secondary school and related fields of study at university. Although I consider the differences in various school resources and characteristics, I pay most of my attention to the effects of single-sex schooling because of arguments that gender-segregated education has a great potential to counteract gender stereotypes and enhance engagement in gender-atypical fields, although I note that empirical evidence for this argument is mixed. More precisely, I examine whether gender differences in the choices of advanced mathematics in secondary school and related disciplines at university are smaller among graduates of single-sex schools than of coeducational schools. My analysis is guided by the research questions listed in the following section.

2.11 Research Questions

To study how family socialisation practices and students' occupational expectations contribute to the gendered choices of advanced mathematics in Year 12, I answer three research questions in Chapter 5:

1. Are girls from families of higher socioeconomic status more likely than boys from families of lower socioeconomic status to study advanced mathematics in Year 12?

2. Are children more likely to be influenced by the same-sex parent who works in science to study advanced mathematics in Year 12?

3. Do students' career expectations in the mathematically intensive sciences at age 15 correspond to the gender gap in studying advanced mathematics in Year 12?

To examine various factors that lead to the gender gap in the choice of a mathematically intensive field of study at university, my analysis in Chapter 6 examines the following research questions:

1. Is the gender gap in the choice of a mathematically intensive university major smaller among students from families of high socioeconomic status?

2. Are young people more likely to be influenced by the same-sex parent than the opposite-sex parent in their choice to pursue mathematically intensive university studies?

3. What is the relative importance of students' occupational expectations, mathematics self-concept, and choice of advanced mathematics and physical science subjects in high school in explaining the gender gap in the choice of a mathematically intensive university major?

In Chapter 7, I assess the impact of attending a single-sex secondary school on students' chances of taking advanced mathematics in Year 12 and on their chances of selecting a mathematically intensive bachelor's degree program. My analysis responds to two research questions as follows:

1. Is the gender gap in advanced mathematics enrolment in Year 12 smaller in single-sex schools than in coeducational schools?

2. Is the gender gap in the choice of a mathematically intensive university major smaller among graduates of single-sex schools than of coeducational schools?

The gender essentialist hypothesis suggests that comprehensive educational systems, such as the Australian one, offer a wide range of curricular options (Charles and Bradley 2009). Therefore, in the next chapter, I present an overview of Australia's

contemporary educational system and discuss its structural features. I also pay attention to single-sex education and the private school sectors in Australia and reveal how these types of schooling may influence a student's decision to pursue advanced mathematics and relevant fields of study. The gender essentialist hypothesis also argues that female students are more likely to steer clear of mathematics and related disciplines and pursue study options that are perceived to be more people-oriented and self-expressive (Charles et al. 2014). Hence, I describe the mathematics curriculum in senior secondary school and discuss how Australian students are given the options to engage in or withdraw from mathematics.

Chapter 3

Mathematics and the transition from secondary to tertiary education

In the previous chapter, I extended the expectancy value theory with a stratification approach to gender essentialism to introduce the theoretical framework for my research. I also reviewed previous studies of gender segregation in mathematically intensive education in advanced industrial countries. By adopting a life course perspective, I discussed the ways in which the decisions of males and females to pursue advanced mathematics and related disciplines were affected not only by their socialisation and educational experiences but also by their surrounding social structures and cultural beliefs. The next question to ask is why this thesis focuses on the Australian context.

From an international perspective, Australia is a fascinating case for study because in its comprehensive education system students are not sorted into either academic or vocational types of upper secondary schools. However, the Australian education system is characterised by high levels of choice, privatisation and competition (Perry and Southwell 2014). In almost all secondary schools students are streamed according to their ability (hereafter, ability streamed) to learn mathematics (OECD 2013). These characteristics of an educational system affect not only the educational attainment of students (Kerckhoff 1995) but also their access to advanced mathematics education (Perry and Southwell 2014). In addition, the wide variety of curricular options provided by the Australian education system makes up an environment that encourages students to pursue fields of study they are keen on. In such an education system driven by student choices, females have abundant opportunities to specialise in

fields that are considered to be people-oriented and feminine (Charles and Bradley 2009).

To understand how the Australian education system might provide opportunities for males and females to make gendered educational choices, I discuss in section 3.1 Australia's contemporary education system with an emphasis on its practices of ability streaming and privatisation. Specifically, I explain how these practices affect students' access to advanced mathematics subjects in secondary school. A continuous decline since the 1990s in advanced mathematics enrolment in the final years of secondary schooling (Years 11 and 12) implies that mathematics is less culturally valued today than over two decades ago. I provide evidence for this argument in section 3.2. As more students and girls in particular refuse to engage in advanced mathematics (Forgasz 2006), it is exceptionally important to understand the dynamics of gender differences in advanced mathematics enrolment. In section 3.3, I discuss the mathematics curriculum in secondary school and reveal when and how students make their subject choices. Next, in section 3.4, I explain how the prerequisite requirements for university education and the scaling mechanism for university admission provide students with the incentives to avoid choosing advanced mathematics subjects in secondary school. Despite only a small proportion of students taking advanced mathematics, in section 3.5 I argue that engagement with advanced mathematics is important to students' futures.

3.1 Students' access to advanced mathematics in secondary school in Australia

3.1.1 Ability streaming and advanced mathematics

Australia has a comprehensive education system that does not separate students into different types of secondary schools according to their performance or limit students' access to specific types of mathematics education. In the analysis of

educational systems, stratification is defined as the degree to which educational systems have clearly differentiated types of schools whose curricula have higher or lower levels of academic offerings (Kerckhoff 2000; Kerckhoff 2001). The stratification literature suggests that educational stratification influences students' access to mathematics education (Buchmann and Park 2009; Kerckhoff 2001). In highly differentiated educational systems, students are separated at an early age, usually into either academic or vocational schools, between which movement is rare (Buchmann and Park 2009; Kerckhoff 2000). In such school systems, the kinds of mathematics curricula that students can get access to depend on the type of school they attend. While students in the academic track are able to take advanced calculus-based mathematics courses, students in the vocational track usually do not have access to such courses. In contrast to the highly differentiated educational systems, the Australian school system does not stratify schools along the academic–vocational divide. It allows students to make their own subject choices at a later age (about 16) when they reach senior secondary school (Years 11 and 12). Therefore, the comprehensive education system in Australia, at least in theory, does not restrict access for either male or female students to a particular type of mathematics education.

In Australia there are no national policies on ability streaming (Johnston and Wildy 2016), but a majority of secondary schools practise ability streaming in mathematics education by offering mathematics subjects at varying levels of difficulty.[4] Since the beginning of the twenty-first century, over 95 per cent of Australian students have been grouped by ability across or within their mathematics classes (OECD 2013). Despite ability streaming in the Australian school system, in theory boys and girls can easily choose to study advanced mathematics or lower levels of mathematics.

[4] I describe the various levels of difficulty of mathematics subjects in more detail in section 3.3.

3.1.2 Students' access to advanced mathematics in the Australian education system

The principle of free choice executed by Australian students in their engagement with mathematics subjects in secondary school is not entirely borne out in practice. Students' choices are in fact related to their socioeconomic background and gender. In Australia, the private school sector which encompasses Catholic and independent schools has been expanding since the 1980s (Campbell and Proctor 2014).[5] Parents from privileged backgrounds are increasingly sending their children to private schools (Campbell, Proctor and Sherington 2009). Today, more than a third of all secondary school students attend a private school in either the Catholic or independent sector (ABS 2014b). Students who attend private schools tend to come from families of higher socioeconomic status, whereas students from families of lower socioeconomic status mostly attend government schools (Watson and Ryan 2010). Compared to private schools, government schools tend to offer fewer advanced academic subjects, including advanced mathematics, mainly due to the differences in socioeconomic composition between private and government schools (Perry and Southwell 2014). Schools in low socioeconomic communities offer fewer advanced academic subjects as the demand for such subjects is lower than schools in high socioeconomic communities. This makes it particularly hard for the relatively few mathematically talented students in low socioeconomic communities to take advanced mathematics. In line with these findings, earlier Australian studies have found that students from privileged families, who are likely to attend schools in high socioeconomic communities, tend to enrol in advanced academic subjects which include advanced mathematics, physics and chemistry (Ainley, Kos and Nicholas 2008; Lamb, Hogan and Johnson 2001; Teese 2007).

[5] In Australia, independent schools receive subsidies from the government and belong to the regulated educational system (Campbell and Proctor 2014).

As discussed in section 2.4 in the previous chapter, early stratification studies in Australia found that in Melbourne girls from families of low socioeconomic status had the lowest chance of studying advanced mathematics (Lamb 1996; Lamb 1997). This is not only because growing up in families of low socioeconomic status hindered these girls from selecting advanced mathematics, but also because gender socialisation practices were likely to be more traditional in their families and therefore they were rarely encouraged to pursue advanced mathematics.

The majority of single-sex schools in Australia are also private schools that charge tuition fees (Forgasz and Hill 2013). In recent decades, single-sex education in Australia has been shrinking. While more than half of the students from the private school sector attended single-sex secondary schools in 1985, the proportion dropped to about 43 per cent in 1995 (ABS 1997). Among those secondary school students who participated in the 2009 cohort of LSAY, only about 30 per cent attended single-sex schools (Sikora 2014a). The decline in the proportion of students enrolling in single-sex schools is worth attention, as early research suggests that when single-sex schools become rare, they become academically selective and are likely to bring about superior educational outcomes (Baker, Riordan and Schaub 1995). Therefore, boys and girls who attend single-sex schools may be more likely than boys and girls in coeducational schools to study advanced mathematics and related subjects because students in these privileged, single-sex schools are encouraged to be ambitious and to study advanced mathematics.

As discussed in the previous chapter, the stratification theory of gender essentialism suggests that the Australian education system, which is driven by student choices, may encourage more females to pursue other disciplines in preference to advanced mathematics and thus intensify gender segregation in fields of study (Charles and Bradley 2009). Specifically, the Australian education system provides a wide range

of curricular options for students to choose from and encourages students to specialise in the disciplines they are interested in. When students make their subject choices for final years of secondary schooling, girls have ample opportunities to select subjects that are regarded as self-expressive, people-oriented and feminine in contrast to advanced mathematics and related disciplines that are commonly perceived as abstract, technical and masculine. To sum up, students' subject choices are not made freely. They are in fact contingent on their socioeconomic background and gender.

3.2 Progressive devaluing of mathematics

Despite the enormous demand in Australia for skilled workers with advanced mathematics skills (Australian Industry Group 2013), enrolments in advanced high school mathematics have been falling since the 1990s (Kennedy, Lyons and Quinn 2014). A possible factor leading to such a decline is that mathematics progressively becomes culturally devalued. In the early 1990s, many Year 11 girls in Queensland and Victoria engaged in advanced mathematics because they perceived that advanced mathematics was required in certain fields of study and occupations, and the inclusion of advanced mathematics kept their options for a tertiary field of study open (Johnston 1994). Today, tertiary institutions remove advanced mathematics from most of their admission prerequisites, and therefore students do not need advanced mathematics to widen their field of study options. Since the 1990s, enrolment in advanced mathematics has declined but more so for girls than boys (Forgasz 2006). This phenomenon highlights the need to examine the dynamics of gendered participation in advanced high school mathematics among the recent cohort of Australian youth.

3.3 Mathematics curriculum in senior secondary school

To understand why girls are more likely than boys to shun advanced mathematics, it is important to know the contemporary mathematics curriculum and to

figure out when and how students make their subject choices in the Australian education system. In Australia, each state or territory is responsible for their own educational administrations and curricula, although the overall structures are similar.[6] The generation of contemporary 15-year-old Australian students in general start their encounter with formal education at the age of 3 or 4 when they participate in early childhood education programs, that is, kindergarten. By the time Australian children reach the age of 5 or 6, they begin their compulsory education from Year 1 to Year 10. In primary school and the first two years of secondary school, students typically follow a general program provided by their school. In the subsequent years of secondary education, they study basic core subjects and select optional subjects. In senior secondary school (Years 11 and 12), most schools offer a broad variety of subjects and students specialise in five or six elective subjects. Students are entitled to choose the combination of subjects that they and their school advisers deem appropriate for their future education and employment (Wernert et al. 2012).

In recent years in consultation with states and territories, the Australian Government has put a considerable amount of effort into developing a national curriculum which covers a range of subjects, including mathematics and science. This is a feature of educational standardisation, that is, 'the degree to which the quality of education meets the same standards nationwide' (Allmendinger 1989, p. 233). The use of a national curriculum is one of the key features of standardisation that reduce socioeconomic inequality in student achievement, as pointed out in stratification research (Van de Werfhorst and Mijs 2010). In 2008, the Australian Curriculum, Assessment and Reporting Authority (ACARA) launched the Australian Curriculum (ACARA 2016). It outlines the core knowledge, understanding, skills and general

[6] Australia is a federation of six states – New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia – and two territories – the Australian Capital Territory and the Northern Territory.

capabilities important for all Australian students across preschool, primary, secondary and senior secondary education. Schools are responsible for implementing the Australian Curriculum. Although they have the authority to choose the mathematics and science textbooks for teachers and students, they need to ensure that those textbooks conform to the Australian Curriculum (Wernert et al. 2012). As the national curriculum was introduced in 2008, the Y03 cohort of students, who represent the nationally representative sample of students in my study, were attending secondary schools at a time when the national curriculum was not yet launched. Therefore, the national curriculum has more implications for the later generation of students than for the Y03 cohort.

Australian schools offer different levels of mathematics subjects and a wide variety of science subjects to Years 11 and 12 students. Every state and territory adopts its own subject labels with varied curricula. Ainley and his colleagues (2008) point out three features regarding subject labels: (1) they may differ between states and territories, although the course content is similar; (2) they may change over time even though there are only minor changes in content; (3) sometimes the same subject label refers to subjects with different content.

Senior secondary mathematics subjects can be classified across states and territories based on their levels of difficulty as elementary, intermediate and advanced, although states and territories do not use these three labels in their subject names (Barrington and Brown 2005; Forgasz 2006). Elementary mathematics is appropriate for students 'who wish to study mathematics in their final year at secondary school, but do not intend to enter tertiary courses that require intermediate or advanced mathematics subjects' (Barrington and Brown 2005, p. 2). These tertiary courses include those in the arts, humanities and social sciences. Intermediate mathematics is suitable for students 'who wish to proceed to tertiary studies that require significant but not extensive

mathematical preparation, such as medicine, economics, commerce, dentistry and agricultural science' (Barrington and Brown 2005, p.1). In general, intermediate mathematics subjects cover materials on functions and graphs, algebra, and an introduction to probability and calculus (Barrington and Brown 2005).

Advanced mathematics subjects refer to the prerequisites or assumed knowledge that provide students with the best start in tertiary studies that require significant mathematical preparations, such as engineering, information technology, mathematics and the physical sciences. This definition was drawn from previous Australian research on school mathematics enrolment (Barrington 2006; Barrington and Brown 2005; Dekkers and Malone 2000; Forgasz 2006; Fullarton et al. 2003). Advanced mathematics subjects encompass calculus, complex numbers, algebra and trigonometric functions, as well as a selection from coordinate geometry, mechanics, logic and proof, sequences and series, vectors and matrices, although the coverage of these topics varies among states and territories (Barrington and Brown 2005).

3.4 Advanced mathematics and its relation to university admission

In the past, Australian students who did not study advanced mathematics in senior secondary school limited their tertiary study options and excluded themselves from further education in mathematically intensive fields such as engineering, information technology and the physical sciences. However, this has become less of a problem since the beginning of the twenty-first century. In response to the declining number of students who enrol in advanced mathematics in senior secondary school, over the last two decades many Australian universities have changed their program prerequisites (Varsavsky 2010). Today, not all engineering programs across the country require advanced mathematics as some of them have changed the prerequisites from

advanced to intermediate mathematics. Many science programs admit students without any senior secondary school mathematics.

To provide a larger number of students with the opportunity to pursue mathematically intensive disciplines and to improve retention, universities offer bridging courses for students who do not have sufficient mathematics background. These bridging courses support student transition from secondary school to university mathematics. They typically run intensively for one or two weeks for students to acquire the assumed knowledge in their university mathematics studies, but they do not necessarily equip students with satisfactory mathematics preparation for two reasons (Rylands and Coady 2009). One reason is that universities do not force students to attend bridging courses. Another is that one or two weeks of intensive studies cannot replace months of secondary school studies in advanced calculus-based mathematics.

An unintended consequence of the change in prerequisite requirements is that advanced mathematics enrolments in senior secondary schools continue to fall. Students have progressively shifted away from intermediate and advanced mathematics to the elementary level. As a result, since the 1990s enrolments in intermediate and advanced mathematics have gradually declined whereas enrolments in elementary mathematics have dramatically increased (Kennedy, Lyons and Quinn 2014). The decline in advanced mathematics enrolments has been more pronounced for girls than for boys (Forgasz 2006). There is a perception that it is easier to get excellent scores in the lowest possible level of mathematics, and therefore a large group of students favours elementary mathematics in order to maximise their Australian Tertiary Admission Ranks (ATAR) used for the competitive admission to university (Varsavsky 2010). This claim is supported by a recent study based on analyses of data for students' mathematics performance in Years 10 and 12 in New South Wales. By employing the scaling algorithm used to derive ATAR, the study demonstrates that, on average, the study of

elementary mathematics leads to higher scaled scores than the study of intermediate mathematics (Pitt 2015). In other words, the ATAR scaling algorithm provides a strong incentive for students to enrol in elementary mathematics even if they are capable of studying intermediate or advanced mathematics.

3.5 The importance of advanced mathematics and the consequences of not taking advanced mathematics

Although enrolments in advanced mathematics keep declining and today only a small proportion of senior secondary students take advanced mathematics, the subject is important and influential to students' futures. The study of advanced mathematics opens the door to a career in the mathematically intensive sciences – a burgeoning industry in Australia and overseas (Marginson et al. 2013). As the demand for skilled workers with quantitative skills continues to grow, tertiary graduates who are equipped with advanced mathematical knowledge are likely to be highly sought after in the labour market around the globe.

Furthermore, the study of advanced mathematics in senior secondary school substantially increases students' chances of university entry in Australia and chances of success in mathematically intensive fields of study at university. An Australian study, controlling for the family's socioeconomic status, school sector and student ability, shows that students who study a course in advanced mathematics, physics or chemistry in senior secondary school are more likely to proceed to university (Marks 2010). Another Australian study demonstrates that students who choose advanced mathematics in senior secondary school have a greater chance of performing well in their first year university mathematics and related science courses (Rylands and Coady 2009). These students are also more likely to take mathematics courses in later years of university education and complete a mathematics major (Varsavsky 2010).

3.6 Summary

In this chapter, I have discussed several major characteristics of the contemporary Australian education system with an emphasis on mathematics education at the secondary and tertiary levels. An important feature of Australian mathematics education is that to a large extent it is dependent on students' choices. Students appear to make their educational choices freely, but in fact their choices are affected by privatisation and competition in the Australian education system, ability streaming that pervades almost all schools, their socioeconomic background and their gender. This thesis reveals the individual and structural factors leading to gendered participation in mathematics education. These findings have implications for other advanced industrial countries which also have comprehensive school systems that do not separate students into different secondary schools according to their performance, such as Canada, New Zealand, the United Kingdom and the United States. As some countries, such as Denmark, Finland, Hungary, Switzerland and Uruguay, are moving towards comprehensive educational systems and increasing the use of ability streaming in mathematics education, Australia is representative of what the future of mathematics education might look like for these countries. The findings of this thesis also have implications for them.

In the next chapter, I explain why the 2003 cohort of LSAY is appropriate for a life course study of gender segregation in Australian mathematics education. I also discuss the variables and methods that I use for the analysis of gendered choices of advanced mathematics in Year 12 (Chapter 5), gendered choices of mathematically intensive university study (Chapter 6), and the impact of single-sex schooling on students' engagement in mathematics and related disciplines (Chapter 7).

Chapter 4

Data and methodology

Over the past five decades, the growth of longitudinal data collections has provided a great incentive to life course research in sociology (Elder, Johnson and Crosnoe 2003; Mayer 2009). This is because longitudinal data make the study of life trajectories across different stages of life methodologically possible (Elder, Johnson and Crosnoe 2003). In this thesis, I analyse data from the 2003 cohort of the LSAY, also known as Y03 (NCVER 2011). Using these data, I examine from a life course perspective how teenage educational experiences and occupational expectations influence the decisions of males and females to engage in advanced mathematics in secondary school and related fields of study at university. In this chapter, not only do I describe the Y03 data, but I also consider the advantages and drawbacks of using the Y03 data for my thesis (section 4.1). Next, I give an overview of the variables of my analysis (sections 4.2 and 4.3). In addition, I discuss the methodological challenges of comparing single-sex and coeducational schooling and suggest the inclusion of several control variables to address those methodological issues (section 4.4). Then I explain why I use weights to adjust for the sampling design of Y03 (section 4.5). This is followed by an overview of my methods used to analyse the Y03 data (section 4.6).

4.1 Data: Y03

Y03 was built on the Australian sample from the OECD's 2003 Programme for International Student Assessment (PISA), one of the most renowned and influential international surveys of educational achievement that evaluates the skills and knowledge of 15-year-old students every three years (OECD 2005). The primary focus

of PISA 2003 was an assessment of mathematical literacy. Reading and science literacy were the secondary foci of PISA 2003.

A two-stage stratified sampling design was used to select students for the PISA assessment. In Australia, in the first stage of sampling, schools with 15-year-old students enrolled were selected with a probability proportional to enrolment size of 15-year-olds (Thomson, Cresswell and De Bortoli 2004). This sample of schools was designed to represent all states and school sectors (NCVER 2011). In the second stage, a random sample of 50 students was selected with equal probability from each school from a list of all 15-year-olds submitted by the school (Thomson, Cresswell and De Bortoli 2004).

A total of 10,370 students who participated in the Australian PISA 2003 survey were included in Y03. A majority of them were attending Year 10 in 2003, whereas some were attending other grade levels. While PISA contains contextual background information and educational achievement data from participating students and schools, Y03 extends the Australian PISA survey by collecting information about students' educational and occupational experiences annually until 2013.

Using longitudinal data from Y03 has some specific merits. First, the longitudinal design of Y03 allows me to examine the relationship between students' experiences of secondary schooling and future engagement in mathematically intensive fields. Furthermore, PISA focused on mathematics in the 2003 assessment, and therefore Y03 provides information not only on students' mathematics achievement but also on their self-assessed competence in mathematics and occupational expectations, which is essential to my thesis. Data from more recent cohorts of LSAY (2006 and 2009) do not provide as comprehensive information on students' mathematics learning as the 2003 data because their foci were on science and reading respectively.

Although Y03 provides a wealth of information about students' educational experiences and subject choice, using the Y03 data has two key drawbacks. One of them is attrition bias, which is a common issue regarding longitudinal surveys. High attrition in longitudinal surveys of youth resulting in a large amount of missing data, often causes methodological challenges in attempting to examine students' educational and occupational outcomes. As some participants withdraw from longitudinal surveys, the remaining sample often becomes different from the original one. Fortunately, statistical methods, such as the use of sampling weights and imputation, are helpful in resolving some of the attrition bias (Lim 2011; Rothman 2007). I further discuss how I use weights to adjust for the sampling design of Y03 in section 4.5 and how I perform multiple imputation of missing values in section 4.6.

Another shortcoming of using the Y03 data is that Y03 does not use a parent questionnaire that captures information on students' early childhood development and learning experiences. A parent questionnaire with such information could provide valuable data for my thesis because gender differences in educational experiences and aspirations may emerge in early childhood and be related to future engagement in mathematics and associated disciplines. Y03 collected students' information from age 15 onwards, and therefore the information on early childhood development is missing. Nevertheless, the Y03 data still provide useful information for examining the relationship between adolescent educational experiences and future outcomes.

4.2 Dependent variables

In this thesis, there are two dependent variables. The first one refers to students' enrolment in advanced mathematics subjects in Year 12. Although Australian states and territories use different subject labels with varied curriculum content, on the whole advanced mathematics subjects equip students with calculus knowledge and prepare

them for tertiary education in mathematically intensive fields (Barrington and Brown 2005; Fullarton et al. 2003). The second dependent variable denotes students' enrolment in a bachelor's degree program in mathematically intensive fields which encompass architecture and building, engineering, information technology, mathematical sciences and physical sciences. I discuss these dependent variables in more detail in Chapters 5 and 6 where I present my analytical results about gendered choices of advanced mathematics in Year 12 and mathematically intensive studies at university.

4.3 Independent variables: student characteristics

In this section, I describe the key independent variables that are included in the empirical analyses throughout Chapters 5 to 7. My thesis contains other predictor variables that are used at the student and school levels in the analyses. As these variables only appear once in a specific analysis, I provide their details in a relevant empirical chapter rather than discussing them here.

4.3.1 Female

The focal independent variable in my thesis is gender (female) where 1 denotes females and 0 denotes males.

4.3.2 Family background – (1) socioeconomic status

I measure the socioeconomic status of a student's family by the index of economic, social and cultural status (ESCS). This index was constructed by the OECD and derived from three variables related to students' family background at age 15:

- the highest educational level of both parents
- the highest occupational status of both parents

- the number of home possessions that encompass cultural possessions (including classic literature, books of poetry and works of art), computer facilities and educational resources at home.

This index was standardised to a mean of 0 and a standard deviation of 1 across the member countries of the OECD that participated in PISA 2003. Larger values indicate higher socioeconomic status. In Australia, Cronbach's alpha for this index is 0.61 (OECD 2005).

4.3.3 Family background – (2) mother has a science job and (3) father has a science job

Another characteristic of family of origin, parental employment in science, should be taken into consideration because it is a source of cultural capital that increases children's engagement in science (Sikora 2014b; Sikora and Pokropek 2012b). In PISA 2003, students reported their parents' occupations and a description of their occupations (OECD 2005). The responses were coded to four-digit International Standard Classification of Occupations (ISCO-88) codes (ILO 1990). Table A1.1 in Appendix 1 lists the science occupations.

4.3.4 Occupational expectations – expected a mathematically intensive career at age 15

In PISA 2003, students were asked what occupations they expected to have when they are about 30 years old (OECD 2005). The responses were coded to four-digit ISCO-88 codes (ILO 1990). Based on the codes, I categorised whether a student expected a mathematically intensive occupation. The examples of such an occupation include architects, computer programmers, engineers, mathematicians, physicists and statisticians (see Table A1.1 in Appendix 1).

4.3.5 Mathematics achievement at age 15

I measure students' mathematics achievement by PISA's five plausible values that capture students' numeracy at age 15 (OECD 2005). These plausible values have a mean of 500 and a standard deviation of 100. In the multilevel analyses, I standardised mathematics achievement to a mean of 0 and a standard deviation of 1.

4.3.6 Mathematics self-concept at age 15

I measure mathematics self-concept by a PISA scale that comprises students' self-evaluation in response to the following five statements: 'I am just not good at mathematics', 'I get good marks in mathematics', 'I learn mathematics quickly', 'I have always believed that mathematics is one of my best subjects', and 'In my mathematics class, I understand even the most difficult work'. Higher values indicate a more positive self-concept in mathematics. In Australia, Cronbach's alpha for this scale is 0.89 (OECD 2005).

4.4 Control variables at the school level for the comparison of single-sex and coeducational schooling

When I examine the effect of single-sex schooling on students' engagement in advanced mathematics and related disciplines in Chapter 7, I consider control variables at the school level with respect to school sectors, school resources, student admission policies and teacher quality. Such a consideration stems from the methodological challenges of comparing single-sex and coeducational schooling.

Thus far scholars have not succeeded in removing doubt from the studies of single-sex schooling because of the methodological weaknesses in the studies. Not only is much of the existing research based on samples without random assignment, but it also confounds the effects of single-sex schooling with omitted factors, such as the

socioeconomic status of the student body, school resources and selective admission procedures (Halpern et al. 2011; Smyth 2010). Accordingly, some scholars emphasise the importance of identifying differences between single-sex and coeducational schools with respect to school resources, teacher quality and selectivity in student admission policies (Halpern et al. 2011; Pahlke, Hyde and Allison 2014; Signorella, Hayes and Li 2013). Marsh (1989) found that, when individual and school controls are introduced properly, the gender gaps in choosing mathematics and science courses in American high schools could not be attributed to single-sex or coeducational education. Likewise, two other Australian studies which took other school characteristics into account also did not find any difference in the probability of taking physical science subjects in Year 12 between single-sex and coeducational school students (Ainley and Daly 2002; Sikora 2014a).

Controlling for selection effects is essential for my thesis because the majority of single-sex schools in Australia belong to the fee-paying Catholic or independent sector (Forgasz and Hill 2013). These schools are usually located in high socioeconomic communities and metropolitan areas, and are able to attract students from families of high socioeconomic status (Sikora 2014a). They are significantly less likely than coeducational schools to have difficulty in recruiting qualified teachers (Sikora 2014a; Tsolidis and Dobson 2006). Therefore, in the Australian literature, Foon (1988) once criticised Carpenter (1985) for comparing the academic achievement of girls in all-girls schools from the non-government sector with those in coeducational schools from the government sector. Furthermore, schools in high socioeconomic communities tend to offer more advanced academic subjects, including advanced mathematics and related science subjects, for Years 11 and 12 students (Perry and Southwell 2014). By contrast, schools in low socioeconomic communities tend to offer fewer advanced academic

subjects, and therefore these schools reduce the students' chances of studying advanced mathematics and related subjects.

To sum up, this section leads to the conclusion that in this thesis it is crucial to take into account the differences in school sectors, selective admission policies and availability of qualified teachers between single-sex and coeducational schools. This helps to identify whether single-sex schooling or the pre-existing differences between single-sex and coeducational schools affect students' engagement in advanced mathematics and cognate disciplines.

4.5 Use of weights to adjust for the sampling design of Y03

Applying appropriate weights when analysing Y03 data is necessary to account not only for the two-stage stratified sampling of PISA but also for the attrition of respondents in each subsequent follow-up survey of Y03 (Lim 2011). As the PISA 2003 and Y03 samples are age-based, students of the same age attended different grade levels in particular Australian states and territories. Students also commenced their university degrees at different ages. In this thesis, I obtain the information about students' enrolment in Year 12 advanced mathematics from 2003 to 2006 and about students' enrolment in mathematically intensive fields of study at university from different LSAY waves between 2006 and 2013. Therefore, neither the PISA nor LSAY weights, which are wave-specific, are suitable for the analysis of the pooled sample. To obtain unbiased estimates, the best procedure is to follow the strategy suggested in the LSAY technical report (Lim 2011). Specifically, in the descriptive statistics and in the final model of the multilevel analysis, I include as controls all variables that were used to construct the LSAY weights.[7] The controls I use at the school level are: state or territory in which the

[7] I built nested models to see how the effect of gender changed. I introduced all control variables only in the final model because one of them, students' mathematics achievement, is the key variable in my

schools are located and the school sector (Catholic, independent and government). I include also five student-level variables, which are gender, the index of ESCS, family structure (denoted by an indicator of whether a family is a nuclear one or has some other forms, such as a single-parent family), students' immigration status that distinguished between Australians born to Australian parents and those born to foreign parents, and students' mathematics achievement.[8]

4.6 Method

This section presents an overview of the methods that I commonly used for analyses in this thesis. I do not describe each step of my analytic strategies in this section because I leave those details to Chapters 5 to 7 where I present the results of my analysis of the Y03 data.

4.6.1 A multivariate approach

Rather than simply assessing the bivariate relationship between students' gender and their enrolment in advanced mathematics and related disciplines, this thesis requires a multivariate approach to the analysis of the Y03 data. As discussed in Chapter 2, girls may be less likely to engage in advanced mathematics than boys because, for example, girls have lower self-concept in mathematics than boys, and students who hold low self-concept in mathematics are less likely than students who hold high self-concept in mathematics to enrol in advanced mathematics. If I simply compare the advanced mathematics enrolment rates of boys and girls without taking other relevant factors into account, I cannot identify the factors that explain why girls have a lower probability of studying advanced mathematics than boys. Therefore, it is necessary to conduct

models. I corrected the estimates in the final model and examined whether the results were similar to the model without any control variable.

[8] Two of the student-level variables, gender and the index of ESCS (that is, the family's socioeconomic status), are also the key independent variables in my analysis.

multivariate analysis involving more than students' gender and their enrolment in advanced mathematics and related disciplines.

4.6.2 Multilevel logistic regressions

The Y03 data are clustered by school and hence the correct procedure is to take this sampling design into account. One may draw incorrect conclusions from the results of analysis if the variability between schools is not distinguished in the analysis (Snijders and Bosker 2012). Because my dependent variables are dichotomous, in my analysis I used two-level logistic regression models with student- and school-level variables of the following form:

$$\text{logit}(Y_{ij}) = \gamma_{00} + X\beta + \text{Z}\delta + u_{0j}$$

where Y_{ij} refers to the dependent variable (that is, either enrolment in advanced mathematics in Year 12 or enrolment in a mathematically intensive study at university) for student i in school j and γ_{00} is the average intercept across schools. X is a vector of student-level independent variables and β is a vector of regression coefficients corresponding to variables in vector X. Z is a vector of school-level variables and δ is a vector of regression coefficients corresponding to variables in vector Z. u_{0j} denotes the error term between schools.

4.6.3 Multiple imputation of missing values

In many surveys, nonresponse to survey items occurs; for example, participants do not know the answers to some questions or refuse to answer specific questions (Rubin 1987; Treiman 2009). Such nonresponse give rise to missing data in surveys. Missing data also arise from attrition where participants drop out before the end of longitudinal surveys (Little and Rubin 2002). The Y03 survey is no exception to having the problem of missing data.

To use maximum information in multilevel analyses, I used Stata 14 to impute missing values on the independent variables resulting from nonresponses by chained equations (Royston and White 2011). As PISA allocates five plausible values to each student to denote mathematics achievement, I created five sets of imputed data and assigned a different plausible value to each set of imputed data.[9] I followed the PISA recommendations on analyses with plausible values by performing multilevel analyses independently on each set of imputed data and aggregating the results from these imputed data to obtain the final estimates of the statistics and their respective standard errors (OECD 2005; OECD 2009).

4.6.4 Computation of standardised coefficients

The goals of the analysis undertaken in this study require that I compare the explanatory power of the independent variables regardless of their metrics. This allows me to determine which variable is the strongest predictor of enrolment in advanced high school mathematics or enrolment in mathematically intensive university studies. To this end, I used Mplus 7 to obtain standardised coefficients. The computation of standardised coefficients involves the following steps (Muthén and Muthén 2012):

$$b_{standardised} = \mathrm{B} \times \mathrm{SD}(x) \div \mathrm{SD}(y)$$

where B is the unstandardised coefficient, $\mathrm{SD}(x)$ is the sample standard deviation of the independent variable x and $\mathrm{SD}(y)$ is the model estimated standard deviation of the

[9] In PISA and other large-scale student assessment surveys, the testing time is restricted to reduce student burden and minimise interruptions to the school schedule (Von Davier, Gonzalez and Mislevy 2009). Therefore, students do not answer all test items that are necessary to cover the topics specified in the PISA assessment framework document. Instead, the mathematics performance of individual student is measured with a subset of the total item pool. Such a measurement contains a substantial amount of measurement error. To account for the measurement error and obtain unbiased population estimates, PISA generates five plausible values based on the students' response to the subset of items they answer using multiple imputations. These plausible values are not test scores; they represent the likely distribution of a student's proficiency in mathematics (OECD 2005; Von Davier, Gonzalez and Mislevy 2009).

dependent variable. The standardised coefficient $b_{standardised}$ is interpreted as the change in y, expressed in y standard deviation units, for a standard deviation change in x. Similar to the steps described in section 4.6.3 regarding the PISA recommendations on analyses with plausible values (OECD 2009), I conducted multilevel analyses independently on each set of imputed data in Mplus 7 and aggregate the results from these imputed data to obtain the final estimates of the standardised coefficients.

4.6.5 Predicted probabilities derived from logistic regression models

In early sociological research, the comparison of odds ratios across groups and across logistic regression models with different independent variables is a common practice. However, this practice should be avoided because, as argued by Mood (2010), odds ratios are sensitive to differences in unobserved heterogeneity.[10] In other words, odds ratios are affected by omitted variables and they reflect not only the differences in effects but also the degree of unobserved heterogeneity in the model (Mood 2010).

To avoid the problems inherent in comparing odds ratios across groups and across models as discussed above, I used Stata 14 to convert the odds ratios from logistic regression models to the predicted proportions of (1) boys and girls enrolling in advanced high school mathematics, and (2) men and women enrolling in a mathematically intensive degree program. Using these predicted proportions does not only allow me to examine whether there are significant gender differences in the predicted outcomes, but it also enables me to assess whether gender differences in the predicted outcomes vary with the level of an independent variable while holding other variables constant (Long 2009). In this thesis, for example, using predicted proportions I

[10] Unobserved heterogeneity refers to 'the variation in the dependent variable that is caused by variables that are not observed' (Mood 2010, p. 67).

can examine whether the gender gap in advanced high school mathematics enrolment is smaller among students who aspire to mathematically intensive careers than among students who aspire to other occupations while keeping other independent variables, such as mathematics achievement and self-concept, constant. Unlike odds ratios, these predicted proportions are unaffected by unobserved heterogeneity, and therefore they can be used to compare groups and across models (Long 2009; Mood 2010).

To provide more intuitive interpretations to the answers to my research questions, in this thesis I present the predicted proportions in the form of graphs with 95 per cent confidence intervals. The inclusion of confidence levels in the graphs demonstrates whether gender differences in the predicted outcomes are statistically significant at the 95 per cent level of confidence.

4.7 Summary

In this chapter, I have introduced the Y03 data in detail and discussed the key variables and method of my analysis. Based on these materials, in Chapter 5, I consider whether the propensities of boys and girls to enrol in advanced high school mathematics are related to each of socialisation practices in the family, teenage occupational expectations and high school educational experiences. In Chapter 6, I continue to examine whether these characteristics have any bearing on the choice of a mathematically intensive study at university. In Chapter 7, I turn my attention to the high school environment and assess its impact on students' engagement in advanced high school mathematics and in mathematically oriented university education.

Chapter 5

Gender differences in the choice of advanced mathematics in Year 12

This chapter considers why boys and girls differ in their propensities to study advanced mathematics in Year 12. Commencing from a discussion of the benefits of studying advanced mathematics subjects in Year 12, I review prior research on gendered participation in such courses drawing on the ideas explicated in Chapter 2. After concluding my literature review with the research questions that guide this chapter, I briefly discuss the data, variables and method of my analysis. Using a life course perspective, I examine how the family's socioeconomic status, parental careers, early occupational expectations, mathematics achievement and self-assessed competence in mathematics influence the decisions of boys and girls to enrol in advanced high school mathematics. I conclude this chapter by summarising my findings and comparing them with the existing literature.

5.1 The importance of studying advanced mathematics in Year 12

Many universities in Australia do not require advanced mathematics as a prerequisite for admission to mathematically intensive programs; nevertheless, its study offers some benefits. It provides students with sound preparation for tertiary education that involves calculus (Barrington and Brown 2005; Fullarton et al. 2003). Studying a mathematically intensive science subject, including advanced mathematics, increases the chance of admission to university (Marks 2010). Some universities award bonus points, applied as a numerical addition to the ATAR, to students who perform in the top 30 per cent (approximately) of an advanced mathematics subject (Pitt 2015). The beneficiaries of this university-specific scheme have their ATAR raised by up to 5

percentage points and they are thus able to pursue a field of study that requires a higher ATAR.[11] In addition, students who take advanced mathematics in Year 12 are more likely than other students to perform well and engage in university mathematics (Rylands and Coady 2009; Varsavsky 2010).

5.2 Gender differences in the choice of advanced mathematics in Year 12: a literature overview

In Figure 5.1, I present the theoretical framework that informs my analysis in this chapter based on my literature review in Chapter 2. In that chapter, I conclude that a student's decision to pursue high-level mathematics in secondary school is influenced by the widely shared gender stereotypes, social structures and gender socialisation that occurs over the life course. In this section, I focus on the impact of gender socialisation in the family, teenage occupational expectations and self-assessed competence in mathematics on the decisions of boys and girls to engage in advanced mathematics in secondary school.

[11] The number of bonus points being awarded to applicants for taking advanced mathematics in Year 12 varies between universities. Some universities award bonus points for high achievement not only in advanced mathematics but also in other subjects, such as physics and chemistry.

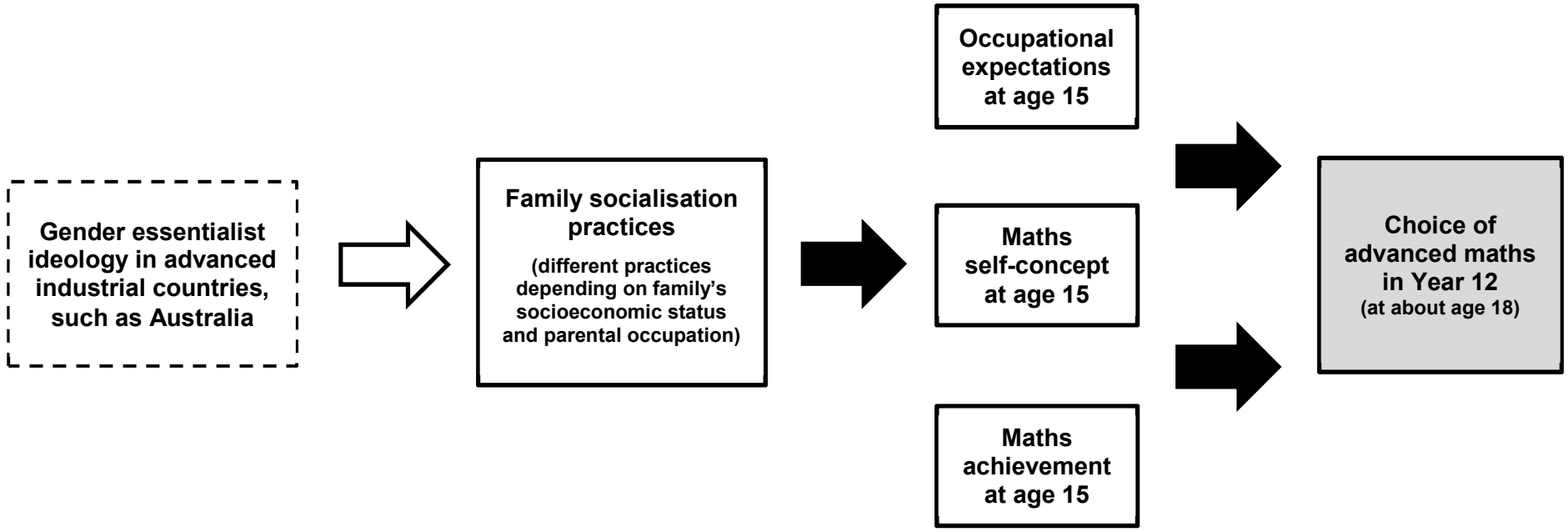

Figure 5.1 Sociocultural, family-related and motivational factors affecting a student's choice of advanced mathematics in Year 12

Note: I adapt parts of this conceptual diagram from the expectancy value theory. I incorporate a stratification approach to gender essentialism into the expectancy value theory to explain how various societal, familial and individual factors influence a student's decision to study advanced mathematics in Year 12. Boxes with solid lines contain the variables I measure in my analysis. I do not directly measure the variables in the box with dashed lines or examine the causal relationships indicated by the white arrow. Yet I argue, based on prior research and theories discussed in Chapter 2, that these factors have a strong impact on the family and motivational contexts of students' decisions.

Source: Charles and Bradley (2009); Charles and Grusky (2004); Correll (2001); Eccles (2011); Schoon and Eccles (2014); Sikora (2014b; 2015); Sikora and Pokropek (2012b); Xie and Shauman (2003)

5.2.1 Gender socialisation in the family

The expectancy value theory suggests, among other things, that gender socialisation in the family may encourage boys to participate in high-level mathematics in secondary school (Eccles 2011). Parents tend to rate highly boys' mathematical abilities and believe that the study of advanced mathematics is more important to boys than to girls (Eccles and Jacobs 1986; Eccles, Jacobs and Harold 1990; Tiedemann 2000). Girls are conscious of the lower expectations regarding mathematics learning from their parents and may thus reduce their efforts and aspirations in mathematics (Eccles and Jacobs 1986; Jacobs and Eccles 1992).

The gender gap in advanced mathematics enrolment is possibly smaller among students from high-status families than others from disadvantaged backgrounds because gender socialisation practices in high status families may be more egalitarian. On the one hand, in a family of high socioeconomic status, parents are likely to have participated in tertiary education and be employed in professional or managerial occupations. These families also tend to have more cultural resources and material home possessions. On the other hand, in a family of low socioeconomic status, parents are less likely to have tertiary qualifications and they tend to be engaged in clerical or manual occupations. In Australia, Lamb (1996; 1997) analysed data from a sample of students who attended Years 11 and 12 in four public secondary schools in the metropolitan area of Melbourne during the late 1980s. He found that nearly three decades ago girls were less likely than boys to engage in advanced mathematics. However, the odds of studying advanced mathematics for girls in privileged families were higher than the comparable odds for boys from lower status families. This finding implies that the girls' disadvantage in advanced mathematics enrolment differs by the family's socioeconomic status. While very interesting, Lamb analysed data from a non-representative sample and measured the family's socioeconomic status by father's

occupation only. To assess more systematically whether this pattern still holds in a younger and larger cohort of Australian students, I use a nationally representative sample and a comprehensive measure of family's socioeconomic status that involves parents' education and occupation, and a variety of cultural and material home possessions.

Apart from the themes that designate the study of mathematics as a potentially elite activity pursued by well-to-do children, parental employment in science may enhance the same-sex children's engagement in advanced mathematics. In this vein, the gender socialisation hypothesis (Marks 2008a; Marks 2008b) has been supported in Australia by the study of Sikora and Pokropek (2012b). They show that during the mid-2000s, adolescent children of parents employed in the physical and life sciences were more likely to expect similar careers for themselves. Specifically, boys tended to follow their fathers in aspiring to careers in the physical sciences, whereas girls tended to refer to their mothers in expecting occupations in the life sciences. Studies using the 2006 cohort of LSAY demonstrate that students whose parents were employed in science had a higher chance of taking physical science and life science subjects in Year 12 and engaging in tertiary studies in physical science (Sikora 2014b; Sikora 2015). These studies, however, do not distinguish whether maternal or paternal employment in science has more influence on the same-sex children's decisions to enrol in advanced mathematics.

5.2.2 Gender-typed occupational expectations

Gender socialisation that occurs in the family and elsewhere affects how students develop their occupational expectations which in turn may influence a student's choice of advanced mathematics in high school (Eccles 2011). The gender-typical occupational orientations boys and girls develop at the pre-adolescent stage

channel them into different career expectations and preferences at a later stage of life (McMahon and Patton 1997; Tai et al. 2006). In Australia, by the time students reach the end of compulsory education, the gender gap in occupational expectations is strongly pronounced with boys much keener to pursue careers in the mathematically intensive sciences, whereas girls are more inclined to expect careers in the life sciences (Jerrim and Schoon 2014; Sikora and Pokropek 2012a). Although these gendered patterns are known, no study has addressed the specific question of how the occupational expectations of boys and girls may affect their decisions to participate in advanced high school mathematics.

5.2.3 Gender-biased self-assessment of mathematical competence

From the rational choice perspectives, one may argue that boys are more likely to pursue high-level mathematics because they outperform girls in mathematics but lag behind girls in verbal skills (Jonsson 1999; Van De Werfhorst, Sullivan and Cheung 2003). Previous studies, however, have pointed out that students who perform well but perceive that they are incompetent in mathematics often opt out of mathematics in their educational careers (Correll 2001; Watt 2005).

Gender socialisation affects students' perceptions of their own abilities in mathematics, which is also known as mathematics self-concept (Correll 2001; Eccles 2011). Although boys and girls perform equally well in mathematics, boys tend to have a higher self-concept in the subject (Wilkins 2004). Such a gender gap has a potentially significant impact on students' decisions to pursue high-level mathematics. When girls have a lower self-concept in mathematics, they are more likely than boys to reduce their efforts and interests in high-level mathematics and associated fields of study and occupations (Correll 2001). During the early 1990s in the United States, boys were more likely than girls to study calculus in high school partly because boys had a higher

self-concept in mathematics (Correll 2001). The same was true during the mid-2000s in Australia where boys had a higher chance of studying advanced mathematics in Years 11 and 12 partially because they held a higher self-concept in mathematics (Guo et al. 2015). Another Australian study based on a sample of students who attended Years 9 through 11 between 1996 and 1998 in north metropolitan Sydney has reported similar findings (Watt 2006). These studies suggest that mathematics self-concept, rather than mathematics achievement, is the crucial factor that discourages girls from participating in advanced mathematics.

5.3 Research questions

In an effort to understand how the gender gap in the choice of advanced mathematics in Year 12 is related to gender socialisation in the family, occupational expectations and mathematics self-concept discussed above, I focus on three research questions as follows:

1. Are girls from families of higher socioeconomic status more likely than boys from families of lower socioeconomic status to study advanced mathematics in Year 12?

2. Are children more likely to be influenced by the same-sex parent who works in science to study advanced mathematics in Year 12?

3. Do students' career expectations in the mathematically intensive sciences at age 15 correspond to the gender gap in studying advanced mathematics in Year 12?

In the first research question, I emphasise gender socialisation in the family. More precisely, I examine whether the gender gap in studying advanced mathematics is smaller among students from families of high socioeconomic status. I also assess whether parental employment in science enhances the same-sex children's engagement in advanced mathematics. My particular interest is in finding out whether such role

modelling, if it exists, is equally likely to occur along and across gender divisions in the family. Next, I assess whether adolescent occupational expectations are relevant to the propensities of boys and girls to pursue high-level mathematics. These stages of my analysis are led by the following questions:

5.4 Data

The information about student subject choices in Y03 was collected between 2003 and 2006 when most participants were attending secondary school. The PISA/Y03 sample is age-based and most students were attending Year 10 in 2003 while some were attending other grade levels. The information about subject choice in Year 12 was obtained from 14 students in 2003, 1,446 students in 2004, 4,814 students in 2005 and 486 students in 2006. Therefore, the resulting pooled sample for the analysis of mathematics subjects comprises 6,760 Year 12 students.[12]

5.5 Variables

5.5.1 Dependent variable: advanced mathematics subjects in Year 12

The dependent variable refers to students' enrolment in at least one advanced mathematics subject in Year 12. Every state and territory adopts its own subject labels with different curriculum content (Ainley, Kos and Nicholas 2008). Nevertheless, across all states and territories, advanced mathematics subjects contain significant calculus content which prepares Year 12 students for further education in the mathematically intensive sciences (Barrington and Brown 2005; Fullarton et al. 2003). Table 5.1 lists all the subjects which have been categorised as advanced mathematics

[12] In the sample, 3.6 per cent (241 students) attended Year 12 more than once. I use information about their subject choice in the latest year they attended Year 12. For example, if a student attended Year 12 in 2005 and 2006, I use their subject choice in 2006.

between 2003 and 2006, that is, in the time period in which the Y03 cohort were attending Year 12.

Table 5.1 Advanced mathematics subjects in Year 12 by state and territory (2003–2006)

State / Territory	Advanced Mathematics Subjects
Australian Capital Territory	Mathematics Extension (in 2003 and 2004) Specialist Mathematics (in 2005 and 2006)
New South Wales	Mathematics Extension
Northern Territory	Specialist Mathematics
Queensland	Mathematics C
South Australia	Specialist Mathematics
Tasmania	Mathematics Specialised
Victoria	Specialist Mathematics
Western Australia	Calculus

Note: This coding is based on the curriculum contents rather than the name of the subject.
Source: Ainley et al. (2008); Y03

5.5.2 Independent variables: student characteristics

Informed by the discussion in section 5.2, my analysis focuses on assessing how family background, teenage occupational expectations and educational experiences may affect the decisions of boys and girls to enrol in or withdraw from high-level mathematics. To this end, I use the following characteristics of the students at age 15 as the independent variables: family's socioeconomic status, parental employment in science, occupational expectations, and scholastic achievement and self-concept in mathematics. The details of these measures were discussed in section 4.3 in Chapter 4.

5.6 Method

The methods that I use in this chapter are similar to those I discussed in Chapter 4. Therefore, in this section, I briefly mention the methods for the analysis of advanced mathematics enrolment in Year 12. The details regarding the use of multiple imputation to handle missing values, computation of standardised coefficients and predicted probabilities are in section 4.6 of Chapter 4.

As the Y03 data are clustered by school, the appropriate analysis must take into account this sampling design. Therefore, I used two-level logistic regression models with student- and school-level variables of the following form:

$$\text{logit}(Y_{ij}) = \gamma_{00} + X\beta + \text{Z}\delta + u_{0j}$$

where Y_{ij} refers to the choice of advanced mathematics subjects in Year 12, for student i in school j and γ_{00} is the average intercept across schools. X is a vector of student-level independent variables and β is a vector of regression coefficients corresponding to variables in vector X. Z is a vector of school-level variables and δ is a vector of regression coefficients corresponding to variables in vector Z. u_{0j} denotes the error term between schools.

Rather than discussing the odds ratios from logistic regression models, I convert the odds ratios to the predicted probabilities of boys and girls studying advanced mathematics in Year 12. In Chapter 4, I explained that I cannot directly compare the odds ratios from different models because they are affected by unobserved heterogeneity (Mood 2010; Riegle-Crumb et al. 2012). By contrast, the predicted probabilities derived from logistic regression models are not under the influence of unobserved heterogeneity. In other words, I can legitimately compare the predicted probabilities between different models and base my conclusions on them.

5.7 Results

Before proceeding to the multilevel analysis, I present the descriptive statistics of the variables classified by gender. Not only do the descriptive statistics show the gender gap in advanced mathematics enrolment, but they also reveal whether adolescent boys and girls differ in their family background, occupational expectations, as well as achievement and self-concept in mathematics.

5.7.1 How many boys and girls study advanced mathematics in Year 12?

Table 5.2 shows that while 13 per cent of boys study advanced mathematics in Year 12, only 8 per cent of girls enrol in the subject. Such a gender gap appears to be small, but in fact the odds of taking up advanced mathematics for girls is only about 62 per cent for the comparable odds for boys. In other words, the girls' relative disadvantage in advanced mathematics enrolment is large.

Table 5.2 Student characteristics by gender: proportions and means

	Boys	Girls	Min.	Max.	*N*
Dependent variable					
Study advanced mathematics in Year 12 [a]	0.13	0.08	0	1	6,760
Family background					
Socioeconomic status	0.37	0.37	-3.05	2.15	6,733
Mother has a science job	0.15	0.15	0	1	6,463
Father has a science job	0.16	0.16	0	1	6,442
Career expectations					
Expected a career in the mathematically intensive sciences at age 15 [a]	0.27	0.07	0	1	6,207
Mathematics					
Mathematics achievement at age 15 [a]	558	541	178	842	6,760
Mathematics self-concept at age 15 [a]	0.37	0.13	-2.12	2.42	6,739

Note: This table contains weighted estimates before multiple imputations of missing data.
[a] indicates that the difference between boys and girls in that variable is statistically significant at $p < 0.05$.

Source: Y03

The gender gap in Year 12 advanced mathematics enrolment does not seem to be related to the family background of boys and girls in this study because boys do not differ from girls in family background. On average, boys and girls have equal levels of family's socioeconomic status. Similar proportions of boys and girls live in families in which parents work in science. There is, however, a striking gender difference in occupational expectations: 27 per cent of boys expected a mathematically intensive career when they were 15 years old, whereas only 7 per cent of girls expected such a career. The gender gap in advanced mathematics enrolment may be associated with the differentials in academic achievement as boys perform better than girls in mathematics, even if this advantage is small. Boys have considerably higher self-concept in mathematics than girls, which attests to the existence of gendered constraints affecting self-assessed mathematical abilities.

5.7.2 Multilevel models

In section 5.2, I concluded that gender socialisation in the family, teenage occupational expectations and self-assessed competence in mathematics are the key factors shaping adolescents' plans to pursue advanced high school mathematics. To find out which of these factors has the largest impact on the gender gap in advanced mathematics enrolment, I estimated five different models with standardised coefficients presented in Table 5.3. My models are nested with a view to first considering the overall size of the gender gap in the choice of advanced mathematics (denoted by the coefficient labelled 'female') controlling for students' socioeconomic status (Model 1). I aimed to assess whether high socioeconomic status raised students' chances of studying advanced mathematics. In my second step, I added the family's socioeconomic status, maternal and paternal employment in science, and their interaction effects with the respondents' gender (Model 2). This step addresses whether the gender gap in taking advanced mathematics differs by the family's socioeconomic status. In addition, it helps to determine whether the decisions of boys and girls to pursue advanced mathematics are more likely to be influenced by the science occupation of their same-sex parent. Next, to examine whether students' teenage occupational expectations have an impact on the gender gap in advanced mathematics enrolment, I added students' occupational expectations at age 15 (Model 3). Then I added students' mathematics achievement and self-concept to examine how influential occupational expectations and mathematics self-concept were for the gender gap irrespective of mathematics achievement (Model 4). Finally, I added all variables which were used to construct the LSAY weights as controls to check whether the results were similar to those of Model 4 after applying appropriate weights (Model 5).

Table 5.3 Odds ratios and standardised coefficients from multilevel logit models for studying advanced mathematics in Year 12

	Model 1			Model 2			Model 3			Model 4			Model 5		
	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient
Fixed effects															
Student characteristics															
Female	0.403***	(0.040)	-0.238	0.440***	(0.055)	-0.215	0.575***	(0.081)	-0.143	0.779	(0.122)	-0.048	0.792	(0.125)	-0.043
Family background															
Socioeconomic status	1.570***	(0.103)	0.189	1.472***	(0.130)	0.262	1.450***	(0.130)	0.153	1.015	(0.109)	0.005	1.019	(0.107)	0.005
× Female				0.994	(0.135)	-0.002	0.991	(0.139)	-0.003	0.972	(0.147)	-0.007	0.995	(0.149)	-0.001
Mother has a science job				1.367*	(0.210)	0.058	1.331†	(0.210)	0.053	1.417†	(0.264)	0.048	1.376†	(0.088)	0.042
× Female				0.705	(0.194)	-0.050	0.737	(0.206)	-0.043	0.710	(0.212)	-0.035	0.797	(0.233)	-0.023
Father has a science job				1.411*	(0.195)	0.065	1.298†	(0.178)	0.048	1.253	(0.204)	0.031	1.132	(0.188)	0.017
× Female				0.896	(0.199)	-0.015	0.948	(0.210)	-0.007	0.800	(0.218)	-0.023	0.764	(0.216)	-0.027
Career expectations															
Expected a career in the mathematically intensive sciences at age 15							2.837***	(0.338)	0.201	2.184***	(0.295)	0.112	2.249***	(0.296)	0.113
× Female							0.851	(0.223)	-0.016	0.872	(0.249)	-0.010	0.855	(0.244)	-0.011
Mathematics															
Mathematics achievement at age 15										2.624***	(0.205)	0.370	2.767***	(0.223)	0.379
Mathematics self-concept at age 15										3.451***	(0.235)	0.426	3.440***	(0.241)	0.411
Constant	0.108***	(0.008)		0.099***	(0.009)		0.070***	(0.007)		0.022***	(0.003)		0.040***	(0.008)	
Random effects															
Variance between schools	0.498***	(0.132)		0.502***	(0.131)		0.515***	(0.135)		0.811***	(0.158)		0.410***	(0.101)	

Note: The sample for this multilevel analysis contains 6,760 students in 314 schools with multiple imputations of missing data. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Model 5 contains weighting variables. The odds ratios and standardised coefficients of the weighting variables in Model 5 are presented in Table A2.1 in Appendix 2.

Source: Y03

Are girls from privileged families more likely than boys from lower status families to study advanced mathematics in Year 12?

If gender socialisation practices tend to be more egalitarian in privileged families with respect to mathematics learning, it is possible that the gender gap in advanced mathematics enrolment is smaller among Year 12 students from privileged families. Therefore, my first research question asks whether girls from families of higher socioeconomic status are more likely than boys from families of lower socioeconomic status to enrol in advanced mathematics. Based on Model 2 (in Table 5.3), I present the predicted probabilities of boys and girls studying advanced mathematics, as well as the male-to-female ratios in the probability of taking advanced mathematics in Table 5.4.

Table 5.4 Predicted probabilities of boys and girls studying advanced mathematics in Year 12 by the family's socioeconomic status

Level of family's socioeconomic status	Boys	Standard error	Girls	Standard error	Male-to-female ratio
-3.0	0.04	(0.01)	0.02	(0.01)	2.3
-2.5	0.05	(0.01)	0.02	(0.01)	2.3
-2.0	0.06	(0.01)	0.03	(0.01)	2.3
-1.5	0.07	(0.01)	0.03	(0.01)	2.3
-1.0	0.08	(0.01)	0.04	(0.01)	2.3
-0.5	0.10	(0.01)	0.04	(0.01)	2.2
0.0	0.12	(0.01)	0.05	(0.01)	2.2
0.5	0.14	(0.01)	0.06	(0.00)	2.2
1.0	0.16	(0.01)	0.07	(0.01)	2.1
1.5	0.19	(0.02)	0.09	(0.01)	2.1
2.0	0.21	(0.02)	0.10	(0.02)	2.0

Note: The predicted probabilities are based on Model 2 (in Table 5.3) and computed with other independent variables held at their means. A higher value of family' socioeconomic status indicates a higher socioeconomic status of the family.

Source: Y03

Table 5.4 shows that girls from families of the highest socioeconomic status (when the level of socioeconomic status lies between 1.5 and 2) are more likely than boys from families of the lowest socioeconomic status (when the level of socioeconomic status lies between -3 and -2) to enrol in advanced mathematics. Nevertheless, the gender gap in advanced mathematics enrolment is similar among students from families of different socioeconomic status. Although the male advantage in pursuing advanced mathematics seems to decrease when the family's socioeconomic status increases (denoted by the male-to-female ratios in Table 5.4), the reduction is trivial. Similarly, in Model 2 (in Table 5.3), the interaction effect between families' socioeconomic status and gender is statistically insignificant (odds ratio of 0.994). It indicates that the slopes depicting the effects of socioeconomic status on advanced mathematics enrolment are similar for boys and girls.

Are children more likely to be influenced by the same-sex parent who works in science to study advanced mathematics in Year 12?

Apart from the family's socioeconomic status, I examine whether parental employment in science brings an additional advantage to the children's propensities to enrol in advanced mathematics. As discussed in section 5.2.2, theories of gender socialisation propose that boys and girls are possibly more responsive to gender-typical role models within their family circles. The Australian studies, however, have rarely examined the link between parental employment in science and the decisions of boys and girls to engage in advanced mathematics at the end of secondary education.

In response to my second research question about the impact of parental employment in science, I find that same-sex and opposite-sex role modelling within the family raises the students' chances of studying advanced mathematics almost equally. Model 2 (in Table 5.3) shows that the odds of studying advanced mathematics for

students whose mothers and fathers work in science-intensive fields are 1.367 and 1.411 times respectively larger than the comparable odds for other students. These advantages are similar for daughters and sons because the interaction effects between mothers' employment in science and gender, and between fathers' employment in science and gender are statistically insignificant (odds ratios of 0.705 and 0.896 respectively). Based on these results, Figure 5.2 further illustrates that same-sex and opposite-sex role modelling enhances the propensity to study advanced mathematics similarly among boys and girls.

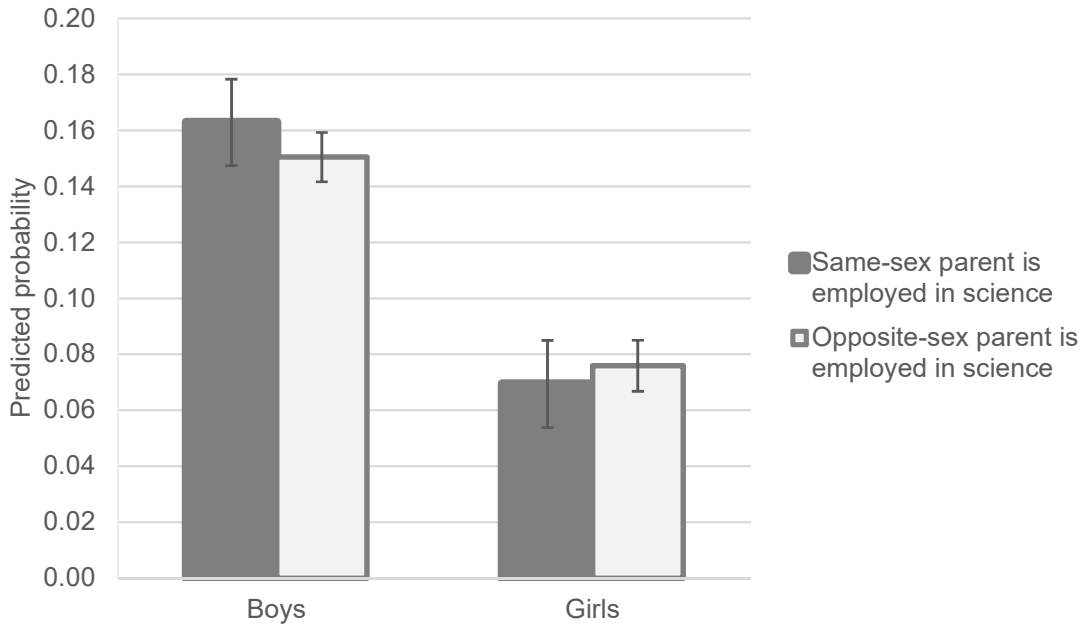

Figure 5.2 Predicted probabilities of boys and girls studying advanced mathematics in Year 12 by parental employment in science

Note: The predicted probabilities are based on Model 2 presented in Table 5.3. 'Same-sex parent is employed in science' refers to role modelling between boys and fathers or between girls and mothers. 'Opposite-sex parent is employed in science' refers to role modelling between boys and mothers or between girls and fathers.

Source: Y03

Do students' career expectations in the mathematically intensive sciences at age 15 explain the gender gap in advanced mathematics enrolment?

To study whether gender-specific occupational orientations at an early age influence educational decisions, my third research question asks whether the occupational expectations of adolescent boys and girls affect their enrolment in advanced mathematics in Year 12.

Figure 5.3 demonstrates that students' occupational expectations in the mathematically intensive sciences at age 15 explain some of the gender gap in advanced mathematics enrolment. With the inclusion of family background and its interaction effects with gender in Model 2, the gender gap decreases slightly to 6.5 percentage points. Adding students' occupational expectations to Model 3 further reduces the gender gap to 4.2 percentage points.

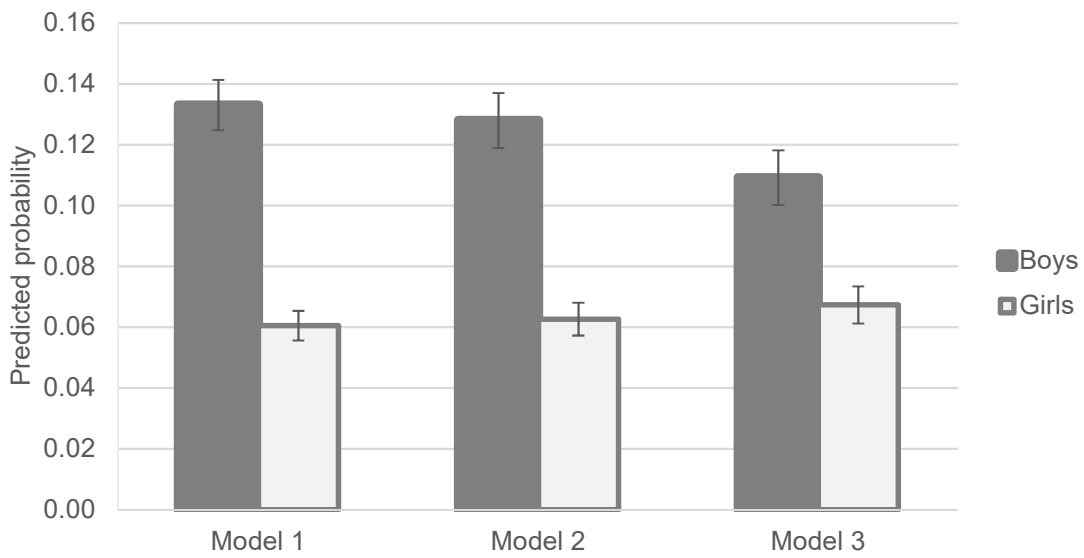

Figure 5.3 Predicted probabilities of boys and girls studying advanced mathematics in Year 12 from Models 1 to 3

Note: The predicted probabilities are based on Models 1, 2 and 3 presented in Table 5.3.

Source: Y03

Although students' occupational expectations bridge some of the gender gap in advanced mathematics enrolment, they do not close it entirely. The results of Model 3 (in Table 5.3) show that the odds of studying advanced mathematics for students who expected mathematically intensive careers is 2.837 times larger than the comparable odds for students who did not have the same occupational expectations. Nevertheless, the interaction effect between occupational expectations and the respondents' gender is statistically insignificant (odds ratio of 0.851). In other words, expecting a mathematically intensive career increases the students' propensities to study advanced mathematics for boys and girls similarly, even though girls are significantly less likely to expect such a career.

Which is more influential to the gender gap in advanced mathematics enrolment, occupational expectations or self-assessed competence in mathematics?

In Model 4 (in Table 5.3), I added students' achievement and self-concept in mathematics. For a given level of mathematics achievement, when girls are less likely than boys to perceive that they are competent in mathematics (that is, having lower self-concept), they are more likely to reduce their efforts in mathematics learning, as suggested by the psychological and sociological theories discussed in section 5.2.3. These girls are also more likely to lower their interests in mathematics, as well as in the fields of study and occupations that require intensive use of mathematics. In Model 5 (in Table 5.3), I added all the weighting variables and this produced similar results to those of Model 4.

Models 4 and 5 (in Table 5.3) demonstrate that the gender gap in advanced mathematics enrolment becomes statistically insignificant once boys and girls are assumed to have the same mathematics achievement and mathematics self-concept. With the inclusion of mathematics achievement and mathematics self-concept in Model

4, the gender gap in advanced mathematics enrolment is largely reduced to only 1 percentage point and it is statistically insignificant (Figure 5.4). Adding all the weighting variables to Model 5 results in a gender gap of merely 0.7 percentage point that reinforces the conclusion reached in Model 4.

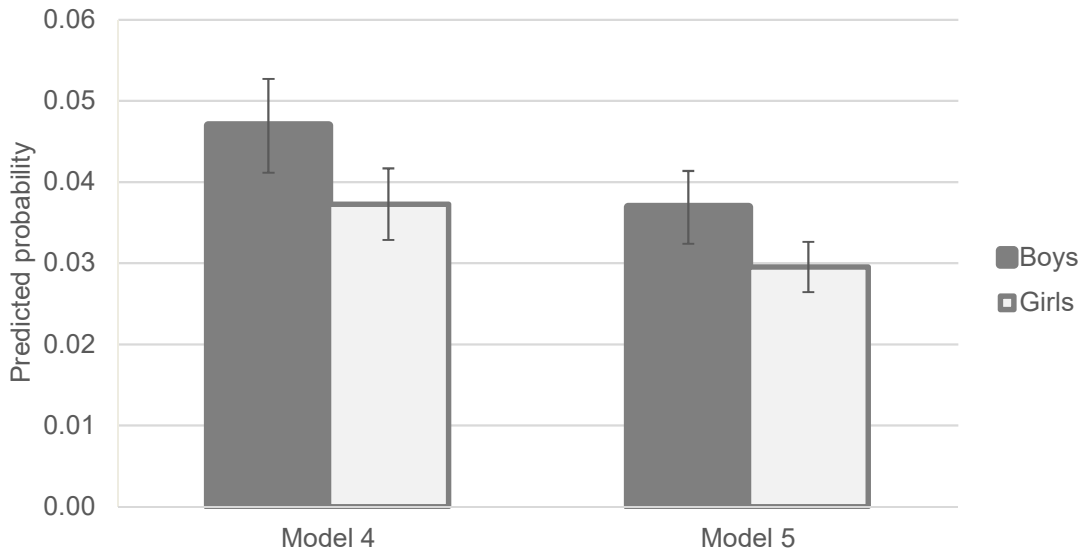

Figure 5.4 Predicted probabilities of boys and girls studying advanced mathematics in Year 12 from Models 4 and 5

Note: The predicted probabilities are based on Models 4 and 5 presented in Table 5.3.

Source: Y03

The standardised coefficients in Models 4 and 5 show that mathematics self-concept is the strongest predictor of the choice of advanced mathematics (0.426 in Model 4 and 0.411 in Model 5), followed by mathematics achievement (0.37 in Model 4 and 0.379 in Model 5). These standardised coefficients, however, do not demonstrate whether mathematics self-concept also has the greatest impact on the gender gap in advanced mathematics enrolment.

To identify whether mathematics self-concept or achievement has a greater influence on reducing the gender gap, I present Figure 5.5 to further demonstrate how

much of the gender gap can be explained by mathematics self-concept and achievement individually. Based on Model 3 (in Table 5.3), I included mathematics achievement in the model but omitted mathematics self-concept. Then I obtained the predicted probabilities of boys and girls studying advanced mathematics. These predicted probabilities are presented on the left of Figure 5.5. Next, I excluded mathematics achievement from Model 3 and added mathematics self-concept to the model. I calculated the predicted probabilities of boys and girls enrolling in advanced mathematics. These predicted probabilities are shown on the right of Figure 5.5.

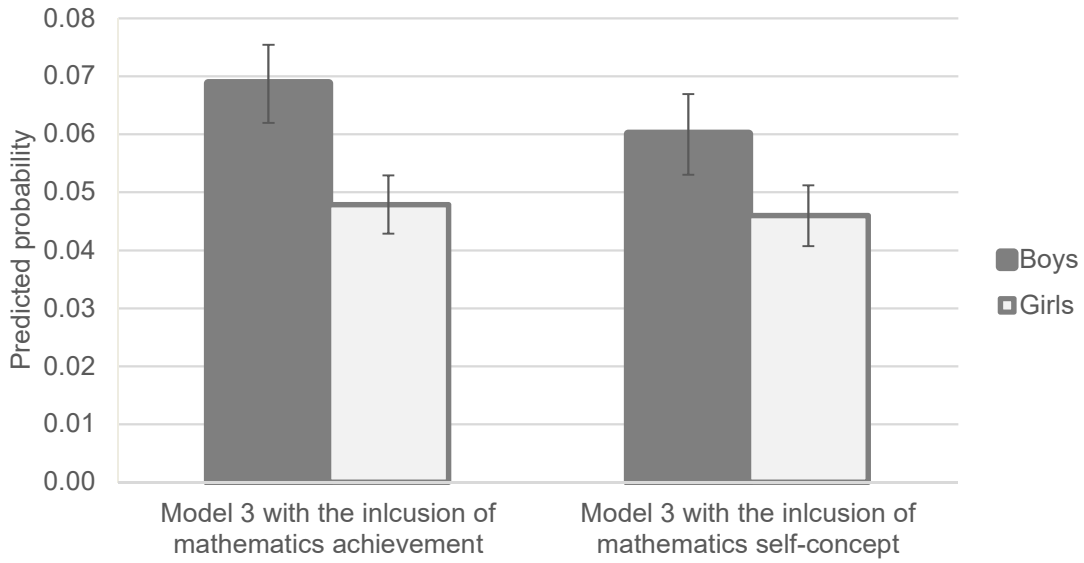

Figure 5.5 Predicted probabilities of boys and girls studying advanced mathematics in Year 12 with the inclusion of mathematics achievement and self-concept

Note: The predicted probabilities are based on Model 3 presented in Table 5.3 with the inclusion of mathematics achievement or mathematics self-concept.

Source: Y03

Mathematics self-concept has a greater influence on the gender gap in advanced mathematics enrolment than mathematics achievement (Figure 5.5). When I take mathematics achievement into account, the gender gap is reduced from 4.2 percentage points in Model 3 to 2.1 percentage points. When I consider mathematics self-concept

in Model 3, the gender gap decreases from 4.2 percentage points to 1.4 percentage point. In other words, self-concept in mathematics, rather than academic achievement in the subject, is the key factor that differentiates the decisions of boys and girls to enrol in advanced high school mathematics.

Although the detailed examination of the intersection of race/ethnicity and gender (see, for example, Riegle-Crumb 2006) is beyond the scope of this thesis, I provide some general comments. My results demonstrate that the gender gap in advanced mathematics enrolment in Year 12 is the same among native and migrant students. In Model 5 (in Table 5.3), two of the weighting variables are associated with the students' immigration background. Table A2.1 (regarding immigration background) in Appendix 2 shows that, compared to native students, first-generation and second-generation students have a higher chance of studying advanced mathematics in Year 12. Adding all the weighting variables, including those related to the students' immigration background, to Model 5 leads to a reduction of only 0.3 percentage point in the gender gap. In other words, the difference between boys and girls in advanced mathematics enrolment is similar among students with different immigration backgrounds.

5.8 Summary of findings and discussion

In this chapter, I considered how family background, teenage occupational expectations and mathematics self-concept would influence the decisions of Australian boys and girls to pursue advanced mathematics in Year 12. My analysis shows that the gender gap in advanced mathematics enrolment disappears if girls are as likely as boys to feel confident of their mathematical abilities, perform well in mathematics and aspire to mathematically oriented careers at age 15. In addition, I found that bridging gender differences in mathematics self-concept has the greatest potential to narrow the gender gap in advanced mathematics study.

While girls do not lag much behind boys in mathematics achievement, they are significantly less confident than boys in their mathematical abilities. This is most likely because girls internalise the widely shared gender stereotypical belief that males have more natural aptitude for mathematics, abstract thinking and technical problem solving, as suggested by the gender stratification theories (Blau, Brinton and Grusky 2006; Charles and Grusky 2004). With less confidence in mathematical competence, girls have a higher chance of eschewing high-level mathematics (Correll 2001; Watt 2005). In confirming the centrality of this factor, my findings align with prior research which concluded that in the 1990s, American girls were less likely to study calculus because they had lower mathematics self-concept even when they performed as well as their male peers in the subject (Correll 2001). My findings are not only in line with existing research, but they also suggest that the problem of downward bias in self-evaluation adversely affects girls in different student cohorts, countries and time periods.

Although my results are similar to the study conducted by Guo and his colleagues (2015) which also shows that girls' lower mathematics self-concept facilitates the gender gap in advanced mathematics enrolment, my analysis further demonstrates, using the same LSAY data, that early occupational expectations contribute to the gender gap. The impact of occupational expectations on the gender gap is less consequential than that of mathematics self-concept. Nevertheless, bridging gender differences in early occupational expectations also considerably reduces the gender gap in advanced mathematics enrolment.

While my analysis does not contain specific details of the direct mechanisms through which gender socialisation in the family occurs, it does not mean that the family has no impact on the pursuit of high-level mathematics by young people. The greatest influence of the family is mediated through the contributions that it makes to the development of students' mathematics self-concept and occupational expectations, as

well as students' mathematic performance. Families of higher socioeconomic status boost their children's academic achievement and self-concept in mathematics (Muijs 1997; Sirin 2005). In turn, mathematics achievement and self-concept increase the students' chances of engaging in advanced courses in mathematics, as demonstrated by my analysis. Parental employment in science conveys an extra advantage to adolescents by generating greater interests in mathematically intensive careers and related disciplines, as demonstrated by recent studies (Sikora 2014b; Sikora 2015; Sikora and Pokropek 2012b). My findings further show that adolescent occupational expectations for mathematically intensive careers enhance the likelihood of choosing advanced mathematics in Year 12.

In this chapter, I examined the impact of family characteristics and students' motivations on the choice of advanced mathematics in Year 12. Students' access to advanced mathematics does not only relate to the family's socioeconomic status, but it may also depend on the opportunity structures embedded in the school environment. In this regard, recent Australian research has found that compared to schools in high socioeconomic communities, schools in low socioeconomic communities are less likely to offer advanced academic subjects (Perry and Southwell 2014). Therefore, the chance of studying advanced mathematics in Year 12 is lower for students who attend a school in a low socioeconomic community because the school may not offer any advanced mathematics subject. In Chapter 7, I will further explore how the opportunity structures within a school affect students' chances of engaging in advanced mathematics.

The key concern arising from the analysis in this chapter is that opting out of advanced mathematics in Year 12 is likely to result in a lack of preparation for tertiary education in mathematically intensive fields, thus reducing the chance of success in tertiary mathematics and cognate disciplines (Rylands and Coady 2009; Varsavsky 2010). The extent to which high school subject choices align with tertiary fields of study

cannot be assumed or deduced, but it must be subject to an empirical examination based on relevant data. Therefore, in the next chapter, I turn to gender segregation in tertiary mathematics education. Specifically, I consider whether any part of the gender gap in choosing a mathematically intensive university major can be attributed to the direct influences of gender socialisation in the family in addition to the early occupational expectations and educational experiences in high school.

Chapter 6

Gender differences in the choice of a mathematically intensive bachelor's degree program

Over the last four decades, the 'leaky pipeline' metaphor has been used frequently to describe the under-representation of women in the mathematically intensive sciences (Blickenstaff 2005; Miller and Wai 2015). According to the metaphor, women are more likely than men to leak out from the mathematically intensive 'pipeline' at various stages. The researchers who use the metaphor claim, for instance, that women are less likely than men to enrol in advanced mathematics and physical science subjects in high school, select and complete post-secondary education in mathematically intensive fields, and choose a career in the same fields upon graduation from mathematically oriented post-secondary education. Among these stages, the choice of a university major is the most critical threshold as early research in the United States has found that once students enter tertiary science fields of study, women do not leave those majors at higher rates than men (Xie and Shauman 2003).

In this chapter, I examine gender differences in the choice of a mathematically intensive university major and the reasons behind the differences using the stratification theory of gender essentialism (Charles and Bradley 2009) and the theory of expectancy value (Eccles 2011). I begin by defining mathematically intensive fields of study. Then I review prior research on gender segregation in tertiary fields of study that seeks to understand the persisting under-representation of women in mathematically intensive fields. In the next section, I discuss the data, variables and method for my analysis. In Chapter 5, I found that adolescent boys dominated advanced mathematics in Year 12 because, compared to adolescent girls, they tended to achieve higher marks in

mathematics and they benefited from higher mathematics self-concept. In line with that, adolescent boys were more likely to aspire to mathematically intensive careers. In this chapter, I continue to use the Y03 data to explore the extent to which these high school educational experiences and career expectations continue to be influential predictors of gender differences in the choice of a mathematically intensive university major. I conclude this chapter by summarising my findings and contrasting them with prior literature.

6.1 What are mathematically intensive fields?

I follow Ceci and his colleagues (2010b; 2009) and use 'mathematically intensive fields' to denote the science fields requiring intensive use of mathematics. They include architecture, engineering, information technology, and the mathematical, earth and physical sciences. These fields are often regarded as masculine, whereas other areas, such as the biological and environmental sciences, are viewed as feminine (Blickenstaff 2005). The general public often views the mathematically intensive sciences as abstract, technical and technology-focused in contrast to the feminine fields which are seen as concrete, social, and people-oriented (Faulkner 2000; Osborne, Simon and Collins 2003). Sikora (2014b) points out that previous studies have used various labels to differentiate masculine and feminine fields within science, such as 'technology' versus 'care-oriented' (Barone 2011), 'hard' sciences versus 'soft' ones (Kjærnsli and Lie 2011), and 'physical sciences' versus 'other sciences' (Ainley and Daly 2002). In summary, there is no consistency in the use of labels in previous studies, and therefore one should always pay attention to the list of science fields included in each label.

6.2 Gender segregation in tertiary fields of study: a literature overview

In Figure 6.1, I present the theoretical framework of this chapter. The stratification theory of gender essentialism suggests that in advanced industrial societies, such as Australia, students' engagement in mathematically intensive fields of study is shaped by gender stereotypical beliefs and self-expressive values that flourish in comprehensive educational systems and service economies (Charles and Bradley 2009; Charles et al. 2014). The comprehensive education system in Australia offers plentiful options not only in high school curricula but also in university majors for students. This enables women to have a higher chance of engaging in female dominated specialisations, such as the humanities, social sciences and life sciences, than students in developing or transitioning countries in which their educational systems usually do not provide a wide range of curricular options. The Australian service economy provides abundant job opportunities that are perceived to be self-expressive, social and people-oriented. Young people may tend to be interested in occupations in the service economy because they may strive to find a career which allows them to express themselves, represent themselves and seek satisfaction and happiness by closely aligning the activities their career offers and their self-perceived identity. Under the influence of gender stereotypical beliefs and self-expressive values in advanced industrial societies, females in these societies have a lower chance of pursuing mathematically oriented education when they perceive ample opportunities in the educational sector and labour market that match feminine identities (Charles and Bradley 2009).

The gender essentialist beliefs which put an emphasis on innate gender differences are ubiquitous, particularly in advanced industrial societies (Charles and Bradley 2009). Children internalise gender stereotypical beliefs through socialisation and convert them into gender-differentiated aspirations and preferences that affect their educational choices (Blau, Brinton and Grusky 2006; Charles and Bradley 2009). Based

on prior research in advanced industrial countries, in this section I discuss how gender essentialist beliefs affect children's socialisation and educational experiences and in turn influence their field of study choices at university.

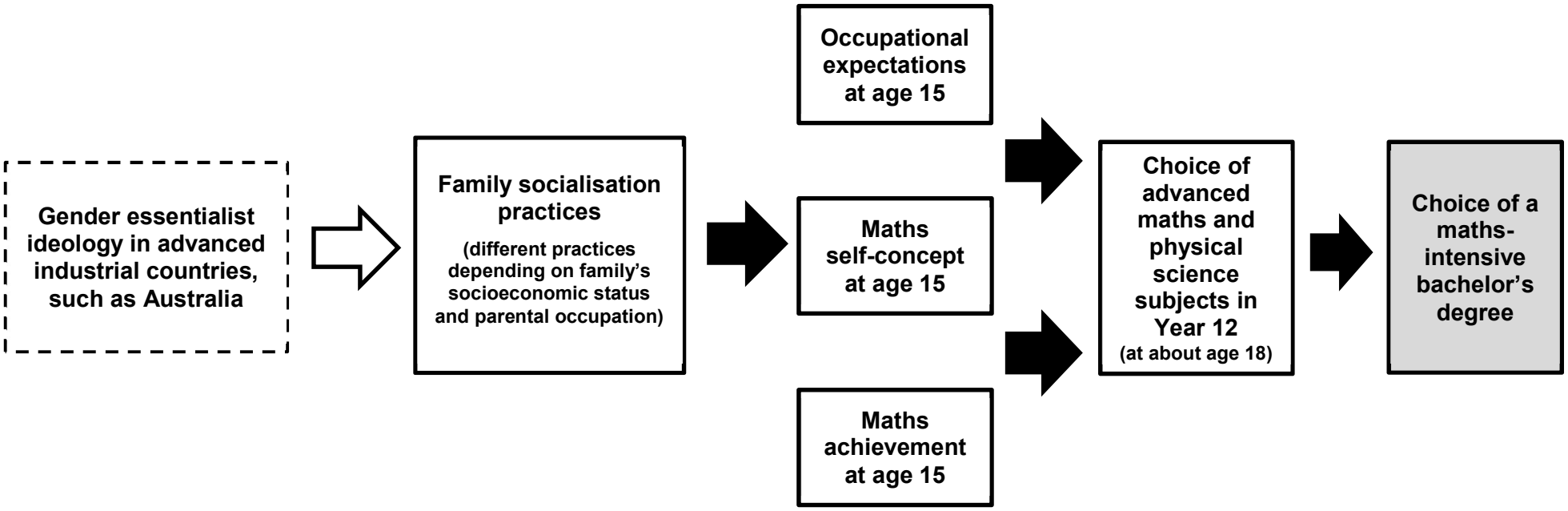

Figure 6.1 Sociocultural, family-related and motivational factors that influence a student's chance of choosing a mathematically intensive university major

Note: I adapt this conceptual diagram from the expectancy value theory. I add stratification explanations to the model and illustrate the factors that influence a student's chance of selecting a mathematically intensive university major. In my analysis, I have placed the variables in boxes with solid lines. By contrast, I do not directly measure the variables in the box with dashed lines or model the causal relationships represented by the white arrow. I review the contributions of these factors and causal relationships based on prior research and theories discussed in Chapter 2.

Source: Charles and Bradley (2009); Charles and Grusky (2004); Correll (2001); Eccles (2011); Schoon and Eccles (2014); Sikora and Pokropek (2012b); Xie and Shauman (2003)

6.2.1 Gender socialisation in the family

The expectancy value theory suggests that socialisation practices in the family may be more likely to encourage males to pursue mathematically intensive fields (Eccles 2011). Not only do parents tend to overrate boys' mathematical abilities (Tiedemann 2000), but they are also more likely to believe that it is more important for boys than girls to engage in advanced mathematics subjects (Eccles and Jacobs 1986; Eccles, Jacobs and Harold 1990). If these gender-specific socialisation practices exist, girls may lower their aspirations and reduce their interest and effort with respect to mathematics learning according to the lower expectations from their parents (Eccles and Jacobs 1986; Jacobs and Eccles 1992). These socialisation practices continue to influence the educational decisions of students as they progress through the tertiary education system (Camp et al. 2009). In summary, gender socialisation in the family may enhance the chances of young men engaging in a mathematically intensive university major while lowering the chances of young women.

If gender socialisation practices are more egalitarian in families of high socioeconomic status, the gender gap in choosing a mathematically intensive university major may appear to be smaller among students from those families. In families of high socioeconomic status, parents are likely to be highly educated and engaged in managerial or professional occupations. In contrast to these families, parents in low status families usually do not have tertiary qualifications and tend to have non-professional occupations. In addition, compared to high status families, low status families have fewer cultural resources and material home possessions. During the late 1980s in four public high schools located in the metropolitan areas of Melbourne, girls' disadvantage in advanced mathematics enrolment was smaller among students from high status families than those from low status families (Lamb 1996; Lamb 1997). This was attributed to the differences in economic, cultural and educational resources

enjoyed by high and low status families. This divide has been found in many countries, including Scandinavian countries which usually serve as exemplars of social equality. For instance, a Swedish study, based on a national sample of teenagers born in the 1970s, has also demonstrated that students tended to make gender-atypical subject choices in upper secondary school if they came from high status families (Dryler 1998). Likewise, in countries such as the United States, renowned for their economic inequalities, differentials in students' socioeconomic backgrounds were found to affect students' decisions not only in high school but also at university. These socioeconomic effects operate differently for men and women. This difference is often referred to as intersectionality (McCall 2005). For example, at the tertiary level, young American women from high status families were found to be more likely than their same-sex peers from low status families to choose male-dominated college majors in the early 1990s (Leppel, Williams and Waldauer 2001). These studies show that the gender gap in the choice of a mathematically oriented university major in Australia is possibly more likely to appear among students from low status families owing to the gender-typed socialisation practices in those families.

Students' career expectations and decisions to engage in mathematically intensive fields are also affected by their parents' occupations. Parents may pass their expertise and skills from their occupations to their children through active involvement in their children's education (Chakraverty and Tai 2013; Ma 2009). If they further show clear support to their children's interest and participation in gender-atypical activities and education, their children may have a higher chance of pursuing the gender-atypical educational pathway and engaging in a similar field of study and career (Bieri Buschor et al. 2014). As suggested by the theories of gender socialisation (Marks 2008a; Marks 2008b), children may be more likely to perceive the parent of the same sex as their role model and thus have a higher chance of aspiring to a similar occupation to that of their

same-sex parent. In line with this hypothesis, in the mid-2000s Australian boys tended to follow their fathers to expect careers in the physical sciences while girls tended to be influenced by their mothers to expect careers in the life sciences (Sikora and Pokropek 2012b). Based on these studies, it is possible that maternal and paternal employment in science has a great impact on the same-sex children's engagement in mathematically intensive fields at university.

6.2.2 Gender-typed occupational expectations

Gender socialisation that takes place in the family, at school and elsewhere influences how students form their occupational expectations, which in turn affect their decisions to engage in mathematically intensive fields (Eccles 2011). Children may internalise the gender stereotypical beliefs that certain occupations and job tasks, such as those related to the mathematically intensive sciences, are more suitable for men than for women. In line with this argument, early research has demonstrated that gender differences in occupational expectations emerge in childhood (McMahon and Patton 1997; Tai et al. 2006). Although very often students change their occupational expectations during adolescence and early adulthood (Rindfuss, Cooksey and Sutterlin 1999), in the early 1990s American adolescent boys were found to be more likely than their compatriot girls to continue to aspire to science and engineering careers (Mau 2003).

Occupational expectations during adolescence may have a strong impact on the gender gap in the choice of a mathematically intensive university major. Recent Australian studies have found that students who expected a career in the physical sciences were more likely to engage in relevant fields of study in post-secondary education (Sikora 2014b; Sikora 2015). As men were more likely to expect a physical science career, their chances of enrolling in related fields were enhanced at the post-

secondary level (Sikora 2014b; Sikora 2015). Two American studies using data from the early 1990s and early 2000s respectively have found that some of the gender gaps in choosing and attaining a bachelor's degree in science could be explained by students' occupational expectations in high school (Legewie and DiPrete 2014b; Morgan, Gelbgiser and Weeden 2013). Thus, in this chapter, I contribute to the Australian literature by examining whether teenage occupational expectations have a prolonged impact on gender differences in field of study choices in the next stage of education, namely, at university.

6.2.3 Gender-biased self-assessment of mathematical competence

From the rational choice perspectives, early research suggests that males have a higher chance of pursuing the mathematically intensive sciences than females because males perform better in mathematics but fall behind females in verbal skills at school (Jonsson 1999; Van De Werfhorst, Sullivan and Cheung 2003). Nevertheless, recent research provides evidence against the early findings. Using national data from three cohorts of high school and tertiary students in the 1980s, 1990s and 2000s, an American study shows that the advantage boys had in mathematics and girls had in verbal achievement does not explain satisfactorily why women are far less likely than men to engage in tertiary mathematics-related studies (Riegle-Crumb et al. 2012). Reviews of prior studies conducted from the 1980s to the 2000s and mostly in the United States also point out that the male advantage in mathematical and spatial ability does not adequately explain why men are largely over-represented in mathematically intensive fields (Ceci and Williams 2010a; Ceci and Williams 2010b).

Rather than gender differences in mathematics achievement, one of the critical reasons that males dominate mathematically intensive fields of study is that they have higher self-concept in mathematics even when females perform as well as males in the

subject (Correll 2001; Eccles 2011). In other words, males are more likely than females to perceive that they are good at mathematics. Although students' mathematics self-concept tends to decline when they progress to higher years of study in secondary school, the gender gap in mathematics self-concept remains unchanged (Nagy et al. 2010). When females have lower self-concept in mathematics, they have a higher chance of reducing their interests and efforts in mathematics and related disciplines (Correll 2001). Using nationally representative student data from the 1990s, an American study shows that male advantage in mathematics self-concept in high school facilitated male dominance in mathematically intensive tertiary education (Correll 2001). Another study using student data collected in Germany from the 2000s also demonstrates similar findings (Parker et al. 2014).

6.2.4 Subject choice in secondary school

Students who study mathematics and related subjects in high school have a higher chance of engaging in mathematically intensive tertiary education (Correll 2001). As boys are more likely than girls to enrol in advanced mathematics and physical science subjects in Australian high schools (Kennedy, Lyons and Quinn 2014), one may expect that subject choice in high school facilitates the gender gap in the choice of a mathematically intensive university major. However, an American study which analyses student data from the 1980s demonstrates that the proportion of women selecting engineering would only increase a little even if girls' enrolment in high school mathematics and science courses rose (Frehill 1997).

In Australia, the study of advanced mathematics and physical science subjects in Year 12 provides students with comprehensive preparation for many tertiary fields of study that involve calculus and fundamental knowledge in the physical sciences (Ainley, Kos and Nicholas 2008; Fullarton et al. 2003). Students who study physical

science subjects also tend to enrol in advanced mathematics subjects (Lamb and Ball 1999). Some students, however, enrol only in physical science subjects without choosing any advanced mathematics subject (Kennedy, Lyons and Quinn 2014). Recent studies have found that students who study physical science subjects in Year 12 have a high chance in Year 12 of choosing similar studies in post-secondary education (Sikora 2014b; Sikora 2015). We do not know, however, whether enrolment in the common subject combination – advanced mathematics and physical science subjects – is more differentiated by gender than enrolment in only physical science subjects, and whether the common subject combination further enhances gender differences in the choice of a mathematically intensive university major. Therefore, in the present study, I assess how the study of advanced mathematics and physical science subjects may contribute to the gendered choices of mathematically intensive university studies.

6.3 Research questions

In my analysis, I focus on three research questions. First, I consider gender socialisation in the family and examine whether the gender gap in choosing a mathematically oriented field of study at university differs according to the family's socioeconomic status. Second, I assess whether maternal and paternal employment in science increases the chances of engaging in a mathematics-related degree program for young men and women. As discussed in section 6.2, prior research has shown that occupational expectations, mathematics self-concept and high school preparation in the early stage of life are the key factors that influence the gender gap in the choice of a mathematically intensive major. Nevertheless, the relative importance of these factors has not yet been examined in the Australian context. Therefore, third, I assess the relative contributions of these factors to the gender gap in selecting a university major in mathematically intensive fields. My analysis is led by the following questions:

1. Is the gender gap in the choice of a mathematically intensive university major smaller among students from families of high socioeconomic status?

2. Are young people more likely to be influenced by the same-sex parent than the opposite-sex parent in their choice to pursue mathematically intensive university studies?

3. What is the relative importance of students' occupational expectations, mathematics self-concept, and choice of advanced mathematics and physical science subjects in high school in explaining the gender gap in the choice of a mathematically intensive university major?

6.4 Data

In this chapter, I examine the educational pathways of men and women from age 15 through Year 12 to the engagement in mathematically intensive science fields at university. Therefore, from the Y03 cohort, I selected participants who completed Year 12, reported that they enrolled in a bachelor's degree program between 2004 and 2013, and provided information about their fields of study. The resulting pooled sample for the analysis comprises 3,502 participants.

6.5 Variables

6.5.1 Dependent variable: majoring in the mathematically intensive sciences

The dependent variable is students' enrolment in a bachelor's degree program in mathematically intensive science fields. They encompass all subfields within the following broad categories listed in the Australian Standard Classification of Education (ASCED) (Trewin 2001): mathematical sciences, physics and astronomy, chemical sciences, earth sciences, information technology, engineering and related technologies,

and architecture and building. These fields of study are dominated by men and they require high-level mathematical knowledge involving calculus.

6.5.2 Independent variables: individual characteristics

Whether a student chooses the mathematically intensive sciences at university depends on a combination of student and school background. I emphasise here the specific characteristics of the early socialisation and educational experiences that enhance the chance of enrolling in mathematically intensive university studies. With this objective in mind, I use the following students' characteristics at age 15 as predictors: family's socioeconomic status, maternal and paternal employment in science, occupational expectations, and scholastic achievement and self-concept in mathematics. These measures have been covered in Chapter 4.

To better understand the broader context in which young people make decisions about transitioning from secondary to tertiary education, I examine specialisation in advanced mathematics in the context of enrolment in other subjects. In particular, it is important for me to consider whether the gender gap in the choice of a mathematically intensive university major is fostered by the possibility that boys and girls tend to select different combination of subjects in high school. For instance, boys might supplement their choice of advanced mathematics with more chemistry and physics subjects. This may be less the case for girls. Therefore, apart from the abovementioned predictors, I include an additional set of independent variables to denote the *subject choice related to the mathematically intensive sciences in Year 12* when the majority of students turned 18 years old and were about to enter tertiary education. To identify whether different subject combinations in high school are relevant to the gender gap in selecting a mathematically intensive university major without unnecessarily complicating my analysis, I classify subject choice related to mathematically intensive fields into two

categories: (1) the first comprises students who enrolled in at least one subject in advanced mathematics and at least one subject in physical science, and (2) the second comprises students who took at least one subject in physical science but did not enrol in advanced mathematics. The simplified classification is the result of my preliminary screening of the data which led me to believe that this solution would be optimal for my purposes. In the multilevel analysis, I compare these students to others who took other subject combinations belonging to my reference category in the language of regression analysis. These combinations include enrolment in advanced mathematics only without taking physical science, enrolment in life science only without any enrolment in physical science courses, and no enrolment in science.

I have described my conceptualisation of advanced mathematics as an independent variable in depth when I used it as an outcome variable in the previous chapter. Therefore, here I only note that all the advanced mathematics subjects taught between 2003 and 2006 as they appear in Table 5.1 in Chapter 5 have been used also in the analysis in the current chapter. In addition, Table 6.1 below presents all the physical science subjects taught between 2003 and 2006 that I have classified as being related to the mathematically intensive sciences. This classification is a matter of judgement and subject to possible adjustments, but I have relied on a number of previous studies to guide me (Ainley, Kos and Nicholas 2008; Sikora 2014b) and therefore I am confident that this conceptualisation represents a realistic and valid approach to understanding how high school subject choice may affect the transition of students to the tertiary study of mathematically intensive degrees.

Table 6.1 Physical science subjects in Year 12 by state and territory (2003–2006)

State / Territory	Physical Science Subjects
Australian Capital Territory	Chemistry, Earth Science (including Geology, Oceanography and Meteorology), Physics (including Electronics)
New South Wales	Chemistry, Earth and Environmental Science, Physics
Northern Territory	Chemistry, Physics
Queensland	Chemistry, Earth Science, Physics
South Australia	Chemistry, Geology, Physics
Tasmania	Chemistry, Physical Science, Physics
Victoria	Chemistry, Physics
Western Australia	Chemistry, Geology, Physical Science, Physics

Note: This coding is based on the curriculum contents rather than the name of the subject.

Source: Y03

6.6 Method

The methods I use in this chapter are similar to those I used for the analysis of advanced mathematic enrolment in Year 12 in Chapter 5. In this section, I briefly explain the methods for the analysis of enrolling in mathematically intensive university studies. Section 4.6 in Chapter 4 contains the details with respect to the use of multiple imputation, computation of standardised coefficients and predicted probabilities.

The Y03 data are clustered by school and hence the appropriate analytical procedure should take this sampling design into account. For this reason, I used two-

level logistic regression models with individual- and school-level variables of the following form:

$$\text{logit}(Y_{ij}) = \gamma_{00} + X\beta + \text{Z}\delta + u_{0j}$$

where Y_{ij} refers to enrolment in a bachelor's degree program in mathematically intensive fields, for individual i in school j and γ_{00} is the average intercept across schools. X is a vector of individual-level independent variables and β is a vector of regression coefficients corresponding to variables in vector X. Z is a vector of school-level variables and δ is a vector of regression coefficients corresponding to variables in vector Z. u_{0j} denotes the error term between schools.

To avoid the unobserved heterogeneity problem with odds ratios in different regression models and provide more intuitive answers to my research questions, I used Stata 14 to convert the odds ratios from logistic regression models to the predicted probabilities of men and women choosing a mathematically intensive university major. These predicted probabilities are not affected by unobserved heterogeneity (Mood 2010), and therefore I can compare the predicted probabilities between different nested models and draw my conclusions based on them.

6.7 Results

Prior to the multilevel analysis, I present the descriptive statistics with respect to the entry and completion rates of mathematically intensive degrees. I do not present the descriptive statistics of other students' characteristics because they are similar to those presented in Table 5.2 in Chapter 5. Instead, I include those descriptive statistics in Table A2.2 in Appendix 2.

6.7.1 How many men and women choose and complete a mathematically intensive degree?

Table 6.2 shows that in the Y03 cohort, men were about 4.1 times more likely than women to select a mathematically intensive bachelor's degree program (29 per cent versus 7 per cent). This is similar to the gender gap in attaining a mathematically oriented degree: men were 4.5 times more likely than women to complete the degree (27 per cent versus 6 per cent). Juxtaposing these two gender gaps makes it clear that the gender imbalance in the composition of the student population in these degrees is created at entry to university and persists, largely unchanged, up to the point of completion. In other words, Table 6.2 does not indicate that women who enrolled in mathematically intensive degrees drop out of them at significantly higher rates than men. This in itself could be considered encouraging. Nevertheless, being outnumbered by men by such a high ratio, women are likely to be affected by self-confidence crises and are at all times a definite minority. The choice of a mathematically intensive study at university is more segregated by gender than enrolment in advanced high school mathematics (13 per cent of boys versus 8 per cent of girls as presented in Chapter 5). This suggests that factors other than high school subject choice may be the major causes of the gender gap in the choice of a mathematics-related degree.

Table 6.2 Respondent characteristics by gender: proportions and means

	Men	Women	Min.	Max.	*N*
Dependent variable					
Entry into a mathematically intensive science degree after completing Year 12 [a]	0.29	0.07	0	1	3,502
Other information					
Attainment of a mathematically intensive degree [a b]	0.27	0.06	0	1	2,282

Note: This table contains weighted estimates before multiple imputations of missing data.

[a] indicates that the difference between men and women in that variable is statistically significant at $p < 0.05$.

[b] The large difference in the sample size between entry into and attainment of a mathematically intensive degree is mainly caused by LSAY attrition.

The descriptive statistics of other key independent variables, including the family's socioeconomic status, parental employment in science, occupational expectations, academic achievement and self-concept in mathematics, and relevant subject choice in Year 12, are presented in Table A2.2 in Appendix 2.

Source: Y03

6.7.2 Multilevel models

My multivariate analysis comprises several nested models that enable me to understand what portion of the gender gap, indicated by the unstandardised regression coefficients, is explained by addition of particular explanatory variables to the model. In Model 1, I consider the overall size of the gender gap in the choice of a mathematically intensive degree program under the assumption that respondents do not differ with respect to their family socioeconomic status. My next step is to consider the impact of gender socialisation in the family; that is, the extent to which the likelihood of pursuing a mathematically intensive degree differs for males and females who originate from various socioeconomic backgrounds. These intersectionality effects are captured by the interaction terms between the respondents' gender and their families' socioeconomic status, but also between the respondents' gender and paternal as well as maternal employment in science (Model 2). I try to understand in Model 2 whether girls from

more advantageous socioeconomic backgrounds are more likely to pursue mathematically intensive degrees and whether in doing so they are more likely to be influenced by the role models provided within their families by mothers or fathers. This is an aspect of within-family socialisation that has rarely been considered in Australia with respect to pursuit of mathematically intensive degrees at the tertiary level.

The family influences may be enhanced or offset by students' occupational expectations, mathematics self-concept and academic achievement in mathematics as well as subject choices in Year 12. I added these variables to Model 3 to capture the cumulative effects of school experiences that contribute to individual educational biographies and to identity formation which underpins crucial educational choices about specialisation in high school. Nevertheless, each of these elements has a specific dimension that must be considered, as discussed in the literature overview in section 6.2. Occupational expectations might reflect as much family socialisation as a range of expected utility values the students attach to particular career outcomes. These expectations also reflect student achievement at school. Mathematics self-concept of students is arguably linked closely to their academic achievement and is likely not only to affect their subject choices but also to reflect or shape their occupational expectations. Subject choices are very likely a reflection of students' occupational expectations, prior academic achievement and the degree of confidence students feel in their numeracy skills. Thus, all of these factors are closely interconnected and reciprocally affect each other over time. In my analysis I assess their relative contributions to individual decision to select a mathematically intensive university major. By comparing the effect of gender in Model 3 to that in Model 1, I could see to what extent these factors measured at the stage of secondary education contribute to bridging the gender gap I described in Table 6.2, which characterises the participation in mathematically intensive university education. In my last model, I added all the

variables that were used to construct the LSAY weights as controls (Model 4) and examined whether the results were similar to those of Model 3. Because my analysis is based on longitudinal data which are subject to attrition, I have to use attrition weights to ensure that my conclusions are unbiased. The attrition weights provided by LSAY were based on several variables, including students' gender and mathematics achievement. However, my theoretical framework requires me to examine the effects of students' gender and mathematics achievement separately. To deal with this difficulty I have adopted the strategy of first estimating the non-weighted data of my models. Doing so enables me to compare the relative contributions of students' academic achievement versus their socioeconomic backgrounds. Next, I rerun my final model in the presence of attrition weights, to ensure that my unweighted analyses do not differ greatly from my weighted analyses and so can be used to draw conclusions about the relative contributions of predictors to explaining my dependent variable.

Table 6.3 Factors affecting enrolment in mathematically intensive university degree programs: odds ratios and standardised coefficients from multilevel logit models

	Model 1			Model 2			Model 3			Model 4		
	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient
Fixed effects												
Individual characteristics												
Female	0.175***	(0.021)	-0.429	0.168***	(0.026)	-0.437	0.334***	(0.068)	-0.246	0.330***	(0.067)	-0.247
Family background at age 15												
Socioeconomic status	1.118	(0.078)	0.042	1.014	(0.090)	0.005	1.050	(0.106)	0.017	1.048	(0.110)	0.016
× Female				1.221	(0.197)	0.065	1.129	(0.187)	0.035	1.139	(0.187)	0.039
Mother has a science job				1.245	(0.189)	0.041	1.185	(0.202)	0.029	1.206	(0.208)	0.032
× Female				0.627†	(0.149)	-0.069	0.648	(0.173)	-0.057	0.653	(0.176)	-0.057
Father has a science job				1.152	(0.148)	0.028	0.902	(0.138)	-0.018	0.899	(0.139)	-0.019
× Female				0.984	(0.235)	-0.002	1.027	(0.269)	0.005	1.057	(0.276)	0.008
Career expectations at age 15												
Expected a career in the mathematically intensive sciences							3.692***	(0.465)	0.230	3.762***	(0.478)	0.232
× Female							1.354	(0.350)	0.029	1.367	(0.354)	0.030
Mathematics												
Mathematics achievement at age 15							1.047	(0.077)	0.021	1.039	(0.080)	0.017
Mathematics self-concept at age 15							1.485***	(0.092)	0.157	1.477***	(0.096)	0.155

(Table continues)

Table 6.3 (Continued)

	Model 1			Model 2			Model 3			Model 4		
	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient
Studied advanced mathematics and physical science							3.381***	(0.655)	0.185	3.551***	(0.681)	0.192
× Female							0.762	(0.258)	-0.025	0.740	(0.249)	-0.028
Studied physical science only							1.927***	(0.303)	0.123	1.953***	(0.309)	0.126
× Female							0.769	(0.202)	-0.038	0.744	(0.193)	-0.043
Constant	0.390***	(0.031)		0.388***	(0.033)		0.112***	(0.016)		0.097***	(0.018)	
Random effects												
Variance between schools	0.068	(0.059)		0.057	(0.059)		0.040	(0.057)		0.027	(0.058)	

Note: The sample for this multilevel analysis contains 3,502 students in 310 schools with multiple imputations of missing data. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Model 4 contains weighting variables. The odds ratios and standardised coefficients of the weighting variables in Model 4 are presented in Table A2.3 in Appendix 2.

Source: Y03

Is the gender gap in choosing a university major in mathematically intensive fields smaller among students from high status families?

If high status families embrace more egalitarian values and therefore strive to encourage their daughters as much as their sons to engage in mathematically intensive fields, the Y03 data should show not only a smaller gender gap in the study of advanced high school mathematics but also a small disparity in the choice of university major between young men and young women, both being from privileged backgrounds. In the previous chapter, however, I found that the gender gap in choosing advanced mathematics in Year 12 was equally wide for students from various socioeconomic backgrounds. Therefore, it is perhaps unsurprising that, at the university level, a high family socioeconomic status does not bridge the gender gap in choosing a mathematically intensive major (odds ratios of 1.014 and 1.221 in Model 2, Table 6.3). To highlight this finding, Figure 6.2 presents the predicted probabilities for men and women of various socioeconomic standings. It shows that while women who come from privileged families (2 standard deviations above the mean) seem to be slightly more likely than other women to engage in mathematically intensive studies at university, this difference is not statistically significant between women of high status and lower status (as shown by confidence intervals around the predictions for women located 2 standard deviations above and below the mean). For all women the probability of pursuing a mathematically intensive degree is significantly lower than the comparable probability for men. The gender gap visually appears to be only marginally smaller, but this is only due to inaccuracy of statistical estimates. There is no actual statistical evidence that the gender gap varies by family socioeconomic status.

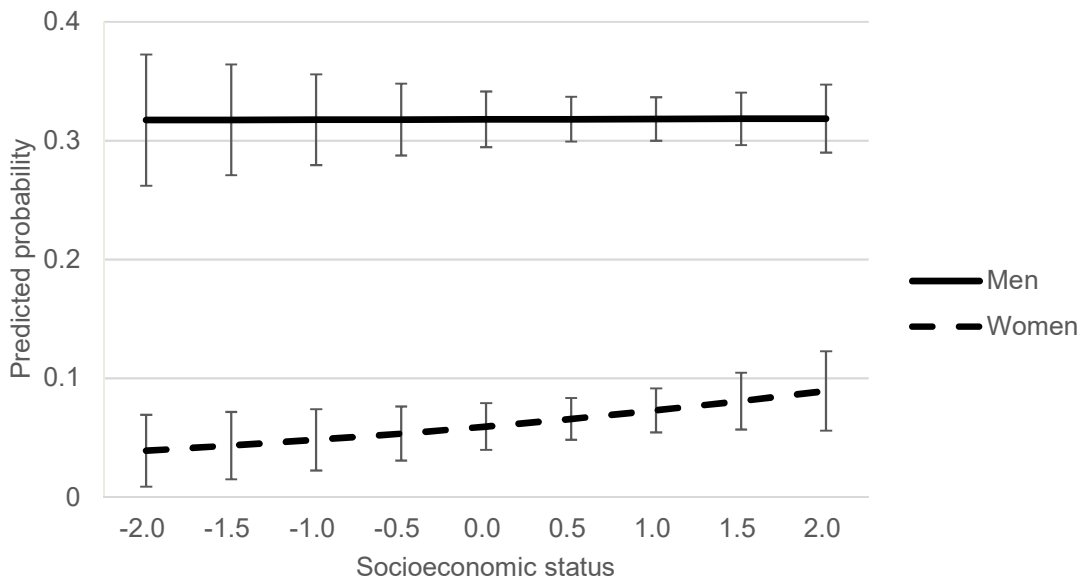

Figure 6.2 Predicted probabilities of men and women enrolling in mathematically intensive degree program by socioeconomic status

Note: The predicted probabilities are based on Model 2 presented in Table 6.3.

Source: Y03

Are young people more likely to be influenced by the same-sex parent to enrol in a mathematically intensive degree program?

Although there is really no indication that the families of higher socioeconomic status have more success in encouraging their daughters to engage in mathematically intensive studies, it is possible that within-family socialisation differs for girls and boys. In particular, the gender socialisation hypothesis proposes that adolescent boys and girls are likely to refer to gendered role models within their families. In this analysis, I examine this proposition in the context of my second research question. To have a clear picture of how this issue is highlighted by my analysis, I show in Figure 6.3 how same-sex and opposite-sex role modelling occurs in the families of Y03 respondents. The contrast between the dark and light bars leaves little doubt that men are more prone to enter mathematics at university while women are quite unlikely to do so, and this is not greatly differentiated by having a same-sex role model, that is, a parent who has a

science job. The clues also lie in Model 2 (in Table 6.3) in which the odds of choosing a mathematically intensive degree program for respondents whose mothers or fathers work in science are positive, but they are statistically insignificant (odds ratios of 1.245 and 1.152, respectively). The interaction effects between mothers' employment in science and the respondents' gender, and between fathers' employment in science and gender, which I have introduced to check whether the impact of particular parent may vary for children of different gender, are also statistically insignificant (odds ratios of 0.627 and 0.984, respectively). Therefore, this analysis suggests that whatever same-sex and opposite-sex role modelling may occur within the family between parents and children, it encourages students to take up advanced mathematics in Year 12 (as presented in Chapter 5) and then follow up with selecting a mathematically intensive major at university at a similar rate within genders. Within-family cross-gender role modelling is not the key to understanding what generates, or contributes to maintaining, the educational gender gap in mathematics in secondary and tertiary education.

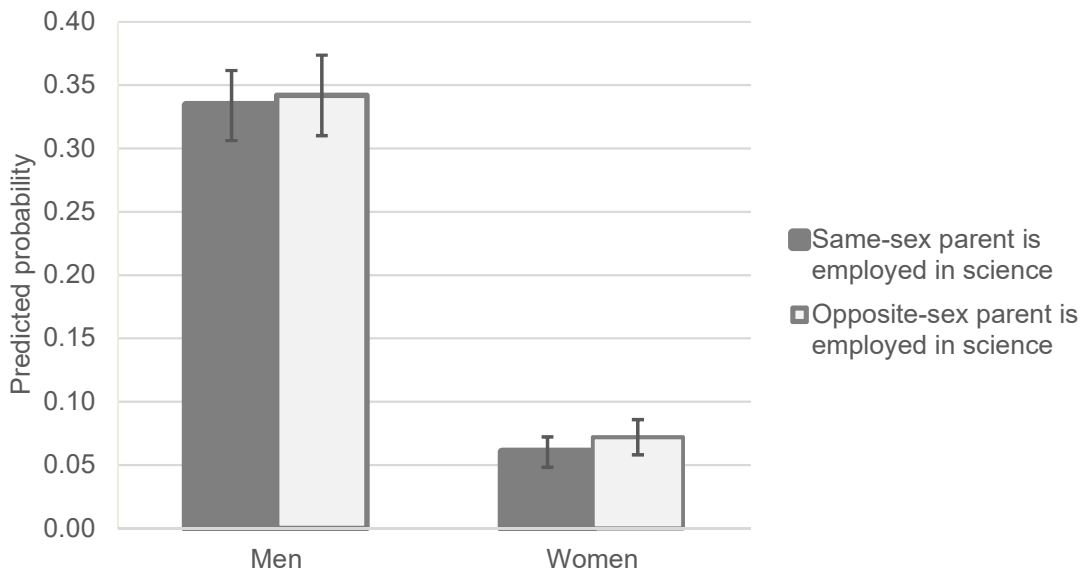

Figure 6.3 Predicted probabilities of men and women enrolling in mathematically intensive degree program by parental employment in science

Note: The predicted probabilities are based on Model 2 presented in Table 6.3. 'Same-sex parent is employed in science' refers to role modelling between boys and fathers or between girls and mothers. 'Opposite-sex parent is employed in science' refers to role modelling between boys and mothers or between girls and fathers.

Source: Y03

What factors matter most as the potential determinants of gender gap in mathematically intensive majors at university?

The question I deal with in this section is concerned with which one of the following factors, (1) students' occupational expectations, (2) self-concept in mathematics, (3) the history of students' success in high school mathematics and (4) the associated subject choices in high school, matters most for the gender gap in entry into mathematically intensive university courses. To distinguish the unique contributions of these factors, I added these factors to Model 3 (in Table 6.3). This model helps to determine which of these characteristics is more influential to students' chances of choosing a mathematically intensive university major. I also included the interaction effects between the respondents' gender and occupational expectations, and between the respondents' gender and subject choice in Year 12. These interaction effects

demonstrate whether expecting a mathematically intensive career and taking relevant subjects in Year 12 influence the chances of enrolling in a mathematically oriented major equally for men and women. In Model 4 (in Table 6.3), I added all the weighting variables and this produced similar results to those in Model 3.

The standardised coefficients in Models 3 and 4 (in Table 6.3) show that, other than the respondents' gender (-0.246 in Model 3 and -0.247 in Model 4), expecting a mathematically intensive career at age 15 (0.230 in Model 3 and 0.232 in Model 4) is the most important predictor of choosing a related field of study. They do not, however, indicate whether occupational expectations at age 15 have a great impact on the gender gap in choosing the major. This is better shown through predicted probabilities.

My strategy is to consider the male-to-female ratios in the predicted probabilities of choosing a mathematically oriented university major for each independent variable in Model 4. More precisely, in Table 6.4, I present the male-to-female ratios derived from relative probabilities comparing young men and women who did or did not know that they wanted to pursue a mathematically intensive profession when they were 15 years of age and then went on to study a mathematically intensive major at university (the first right hand column in the table). Among the respondents who did not expect a mathematics-related career at age 15, men are 3.5 times more likely than women to choose a relevant major. The male advantage falls dramatically among respondents who expected a mathematically intensive career: men are 1.9 times more likely than women to choose a related major. Based on this table, there is little doubt that getting young people to identify their interest in mathematical careers early is possibly a good way of reducing the gender gap. While promising, this may also be challenging, given that very few girls express in high school an interest in careers that involve advanced mathematics.

Table 6.4 Predicted probabilities of men and women enrolling in mathematically intensive degree program and male-to-female ratios by occupational expectations at age 15

	Men	Standard error	Women	Standard error	Male-to-female ratio
Did not expect a mathematically intensive career at age 15	0.27	(0.03)	0.08	(0.02)	3.5
Expected a mathematically intensive career at age 15	0.58	(0.03)	0.30	(0.05)	1.9

Note: The predicted probabilities are based on Model 4 (in Table 6.3) and computed with other independent variables held at their means.

Source: Y03

Then I consider the impact of students' mathematics achievement in high school on the gender gap in choosing a mathematical university major. In Table 6.5, I present the predicted probabilities of young men and women choosing a mathematically intensive major according to different levels of standardised mathematics achievement at age 15. The table further shows that the male-to-female ratios are similar regardless of how students performed in high school mathematics. In other words, high school mathematics achievement is not relevant to the gender gap in the choice of a mathematical major.

Table 6.5 Predicted probabilities of men and women enrolling in mathematically intensive degree program and male-to-female ratios by standardised mathematics achievement at age 15

Standardised mathematics achievement	Men	Standard error	Women	Standard error	Male-to-female ratio
-4	0.38	(0.08)	0.14	(0.05)	2.7
-3	0.39	(0.07)	0.14	(0.04)	2.7
-2	0.40	(0.05)	0.15	(0.03)	2.7
-1	0.40	(0.04)	0.15	(0.03)	2.7
0	0.41	(0.03)	0.16	(0.03)	2.6
1	0.42	(0.03)	0.16	(0.03)	2.6
2	0.43	(0.04)	0.17	(0.03)	2.6
3	0.44	(0.05)	0.17	(0.04)	2.6

Note: The predicted probabilities are based on Model 4 (in Table 6.3) and computed with other independent variables held at their means. A higher value of standardised mathematics achievement indicates better performance in high school mathematics at age 15.

Source: Y03

Next, I turn to considering the second motivational factor in my model, namely mathematics self-concept, which was measured by a continuous variable expressed in standard deviations. In Table 6.6, I show the predictions for students whose levels of mathematics self-concept ranging from 2 standard deviations below the mean to more than 2 standard deviations above the mean. As the respondents' levels of mathematics self-concept increase, the male advantage in choosing a mathematically intensive major decreases. While men were 3.2 times more likely than women to choose a mathematically intensive major when their levels of mathematics self-concept are 2.1 below the average, men are only 2.1 times more likely than women to choose a mathematics-related major when their levels of mathematics self-concept are 2.4 above the average for all students. This change is comparable to the change attributable to a high school plan to pursue a mathematically intensive career. Undoubtedly motivational factors matter a lot.

Table 6.6 Predicted probabilities of men and women enrolling in mathematically intensive degree program and male-to-female ratios by mathematics self-concept at age 15

Level of mathematics self-concept	Men	Standard error	Women	Standard error	Male-to-female ratio
-2.1	0.21	(0.03)	0.07	(0.02)	3.2
-1.6	0.24	(0.03)	0.08	(0.02)	3.1
-1.1	0.28	(0.03)	0.09	(0.02)	3.0
-0.6	0.32	(0.03)	0.11	(0.02)	2.9
-0.1	0.37	(0.03)	0.13	(0.02)	2.8
0.4	0.41	(0.03)	0.16	(0.03)	2.6
0.9	0.46	(0.03)	0.18	(0.03)	2.5
1.4	0.51	(0.03)	0.21	(0.04)	2.4
1.9	0.56	(0.04)	0.25	(0.04)	2.2
2.4	0.60	(0.04)	0.29	(0.05)	2.1

Note: The predicted probabilities are based on Model 4 (in Table 6.3) and computed with other independent variables held at their means. A higher value of mathematics self-concept indicates a more positive rating of self-assessed competence in mathematics.

Source: Y03

As to high school subject choices in Table 6.7, it is evident that different subject combinations with respect to advanced mathematics and physical science make little difference for the gender gap in the choice of a mathematically intensive field of study at university. Men who studied both advanced mathematics and physical science in high school were about 2.5 times more likely than women to transfer into a similar degree at university. This was also the case for men who in high school took physical science without advanced mathematics or have taken other subject combinations. Therefore, supplementing the study of advanced mathematics with physical science or making some other choices of subject combinations affects little the male-to-female ratios in choosing a mathematically intensive university major.

Table 6.7 Predicted probabilities of men and women enrolling in mathematically intensive degree program and male-to-female ratios by subject choice in Year 12

	Men	Standard error	Women	Standard error	Male-to-female ratio
Studied advanced mathematics and physical science in Year 12	0.57	(0.04)	0.23	(0.06)	2.5
Studied physical science but did not choose advanced mathematics in Year 12	0.50	(0.04)	0.18	(0.04)	2.7
Other subject combinations in Year 12	0.21	(0.02)	0.09	(0.01)	2.5

Note: The predicted probabilities are based on Model 4 (in Table 6.3) and computed with other independent variables held at their means.

Source: Y03

Overall, comparing the three tables reviewed above leads to an unequivocal conclusion: that students' career orientation towards mathematically intensive occupations and their high mathematics self-concept, namely the two motivational factors considered here, are the ones that hold the most promise of bridging the gender gap in mathematical majors between young men and women who enter university.

How much of the gender gap in university major choices could be reduced if boys and girls had the same occupational expectations, achievement and self-concept in mathematics, and subject choice when they attended high school?

While most of the gender gap in the choice of a mathematically oriented major at university remains unexplained in Models 1 and 2, adding students' occupational expectations, achievement and self-concept in mathematics, and subject choices in Year 12 to Model 3 reduces the gender gap almost by half. Figure 6.4 demonstrates that the gender gap is largely reduced from about 23 percentage points in Models 1 and 2 to about 12 percentage points in Model 3. Taking all the weighting variables into account in Model 4 results in a similar gender gap at about 12 percentage points. In short, the

gender gap in choosing a mathematically oriented major is greatly reduced (by 48 per cent) if girls are as likely as boys to aspire to mathematically intensive careers, perform well and feel competent in mathematics, and enrol in advanced mathematics and physical science subjects in Year 12.[13]

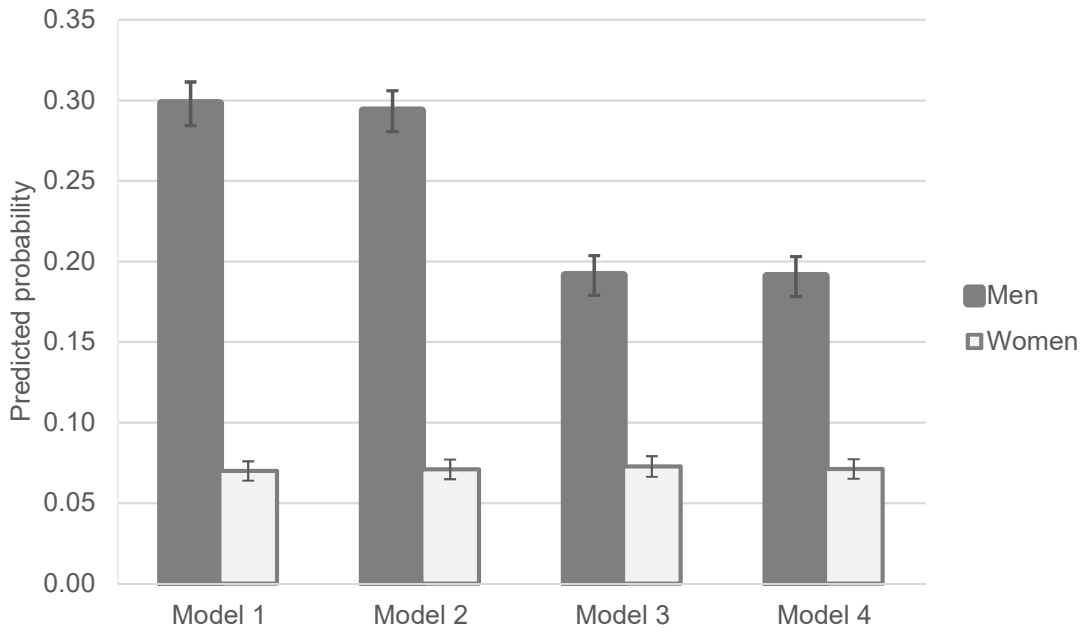

Figure 6.4 Predicted probabilities of men and women enrolling in mathematically intensive degree program from Models 1 to 4

Note: The predicted probabilities are based on Models 1, 2, 3 and 4 presented in Table 6.3.
Model 1: Female + Socioeconomic status at age 15
Model 2: Model 1 + Mother has a science job + Father has a science job + interaction effects with gender
Model 3: Model 2 + Career expectations at age 15 + Mathematics achievement at age 15 + Mathematics self-concept at age 15 + Relevant subject choice in Year 12 + interaction effects with gender
Model 4: Model 3 + weighting variables

Source: Y03

Although the detailed examination of the intersectionality between gender and race/ethnicity of the type often undertaken in the United States (see, for example, Riegle-Crumb and King 2010) is beyond the scope of this study, I have performed some

[13] I obtained 48 per cent by calculating the proportion of the gender gap explained using the following formula: $(22.8 - 11.9) \div 22.8 \approx 47.6$

analyses that speak to this issue. My additional results show that the gender gap in choosing a mathematically intensive major is comparable among native and migrant students. Two of the weighting variables that are necessary in Model 4 (in Table 6.3), because of how LSAY weights have been constructed, are related to the students' immigration background. Table A2.3 (regarding immigration status) in Appendix 2 shows that, compared to native students, first-generation students have a higher chance of choosing a mathematically intensive major. Second-generation students are just as likely as native students to choose this kind of major. Nevertheless, Figure 6.4 (derived from Model 4) demonstrates that the gender gap in choosing a mathematically intensive major remains similar regardless of whether we control for students' immigration backgrounds, as is done in Model 4. In other words, the gender gap is similar among migrants and non-migrants.

6.8 Summary of findings and discussion

In this chapter, I considered the extent to which students' family socialisation and educational experiences as well as motivation in high school would explain the gender gap in the choice of a mathematically intensive university major. My conceptualisation of family socialisation was specific in that I mostly focus on the role modelling that occurs within a student's family when one of the parents or both of them engage in science-related career fields. This is not the only form of role modelling available to young people, but in most cases the influence of parents as role models lasts longer than that of teachers or other inspirational adults. This is not to say that parents are the only influential role models, but without doubt they are important role models. My conceptualisation of motivational factors focused on early career expectations and mathematics self-concept of students.

Overall I found that the gender gap in enrolling in a mathematically intensive university major could be reduced by almost half if women were as likely as men to aspire to mathematically oriented careers while in secondary school, to have more confidence in their mathematical abilities, to perform as well in school mathematics as men and to engage at higher rates in advanced mathematics and physical science subjects in Year 12. Out of these factors I established that the expectation of a mathematically intensive career and mathematics self-concept in adolescence, which make up important components of student motivation to study mathematics, have the greatest potential to bridge the gender gap. This finding fits the expectancy value theory which suggests that women are less likely than men to pursue mathematically intensive fields of study because they place less subjective value on those fields and they have lower confidence in their mathematical abilities than men (Eccles 2011). Nevertheless, even if these motivational factors could operate similarly for men and women, we would still have twice as many men as women in mathematically intensive majors at university. This is preferable to three times as many, but still far from satisfactory.

My results demonstrate that Australian youth aspire to gender-typical careers and they reproduce their gendered preferences in their field of study choices. As suggested by the stratification theory of gender essentialism, many students embrace the gender stereotypical belief that the mathematically intensive fields are more appropriate for males than for females (Charles and Bradley 2009). As a result, adolescent boys are far more likely than girls to aspire to a mathematically intensive career, as evident in my analysis. The importance of occupational expectations at age 15 for later gender differences in field of tertiary study choices is hard to overestimate. Thus, not only should we strengthen career education in secondary school and signal to both adolescent boys and girls that they can engage and succeed in mathematically intensive fields (Cheryan et al. 2017), but we should also do so in novel and more effective ways.

Adolescents are known to change their occupational expectations quite often (Rindfuss, Cooksey and Sutterlin 1999), and therefore high school years seem particularly promising in offering opportunities to foster girls' interest in mathematically intensive careers. It is particularly important, however, to strengthen career education in secondary school in ways that effectively help adolescent boys and girls not only to gain accurate career information but also to combat gender stereotypes that affect perceptions of various occupations. Attempts to promote female engagement in mathematically intensive fields are likely to be less effective when undertaken at a stage when females have already disengaged from mathematics and related disciplines.

Another opportunity to further narrow the gender gap in mathematically intensive studies at university lies in finding more effective ways to enhance girls' self-confidence in their mathematical abilities. As with occupational expectations, this concerns motivational factors and the identity formation process which arguably begins much earlier than adolescence. My results in Chapter 5 show that although high school girls almost catch up with their male peers in mathematics performance, they continue to have significantly lower levels of confidence in their mathematical abilities. Such low levels of self-confidence in mathematical abilities, rather than mathematical achievement, are among the key reasons that few females are found among students in advanced high school mathematics and related fields of study at university, as presented in my results. Undeniably the world of work and academia itself are segregated by gender, so it might take significant changes to successfully counteract the deeply entrenched and widely diffused gender stereotypical beliefs that males are more talented in mathematics and that mathematics is a male domain. Nevertheless, high school teachers, counsellors, parents and other people who interact with adolescents can help girls to build up and sustain their confidence in mathematics by systematically signalling to girls that their mathematical abilities are as good as those of boys. It is also

possible to encourage boys to be more positive towards girls in mathematics classrooms and to behave in a manner that does not result in an unintended, or perhaps sometimes intended, intimidation of female classmates. There are also opportunities for mathematics teachers to create student-centred and 'mistake friendly' learning environments that allow girls to feel more comfortable and confident engaging with mathematics (Prinsley, Beavis and Clifford-Hordacre 2016).

The key implication of my analysis is that the gender gap in the choice of a mathematically oriented university major must be seen as a continuation of the gendered patterns in teenage occupational expectations and educational experiences during adolescence. Compared to the gendered patterns in occupational expectations, enrolment in Year 12 advanced mathematics (as demonstrated in Chapter 5) is less segregated by gender. Once students leave school, however, young women are more likely than their male peers to leak from the mathematically intensive science pipeline by turning to the pursuit of non-mathematical qualifications. My analysis shows that this process affects education in advanced mathematics and related fields just as it was shown to affect other types of post-secondary science education in Australia (Sikora 2014b) in accordance with the 'leaky pipeline' argument (Blickenstaff 2005; Xie and Shauman 2003).

In this chapter, I intended to identify the key factors in the pre-adolescent and adolescent socialisation, motivation and educational pathways that encouraged students to engage in mathematically oriented education at university. However, one class of factors that I have not yet considered relates to the specific features of the Australian education system, namely the difference between schooling sectors as well as gender composition of schools. Research has long indicated, most recently in the United States, that opportunity structures embedded in the high school environment may also affect students' attainment of a mathematically oriented university qualification (Legewie and

DiPrete 2014a). Therefore, in the next chapter, I examine whether specific school environments influence students' chances of enrolling in mathematically intensive studies at the secondary and tertiary levels.

Chapter 7

The impact of single-sex schooling on students' engagement in mathematically intensive fields at secondary and tertiary levels

My study of adolescent educational careers, informed by the life course perspective, presented in Chapters 5 and 6 demonstrated that motivational factors, including teenage occupational expectations and self-confidence in mathematics, strongly shape the decisions that males and females make about pursuing mathematically intensive specialisations. At the institutional level, educational systems are not designed to channel students into gender-typical specialisations, but they can operate in ways that effectively facilitate self-sorting by youth (Charles and Bradley 2002; Smyth and Steinmetz 2008). To illustrate the importance of institutional arrangements in enabling young people to enact certain choices, in this chapter, I switch my focus to school characteristics. Specifically, I assess whether they make it easier or more difficult for students to engage in advanced mathematics and related fields. The literature in this area emphasises the potential of gender-segregated education as a panacea for the shortage of women in mathematics (Signorella, Hayes and Li 2013; Spielhofer, Benton and Schagen 2004), and therefore I examine the extent to which single-sex schooling may counteract gender stereotypes and influence students' decisions to pursue advanced mathematics in Year 12. Next, I examine whether youth experiences with gender-segregated secondary education affect their choices of university majors.

I begin by reviewing previous studies which examined the impact of single-sex schooling on students' engagement in mathematics and related disciplines. Then I discuss the methodological challenges in these studies which often led to problematic

conclusions and I propose feasible solutions. Following the discussion of my data, variables and methods, I present the empirical evidence about the role of all-boys and all-girls schooling in fostering Year 12 advanced mathematics enrolment. Given the dearth of comprehensive Australian evidence regarding whether or not gender-segregated secondary schooling has an influence on students' choices of university majors, I next ascertain whether graduates of single-sex schools are more likely than their peers to engage in mathematically oriented university studies. I conclude with a discussion of the extent to which single-sex education can be credited with having the effect of fostering greater participation in mathematics among Australian youth.

7.1 The impact of single-sex schooling on students' engagement in mathematically intensive fields of study: a literature overview

Sociology as a discipline, makes a vital contribution to the conceptual framework used by other social scientists in addressing the relationship between gender and mathematics. My theoretical framework in Figure 7.1 highlights the sociological focus on single-sex schooling and other school characteristics. This complements an array of cultural and familial factors that affect students' learning of mathematics. Those factors have been analysed in Chapters 5 and 6.

Apart from family influences, educational systems and schools may enable or constrain how adolescents act on their educational and occupational expectations, and choose to specialise in particular fields (Connell and Pearse 2015; Legewie and DiPrete 2014a; Sikora 2014a). Of the many aspects of schooling that can foster greater enthusiasm for the field of mathematics, the international research on gender has long singled out the gender-segregated context as the school characteristic with the potential to most effectively counteract gender stereotypes (Signorella, Hayes and Li 2013; Smithers and Robinson 2006).

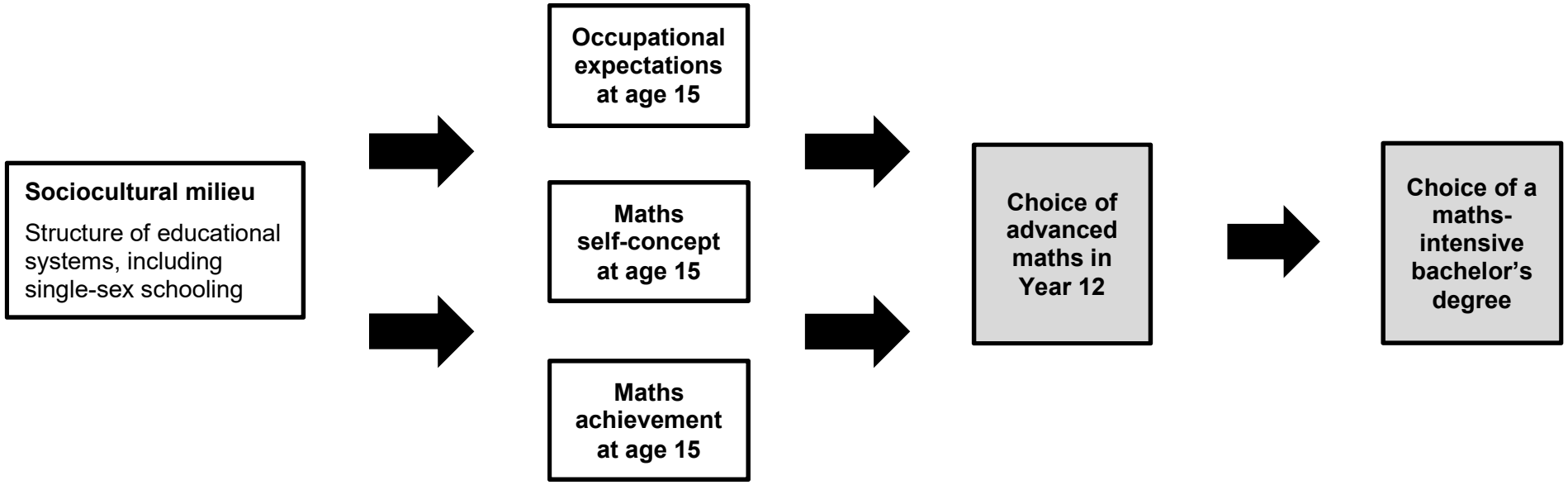

Figure 7.1 The impact of single-sex schooling on students' engagement in mathematics and related disciplines

Note: This conceptual diagram illustrates how single-sex schooling affects students' choices of advanced mathematics in Year 12 and of a university major in mathematically oriented fields through students' development of occupational expectations, mathematics self-concept and mathematics achievement.

Source: Charles and Bradley (2002; 2009); Sikora (2014a); Smyth and Steinmetz (2008)

The advocates of single-sex schooling claim that it encourages boys and girls to engage in gender-atypical activities and specialisations (Salomone 2003). Their arguments usually involve several statements. First, in all-girls schools, effective female role models are provided by the greater percentage of women among teachers of mathematics and science (Catsambis 2005; Mallam 1993). Second, the absence of boys in all-girls schools creates an environment that is free of competition with male peers (Watson 1997). This helps to relieve the pressure on girls to conform to gender role expectations, which, in turn, enhances their confidence in mathematics (Catsambis 2005; Foon 1988). By analogy, in all-boys schools, students may experience less pressure to comply with gender role expectations, and may thus develop their interests in gender-atypical fields, such as English literature and drama (Foon 1988; James and Richards 2003; Salomone 2003). By contrast, in coeducational schools, girls often struggle to overcome traditional gender stereotyping which supresses their enjoyment of high-level mathematics and the potential to form plans to specialise in mathematics (Salomone 2003).

Indeed, studies in Australia and overseas show that single-sex schooling may enhance students' achievement and confidence in gender-atypical subjects. In the 1980s, among 16 non-government schools in Melbourne, students in all-boys schools had a higher chance of engaging in English than students in all-girls schools and boys in coeducational schools (Foon 1988). The same study also found that girls in all-girls schools were more likely to study science and achieve good results in mathematics and science than girls in coeducational schools. In the 1970s, among a group of 16-year-old British students, the gender gaps in English and mathematics self-concepts were smaller in single-sex schools than in coeducational schools (Sullivan 2009).

Yet, the balance of evidence is far from unequivocal. Numerous studies that compare teaching advanced mathematics and physical science between single-sex and

coeducational schooling reach mixed conclusions. In the mid-1990s in England, boys and girls in single-sex schools were more likely than their same-sex peers in coeducational schools to study high-level mathematics (Spielhofer, Benton and Schagen 2004). Two other Australian studies that considered a variety of school characteristics, however, showed that during the late 1990s and mid-2000s, students in single-sex schools were just as likely as students in coeducational schools to study physical science subjects in Year 12 (Ainley and Daly 2002; Sikora 2014a).

With respect to the lasting effects of single-sex schooling, some international research concludes that students with experiences of gender-segregated high school learning are more likely to engage in gender-atypical fields than students who graduated from coeducational schools. A study based on a sample of British people who were born in 1958 found that those who had single-sex education were more likely to gain post-secondary qualifications in gender-atypical areas (Sullivan, Joshi and Leonard 2010). Along the same lines, James and Richards (2003) reported that from the 1970s to the 1990s in the United States, boys in single-sex schools took more interest in the humanities than their same-sex peers in coeducational schools. These boys also retained their early interests in their post-secondary education and careers. In the same country, men who went to all-boys schools in the 1990s were more likely to graduate with a bachelor's degree in gender-neutral fields than men who attended coeducational schools (Karpiak et al. 2007).

However, this body of the literature is also inconclusive. There is no consensus that single-sex schooling offsets the tendency to specialise in a field of study that is typical for one's gender. In Australia, for example, two studies based on a sample of university undergraduates in the 1990s did not provide any evidence that young women from all-girls schools were more likely than other women to pursue mathematics or science at university (Forgasz 1998; Lumley 1992). Similarly, in the United States,

women who attended all-girls schools in the 1980s and 1990s had a higher chance of declaring a major in gender-neutral fields, but they were just as likely as women from coeducational schools to complete these majors (Karpiak et al. 2007; Thompson 2003). In sum, this pattern of mixed evidence suggests that the effectiveness of single-sex schooling in counteracting gender stereotypes in the choice of study varies over time and from place to place (Kim and Law 2012; Law and Kim 2011; Sikora 2014a). Apart from historical and geographic contingencies, an argument has been put forward that attributes this variability to various methodological problems that many previous studies suffer from.

7.2 Methodological issues in prior research on the impact of single-sex education

The typical methodological problems in the studies of single-sex schooling involve insufficient accounting for confounding variables. As a result, what appears to be the beneficial effect of single-sex schooling should truly be attributed to other school characteristics that happen to be correlated with the gender-segregated school environment. With this in mind, I take into account a rich array of differences between single-sex and coeducational sectors in Australia by paying particular attention to school resources, as well as the differences between schools in student admission policies and in teacher quality (Halpern et al. 2011; Pahlke, Hyde and Allison 2014; Signorella, Hayes and Li 2013). In Australia, most single-sex schools are situated in the Catholic and independent sectors that charge tuition fees (Forgasz and Hill 2013). These schools tend to be located in affluent communities and metropolitan areas, and attract students from families of higher socioeconomic status in which parents can afford out-of-pocket expenses (Sikora 2014a). Furthermore, single-sex schools have considerably fewer difficulties in recruiting qualified teachers as they offer competitive salaries and better work conditions (Sikora 2014a; Tsolidis and Dobson 2006). Despite the barriers

in access to single-sex schools created by tuition fees, admission to many single-sex schools is competitive and such schools have long waiting lists (Campbell, Proctor and Sherington 2009). The situation of single-sex schooling varies from country to country, but similar arguments have been put forward with respect to the analysis of the beneficial effect of gender segregation in the learning of mathematics and science in other countries (Halpern et al. 2011; Signorella, Hayes and Li 2013; Smyth 2010). Arguably many previous studies failed to account for the differences between single-sex and coeducational schools apart from the gender-segregated environment. Therefore, they ended up confounding the benefits of single-sex schooling with the benefits of private, more selective or better resourced schools. In my analysis presented in this chapter, I make an effort to avoid such a risk.

7.3 Research questions

To understand the extent to which attending a single-sex school boosts participation in advanced mathematics in Year 12 and the likelihood of completing a mathematically intensive degree, my analysis focuses on two research questions:

1. Is the gender gap in advanced mathematics enrolment in Year 12 smaller in single-sex schools than in coeducational schools?

2. Is the gender gap in the choice of a mathematically intensive university major smaller among graduates of single-sex schools than of coeducational schools?

7.4 Data

The first part of the analysis is devoted to the difference in advanced mathematics enrolment in Year 12 between single-sex and coeducational schools. This analysis had to be restricted to students who had not changed schools between 2003 and the time of completing Year 12. The year 2003 was the only occasion on which the

information about schools was collected from principals, along with the time of completing Year 12. The pooled sample for the analysis of advanced mathematics enrolment in Chapter 5 comprised 6,760 Year 12 students. The analysis in this chapter excluded 241 students because they had changed schools since 2003 or they attended a school which did not provide the information about the proportion of girls in the school. In Tasmania and the Australian Capital Territory, students who complete Year 10 in the government sector usually have to enrol in another senior secondary school in order to proceed to Year 11. In this sample, there were 436 such students. These students were also excluded from the analysis in addition to the 241 students. Therefore, my analytical sample in this chapter involves 6,083 Year 12 students.

In the second part of my analysis presented in this chapter, I examine how attending a single-sex secondary school is associated with the choice of university education in mathematically intensive fields. For this analysis, I selected participants who completed Year 12 and reported that they enrolled in a bachelor's degree program between 2004 and 2013. Beginning with the sample of 3,502 respondents used in Chapter 6, I excluded 113 students who changed schools since 2003. Another 213 participants were excluded from this part of the analysis because they attended government schools in Tasmania and the Australian Capital Territory and they had to change schools. I omitted two more participants from the analysis because the school they attended did not provide the information about its proportion of girls. The resulting analytical sample involves 3,174 participants. The difference in sample sizes between the first and second part of my analysis arises mainly due to attrition in subsequent waves of the LSAY study.

7.5 Variables

7.5.1 Dependent variables

As in Chapter 5, the dependent variable in the first part of the analysis is the students' enrolment in at least one advanced mathematics subject in Year 12. In the second part of the analysis, I look at the effect of attending a single-sex school on the enrolment in a bachelor's degree program in mathematically intensive fields. This is the dependent variable for which I analysed the impact of non-school predictors in Chapter 6.

7.5.2 Independent variables: individual characteristics

In the previous two chapters, mathematics self-concept came across as the strongest determinant of gendered participation in advanced mathematics enrolment in Year 12 while teenage occupational expectations and mathematics self-concept were the most powerful predictors of gendered choices of a mathematically intensive degree. The question that arises is to what extent single-sex schooling moderates these relationships. To examine this issue, I consider whether single-sex schooling counteracts gender stereotypes and narrows the gender gaps in studying advanced mathematics in Year 12 and in engaging in a related degree. However, it is possible that single-sex schools do not raise the academic achievement and self-concept in mathematics of students, but attract more students who already possess these characteristics. Therefore, taking the differences in student and school characteristics between single-sex and coeducational schools into account is essential to avoid confounding the effects of single-sex schooling with other factors. Such factors could include the socioeconomic status of the student body, school resources and selective admission procedures (Halpern et al. 2011; Smyth 2010). In the characteristics of students, I consider their gender, socioeconomic status of the family of origin, occupational expectations, as well as mathematics

achievement and self-concept. In the analysis of the impact of single-sex schooling on students' engagement in mathematically intensive university education, I also include relevant subject choice in Year 12 as my predictor. The measurement properties of these variables have been discussed in detail in section 4.3 in Chapter 4 and in section 6.5.2 in Chapter 6.

7.5.3 Independent variables: school characteristics

Single-sex schools (all-girls and all-boys schools). As my analysis focuses on the impact of single-sex schooling, I constructed three indicators at the school level that identify all-girls, all-boys and coeducational schools. The information about the proportion of girls at school was collected in 2003. Schools with only girls attending (100 per cent) and no girls attending (0 per cent) are treated as all-girls and all-boys schools, respectively. I categorised schools with other proportions of girls attending as coeducational schools. These schools form the reference category in the multilevel analysis.

To distinguish the pre-existing differences between single-sex and coeducational schools concerning school resources, selectivity in student admission policies and teacher quality, I include the following variables at the school level:

School sector denotes Catholic, independent and government schools. The government sector is the reference category.

School policies and resources – (1) selective admission to school refers to the school principal's report on whether the school considers students' academic records (including placement tests) as a relevant criterion for admission.

School policies and resources – (2) shortage of qualified teachers. I specify the shortage of qualified teachers by an index of five items. They are based on school

principals' reports that the following factors hinder instruction at school: (a) shortage of qualified mathematics teachers, (b) shortage of qualified science teachers, (c) shortage of qualified English teachers, (d) shortage of qualified foreign language teachers and (e) shortage of experienced teachers. Positive values of this index indicate shortages. Cronbach's alpha for this index in Australia is 0.78 (OECD 2005).

7.6 Method

A preliminary discussion of my methods used in this chapter has been provided in sections 4.5 and 4.6 in Chapter 4 in which the details on the use of weights to adjust for sampling design, multiple imputation of missing values, multilevel logistic regression and standardised coefficients have been discussed. In this section, I briefly discuss how I make use of multilevel logistic regressions and derive predicted probabilities from them.

The Y03 data are clustered by school, and my analysis has to take this into consideration. To this end, I used two-level logistic regression models with student- and school-level variables of the following form:

$$\text{logit}(Y_{ij}) = \gamma_{00} + X\beta + \text{Z}\delta + u_{0j}$$

where Y_{ij} refers to the choice of advanced mathematics subjects in Year 12 (in the first part of my analysis) and the enrolment in a mathematically intensive bachelor's degree program (in the second part of my analysis), for student i in school j and γ_{00} is the average intercept across schools. X is a vector of student-level independent variables and β is a vector of regression coefficients corresponding to variables in vector X. Z is a vector of school-level variables and δ is a vector of regression coefficients corresponding to variables in vector Z. u_{0j} represents the error term between schools.

It is not legitimate to compare the odds ratios across logistic regression models with different predictors because those odds ratios are sensitive to differences in unobserved heterogeneity (Mood 2010; Riegle-Crumb et al. 2012). Therefore, in the first part of the analysis, I compute from the logistic regression models using Stata 14 the predicted probabilities of boys and girls in different types of school who study advanced mathematics in Year 12. Based on these predicted probabilities, I compare the gender gap in studying advanced mathematics between single-sex and coeducational schools. Similarly, in the second part of the analysis, I obtain the predicted probabilities of men and women who graduated from different types of schools and who selected a mathematically intensive university major.

7.7 Does single-sex schooling narrow the gender gap in the choice of advanced mathematics in Year 12?

As the first step to assuring that I take into account pre-existing differences between students who attend single-sex and coeducational schools, I describe and contrast, in the following section, student and school characteristics in single-sex and coeducational sectors. In light of the existing literature, a range of systematic differences is to be expected, but it is important to highlight them for the 6,083 Year 12 students who did not change schools between 2003 and 2006. These students are the focus of my analysis.

7.7.1 How different are students in single-sex schools from students in coeducational schools?

The gender gap in advanced mathematics enrolment is smaller in single-sex schools (Table 7.1). In single-sex schools, 11 per cent of boys and 9 per cent of girls study advanced mathematics. In coeducational schools, there are almost twice as many boys as girls in advanced mathematics: 13 per cent of boys, but only 7 per cent of girls.

Table 7.1 Student characteristics by gender composition of school: proportions and means

	Single-sex schools		Coeducational schools		Min.	Max.	*N*
	Boys	Girls	Boys	Girls			
Dependent variable							
Study advanced mathematics in Year 12 [b]	0.11	0.09	0.13	0.07	0	1	6,083
Family background							
Socioeconomic status	0.53	0.56	0.32	0.31	-3.05	2.15	6,057
Career expectations							
Expected a career in the mathematically intensive sciences at age 15 [a b]	0.25	0.09	0.27	0.07	0	1	5,586
Mathematics							
Mathematics achievement [a b]	574.56	556.27	555.88	537.98	177.78	842.37	6,083
Mathematics self-concept [b]	0.23	0.09	0.39	0.15	-2.12	2.42	6,064

Note: This table contains weighted estimates before multiple imputations of missing data.
[a] indicates that the difference between boys attending an all-boys school and girls attending an all-girls school in that variable is statistically significant at $p < 0.05$.
[b] indicates that the difference between boys attending a coeducational school and girls attending a coeducational school in that variable is statistically significant at $p < 0.05$.

Source: Y03

Tables 7.1 and 7.2 demonstrate that single-sex and coeducational schools tend to cater to students with considerably different characteristics. Students in all-boys and all-girls schools are more likely than their peers in coeducational schools to come from families of higher socioeconomic status (Table 7.1). Among students who attend single-sex schools, boys were about 2.8 times more likely than girls at age 15 (25 per cent versus 9 per cent) to expect that they would have careers in the mathematically intensive sciences. Among students who attend coeducational schools, boys were almost 4 times more likely than girls at age 15 (27 per cent versus 7 per cent) to plan their careers in the mathematically intensive sciences. In all types of schools, boys on average performed better and had higher self-concept in mathematics. While boys' advantage in

mathematics achievement is evident among those who attend single-sex schools, their advantage in mathematics self-concept is greater in coeducational settings. In line with Sikora (2014a) who analysed the 2009 cohort of LSAY, the Y03 data in Table 7.2 show that a majority of single-sex schools are situated in the Catholic and independent sectors. These sectors are better resourced and are thus significantly less likely than coeducational schools to struggle with shortages of qualified teachers.

Table 7.2 School characteristics by gender composition of school: proportions and means

	All-boys schools (*J*=24)	Coeducational schools (*J*=240)	All-girls schools (*J*=25)	*N*
Proportion of school type by sector				
Government school	0.02	0.95	0.03	183
Catholic school	0.23	0.60	0.17	58
Independent school	0.17	0.64	0.19	48
Proportion of students				
Government school	0.02	0.93	0.05	3,365
Catholic school	0.21	0.61	0.18	1,495
Independent school	0.18	0.61	0.21	1,223
Proportion or mean for schools (min., max.)				
Schools that consider students' academic record in admission (0, 1)	0.63	0.48	0.32	288
Shortage of qualified teachers (-1.20, 2.46) [a b]	-0.16	0.28	-0.60	289

Note: This table contains unweighted estimates. *J* refers to the number of schools.

[a] indicates that the difference between all-boys schools and coeducational schools in that variable is statistically significant at the 0.05 level.

[b] indicates that the difference between all-girls schools and coeducational schools in that variable is statistically significant at the 0.05 level.

Source: PISA 2003; Y03

7.7.2 Multilevel models: does single-sex schooling narrow the gender gap in Year 12 advanced mathematics enrolment?

As discussed in section 7.2, a scrutiny of evidence supporting single-sex schooling reveals that many studies in this area suffer from methodological weaknesses. They tend to confound the effects of single-sex schooling with the socioeconomic status of the student body, school resources and selective admission procedures (Halpern et al. 2011; Smyth 2010). To perform more robust multivariate analysis one must, therefore, take these factors into account as has been done in Table 7.3. The analysis presented in this table controls for a range of student and family characteristics previously discussed in Chapter 5. Shifting my attention to school-level effects, I began with a two-level logistic regression model that considered the effect of attending a single-sex school as well as of gender gap and family's socioeconomic status (Model 1). I aimed to examine whether attending a single-sex school would enhance students' chances of studying high-level mathematics regardless of the socioeconomic status of the students' families. Next, I added a range of school-level variables including the sector, admission selectiveness and the availability of qualified teaching staff to examine whether these characteristics could explain any apparent benefits of single-sex schooling (Model 2).

I recognised that single-sex schooling might affect the development of occupational expectations and mathematics self-concept, as well as raising academic achievement. Therefore, I added students' occupational expectations, mathematics achievement and mathematics self-concept to examine if they explained the apparent advantages of attending a single-sex school (Model 3). I do not present the odds ratios and standardised coefficients of these variables in Table 7.3 because taking them into account in Model 3 does not result in any substantial changes in the effects of single-sex schooling on advanced mathematics enrolment. I present their odds ratios and standardised coefficients in Table A2.4 in Appendix 2. Finally, I added as predictors all

remaining variables which were used to construct the LSAY weights to examine whether the results changed with the use of weights (Model 4). The odds ratios and standardised coefficients of these control variables also appear in Table A2.4 in Appendix 2.

Table 7.3 Odds ratios and standardised coefficients from two-level logit models predicting the study of advanced mathematics in Year 12: school-level variables added as predictors

	Model 1 [a]			Model 2 [a]			Model 3 [b]			Model 4 [c]		
	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient
Fixed effects												
School characteristics												
Gender composition of school (reference = coeducational school)												
All-girls school	2.241***	(0.472)	0.301	2.207***	(0.504)	0.295	2.377**	(0.639)	0.260	1.594*	(0.333)	0.144
All-boys school	1.160	(0.305)	0.056	1.192	(0.356)	0.066	1.117	(0.370)	0.032	0.800	(0.213)	-0.068
School sector (reference = government school)												
Catholic school				0.787	(0.133)	-0.128	0.722	(0.148)	-0.139	0.837	(0.150)	-0.078
Independent school				1.000	(0.184)	-0.001	0.915	(0.225)	-0.035	1.143	(0.227)	0.055
School policies and resources												
Selective admission to school (reference = no selective admission)				1.105	(0.141)	0.066	1.109	(0.174)	0.055	0.922	(0.131)	-0.045
Teacher shortage				0.899	(0.072)	-0.122	0.903	(0.090)	-0.096	0.944	(0.080)	-0.056
Student characteristics [a]												
Female	0.361***	(0.041)	-0.267	0.361***	(0.041)	-0.267	0.586***	(0.078)	-0.104	0.599***	(0.082)	-0.095
Constant	0.109***	(0.010)		0.111***	(0.013)		0.026***	(0.005)		0.050***	(0.010)	
Random effects												
Variance between schools	0.515***	(0.138)		0.498***	(0.131)		0.798***	(0.160)		0.416***	(0.114)	

Note: The sample for this multilevel analysis contains 6,083 students in 289 schools after multiple imputations of missing data. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
[a] Models 1 and 2 control for students' socioeconomic status at the student level. [b] Model 3 controls for students' socioeconomic status, expectation of a mathematically intensive career, mathematics achievement and mathematics self-concept. [c] Model 4 adds controls for students' immigration status and family structure, and the state or territory in which the school is located. In this table, I do not present the student-level and weighting variables because I focus on examining the impact of single-sex schooling on the propensity to study advanced mathematics in Year 12. The odds ratios and standardised coefficients of all student-level and weighting variables are presented in Table A2.4 in Appendix 2.

Source: Y03

Table 7.3 shows that relative to a coeducational school, all-girls education encourages the pursuit of advanced mathematics, although all-boys education does not convey any additional benefit. Without controlling for any other school characteristics in Model 1, the odds of studying advanced mathematics for girls in all-girls schools are 2.241 times larger than the comparable odds for students in coeducational schools. Even when the school sector, admission selectiveness and human resources are assumed to be the same across schools in Model 2, girls in all-girls schools have greater odds (2.207 times) of taking advanced mathematics subjects. Therefore, the school characteristics which are usually cited as possible sources of confusion in attributing a positive effect to single-sex schooling cannot account for the advantage apparent in all-girls settings in this analysis.

After taking students' occupational expectations, mathematics achievement and mathematics self-concept into account in Model 3, the odds of taking high-level mathematics for girls in all-girls schools is 2.377 times larger than the comparable odds for students in coeducational schools. The addition of weighting variables in Model 4 reduces the advantage of all-girls schools to the factor of 1.594. Yet, the conclusion remains the same: girls in single-sex schools are more likely to take advanced mathematics courses.

Thus, in response to my first research question, I conclude that single-sex schooling narrows the gender gap by encouraging more mathematics engagement in all-girls education. All-girls schools succeed in generating higher rates of advanced mathematics uptake than is typical for girls receiving mathematics education in coeducational settings.

The size of this advantage is highlighted by a more intuitive scale in Figure 7.2 which reports the predicted probabilities of boys and girls studying advanced

mathematics in Year 12 based on Model 4 in Table 7.3. The apparent difference between 7.3 per cent of boys in all-boys schools who study advanced mathematics and 5.3 per cent of girls in all-girls schools is statistically insignificant. In other words, boys and girls are equally likely to study high-level mathematics when they are in environments comprising solely peers of their own sex. There is, however, a statistically significant gap in coeducational schools where 5.5 per cent of boys in contrast to 1.5 per cent of girls participate in advanced mathematics. This 4 per cent difference is considerable. More importantly, the rate of advanced mathematics uptake among girls in all-girls schools is much higher than the comparable rate in coeducational schools (5.3 per cent versus 1.5 per cent). In summary, all-girls schools succeed in engaging more of their students in high-level mathematics subjects.

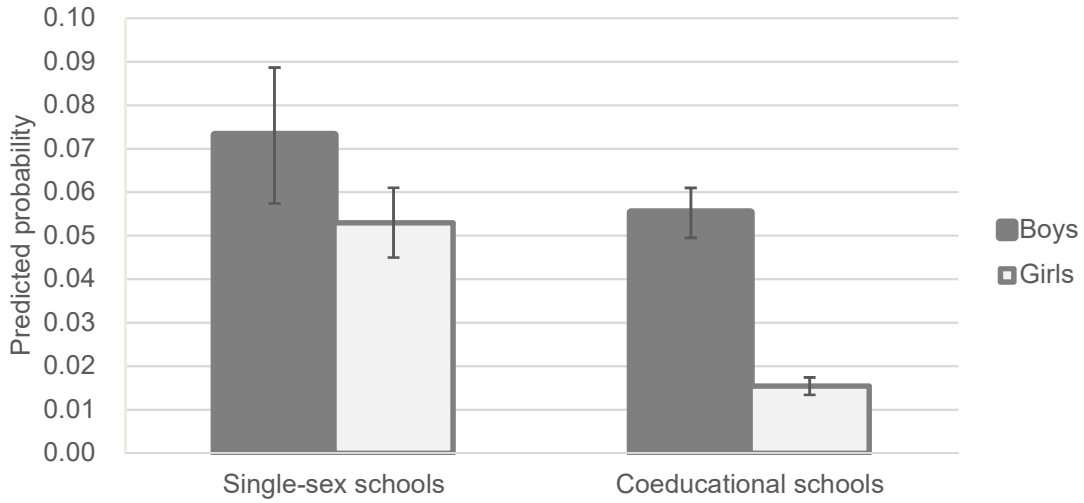

Figure 7.2 Predicted probabilities of boys and girls studying advanced mathematics in Year 12 in single-sex and coeducational schools

Note: The predicted probabilities are based on Model 4 presented in Table 7.3 and computed with other variables held at the mean for each type of school.

Source: Y03

7.8 Does single-sex schooling narrow the gender gap in the choice of a mathematically intensive degree?

The arguments in favour of single-sex schooling reviewed in section 7.1 make it plausible to expect that the experience of gender-segregated education has not only a short-term but also a long-term positive effect on mathematical self-concept of girls, and particularly, on their commitment to engagement in advanced mathematics and related disciplines in their later educational and occupational pursuits (Catsambis 2005; Foon 1988; Spielhofer, Benton and Schagen 2004). If single-sex schooling is effective in promoting girls' engagement in advanced high school mathematics, its positive effect should last beyond school years and continue to counteract gender stereotypes in the choice of a university major. Therefore, in this section, I seek to establish whether the advantages of single-sex schooling may last beyond secondary education and thus enhance the likelihood of engaging in mathematically oriented university education.

7.8.1 How many female and male graduates of single-sex and coeducational schools choose a mathematically intensive degree?

Table 7.4 shows that the gender gap in the choice of university education in mathematically oriented areas is smaller among the graduates of single-sex schools than among the graduates of coeducational schools. This is because, as compared to the men educated in coeducational schools, those educated in all-boys schools are far less likely to enrol in a mathematically intensive degree. Men who graduate from all-boys schools are 2.3 times more likely than women who are graduates of all-girls schools to engage in mathematically intensive university studies (23 per cent versus 10 per cent). Men educated in coeducational schools are about 5 times more likely than women from the same educational background to select a mathematically oriented degree (31 per cent as opposed to 6 per cent).

Table 7.4 Respondent characteristics by gender composition of school: proportions and means

	Single-sex schools		Coeducational schools		Min.	Max.	*N*
	Men	Women	Men	Women			
Dependent variable							
Entry into a mathematically intensive science degree [a b]	0.23	0.10	0.31	0.06	0	1	3,174

Note: This table contains weighted estimates prior to multiple imputations of missing data. The descriptive statistics of other student-level variables are presented in Table A2.5 in Appendix 2.

[a] indicates that the difference between men from all-boys schools and women from all-girls schools in that variable is statistically significant at $p < 0.05$.

[b] indicates that the difference between men who attended a coeducational school and women who went to a coeducational school in that variable is statistically significant at $p < 0.05$.

Source: Y03

7.8.2 Multilevel models: does single-sex schooling narrow the gender gap in the choice of a mathematically intensive degree?

In Table 7.5, I present the analysis of the effects of single-sex schooling on the choice of a mathematically intensive degree using logistic regression models. I built four nested models to carefully account for the pre-existing differences between single-sex and coeducational schools with respect to the socioeconomic status of students, school resources and selective admission policies (Halpern et al. 2011; Smyth 2010). I began with a model that considered the effects of attending an all-girls and all-boys school, students' gender and the socioeconomic status of the students' families. This was done with a view to assessing whether attending a single-sex school increased students' chances of engaging in mathematically intensive university education regardless of students' socioeconomic background. In Model 2, I controlled for the school characteristics that could be confounded with the effects of single-sex schooling. These characteristics were the school sectors, admission selectiveness and school human resources. I examined whether any apparent benefits of attending a single-sex school remained after taking the differences in those characteristics into account.

In Model 3, I added students' occupational expectations, achievement and self-concept in mathematics, and relevant subject choice in Year 12 to examine if they explained any apparent advantage of attending a single-sex school. These variables were added because my review of previous studies supporting single-sex schooling presented in section 7.1 suggests that students in single-sex schools are more likely to develop gender-atypical occupational expectations, have higher self-concept, achieve better in mathematics and engage in gender-atypical subjects. I do not present the odds ratios and standardised coefficients of these variables in Table 7.5 because, as shown in Model 3 in the table, these variables do not affect the relationship between single-sex schooling and the students' choices of a mathematically intensive major. Their odds ratios and standardised coefficients are shown in Table A2.6 in Appendix 2. Finally, in Model 4, I added all variables which were used to construct the LSAY weights as predictors to assess whether the results were similar to those of Model 3. I also present the odds ratios and standardised coefficients of these predictors in Table A2.6 in Appendix 2.

Table 7.5 Odds ratios and standardised coefficients from two-level logit models predicting the choice of mathematically intensive university education: school-level variables added as predictors

	Model 1 [a]			Model 2 [a]			Model 3 [b]			Model 4 [c]		
	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient
Fixed effects												
School characteristics												
Gender composition of school (reference = coeducational school)												
All-girls school	1.779**	(0.355)	0.650	1.784**	(0.343)	0.626	1.629*	(0.316)	0.621	1.744**	(0.347)	0.609
All-boys school	0.640**	(0.087)	-0.495	0.651**	(0.092)	-0.457	0.710*	(0.108)	-0.433	0.686*	(0.109)	-0.411
School sector (reference = government school)												
Catholic school				0.843	(0.117)	-0.265	0.914	(0.132)	-0.162	0.875	(0.124)	-0.203
Independent school				1.159	(0.146)	0.210	1.306	(0.184)	0.447	1.250	(0.184)	0.323
School policies and resources												
Selective admission to school (reference = no selective admission)				0.982	(0.104)	-0.036	1.011	(0.115)	0.019	1.045	(0.124)	0.076
Teacher shortage				1.004	(0.064)	0.014	1.015	(0.069)	0.066	1.022	(0.072)	0.086
Student characteristics												
Female	0.134***	(0.192)	-0.480	0.133***	(0.019)	-0.481	0.253***	(0.038)	-0.301	0.246***	(0.036)	-0.306
Constant	0.447***	(0.039)		0.462***	(0.053)		0.122***	(0.019)		0.105***	(0.021)	
Random effects												
Variance between schools	0.016	(0.052)		0.011	(0.053)		0.001	(0.032)		2.46×10^{-33}	(5.34×10^{-33})	

Note: The sample for this analysis contains 3,174 students in 282 schools with multiple imputations of missing data. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
[a] Models 1 and 2 control for students' socioeconomic status at the student level. [b] Model 3 controls for students' socioeconomic status, expectation of a mathematically intensive career, mathematics achievement, mathematics self-concept and enrolment in advanced mathematics and physical science in year 12. [c] Model 4 adds controls for students' immigration status and family structure, and the state or territory in which the school is located. In this table, I do not present the student-level and weighting variables because I focus on examining the impact of single-sex schooling on the propensity to choose a mathematically intensive university major. The odds ratios and standardised coefficients of all student-level and weighting variables are presented in Table A2.6 in Appendix 2.

Source: Y03

Table 7.5 shows that across all four models, compared to coeducational schooling, all-girls schooling enhances the likelihood of engaging in mathematically intensive university education. By contrast, all-boys education lowers the likelihood.

Based on Model 4 in Table 7.5, I further show in Figure 7.3 that single-sex schooling can reduce the gender gap in the choice of mathematically intensive university education by half. Figure 7.3 shows that the gender gap in choosing a mathematically oriented field among single-sex school graduates is about 11 per cent, whereas the gender gap among coeducational school graduates is about 24 per cent. The large reduction of the gender gap is mainly caused by the lower likelihood of engaging in mathematically intensive fields of study among the graduates of all-boys schools. Compared to 28 per cent of male graduates of coeducational schools choosing a mathematically oriented degree, only 19 per cent of graduates of all-boys schools made such a choice. Compared to coeducational schools where only 4 per cent of female graduates engage in mathematically oriented university education, all-girls schools enhance the female participation rate by 4 per cent.

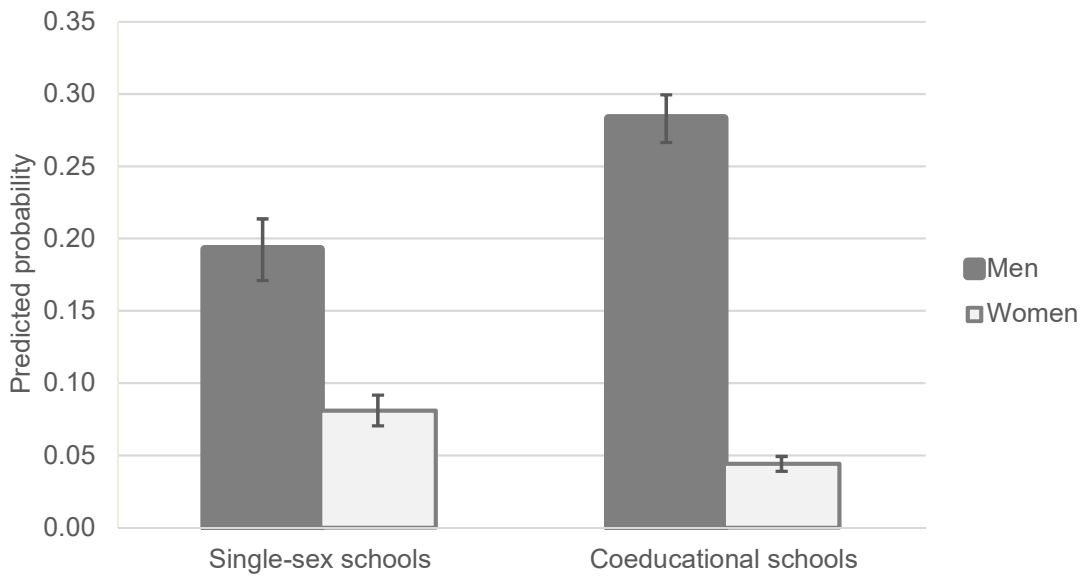

Figure 7.3 Predicted probabilities of men and women choosing a mathematically intensive degree by gender composition of school

Note: The predicted probabilities are based on Model 4 presented in Table 7.5 and computed with other variables held at the mean for each type of school.

Source: Y03

In response to my second research question in this chapter, my analysis demonstrates that single-sex schooling reduces the gender gap in choosing a mathematically intensive university major. Not only does single-sex schooling foster higher levels of participation in advanced mathematics among girls (as presented in section 7.7.2), in the long run it also has the benefit of encouraging its female graduates to specialise in mathematically oriented fields at university, as demonstrated by my analysis in this section. By contrast, single-sex education reduces the chances of male graduates to engage in mathematics-related studies at university.

7.9 Summary of findings and discussion

In this chapter, I examined to what extent single-sex schooling could counteract gender stereotypes and narrow the gender gap in advanced high school mathematics enrolment and in the choice of a mathematically intensive bachelor's degree. As many

existing studies confound the advantage of single-sex education with that of private, selective or better resourced schools (Halpern et al. 2011; Smyth 2010), in my analysis I took into account the pre-existing differences between single-sex and coeducational schools. My analysis shows, in line with Sikora (2014a), that single-sex schools in Australia tend to admit students from high socioeconomic backgrounds and the majority of them are Catholic or independent schools, which enjoy more resources than government schools. This phenomenon confirms the importance of considering the differences between schools in their resources and student admission policies, and in the socioeconomic status of the student body (Halpern et al. 2011; Signorella, Hayes and Li 2013).

In my multilevel analysis, I found that all-girls schools had a much higher level of participation in advanced high school mathematics among their students than is typical for girls in coeducational schools. The advanced mathematics enrolment rate in all-girls schools was also comparable to that for boys in coeducational schools. This pattern cannot be attributed to the advantageous characteristics of all-girls schools that denote ample resources, student selection on academic abilities or the quality of the teaching force. Therefore, it must be accepted as an indicator that all-girls schools provide a more favourable atmosphere than coeducational schools for girls to pursue high-level mathematics. Existing studies point out that a girls-only environment not only frees girls from the pressure of competition with boys (Watson 1997), but also counteracts traditional gender stereotypes and encourages girls to engage in traditionally male dominated subjects, including advanced mathematics and the physical sciences (Catsambis 2005; Cherney and Campbell 2011). There are possibly more female teachers of mathematics and science in all-girls schools than in coeducational schools to provide effective role models (Catsambis 2005; Mallam 1993). By contrast, my results show that the gender gap in advanced high school mathematics enrolment in

coeducational settings is considerably large. These findings imply that the gender stereotype which regards mathematics as a male domain is prominent in coeducational schools.

My findings suggest that single-sex secondary education is likely to be an effective policy to enhance women's propensities to choose mathematically oriented studies at university. In contrast to early Australian studies (Forgasz 1998; Lumley 1992), I demonstrate, using data from a more recent cohort of Australian youth, that all-girls secondary schools encourage their graduates to engage in mathematically intensive university education. After considering all the pre-existing differences between all-girls and coeducational schools with respect to their resources, teaching force and student selection on academic abilities, women from all-girls secondary schools are still more likely than their same-sex peers in coeducational schools to choose mathematics-related education at university. These results imply that single-sex secondary education provides a favourable environment for girls to resist gender stereotypes and pursue mathematically oriented studies not only in high school but also in tertiary education.

While single-sex education has little impact on the chance of boys to enrol in advanced high school mathematics, it significantly lowers the chance of young men to engage in mathematically intensive education at university. These results suggest that students in all-boys schools may have less pressure to fulfil the social expectations of their traditional gender roles and may thus be more willing to choose gender-atypical fields at university (James and Richards 2003; Sullivan, Joshi and Leonard 2010). The fact that in coeducational settings boys and girls make highly gendered educational choices suggests that more needs to be done within coeducational schools to challenge the gender stereotypes associated with mathematics learning.

Chapter 8

Conclusion

In this thesis, I have presented a systematic study of gender differences in the pursuit of advanced mathematics and related disciplines – a phenomenon that has persisted over the past four decades in Australia (Dekkers, de Laeter and Malone 1991; Dekkers and Malone 2000; Kennedy, Lyons and Quinn 2014). This phenomenon occurs not only in senior secondary school but also at university, as demonstrated by this thesis. From a social stratification perspective, gendered participation in advanced mathematics and cognate fields represents the horizontal dimension of gender inequalities in education (Charles and Bradley 2002; Jonsson 1999) that adversely affects individuals and society.[14] Previous studies have found that gender segregation in fields of study does not only generate labour market disparities by gender but also has a considerable influence on the gender gap in salaries (Brown and Corcoran 1997; Shauman 2016). Furthermore, such a form of segregation may reinforce gender stereotypical beliefs across society, and in turn, encourage adolescents to aspire to gender-typical occupations (Charles and Bradley 2009; OECD 2006). The persistence and consequences of gender segregation in fields of study call for the need to examine why enrolments in advanced mathematics and related disciplines continue to be segregated by gender in Australia.

This thesis offers a thorough examination of gendered participation in advanced mathematics and cognate disciplines in Australia by drawing on the stratification theory of gender essentialism, the expectancy value theory and the allocation model of status

[14] As discussed in section 1.2 in Chapter 1, the horizontal dimension of gender inequalities in education refers to the concentration of males and females in different fields of study.

attainment. A combination of these theories explains how social structures, cultural norms, the organisation of the education system and the labour market, and psychological characteristics of individuals interact to influence youth decisions to pursue advanced mathematics and related courses. The theory of gender essentialism suggests that at the institutional and macro levels structural features of the comprehensive education system and the service economy in Australia provide a favourable environment for gender stereotypical beliefs and self-expressive values to thrive (Charles and Bradley 2009). Stereotypes construe males as being more capable by nature than females of abstract thinking and technical problem solving (Barone 2011). These stereotypical beliefs are reinforced when the culture underscores and legitimises individual self-expression in making educational and occupational choices. Therefore young people can engage in fields of study and careers that fit in with their gendered identities (Charles and Bradley 2009). Another theory that emphasises the importance of institutional arrangements to student outcomes is the allocation model of status attainment (Kerckhoff 1976; Kerckhoff 1995). Based on this model, stratification research has shown that the institutional arrangements of educational systems and schools sort students into different educational specialisations and occupations according to their genders (Charles and Bradley 2002; Smyth and Steinmetz 2008). The expectancy value theory provides a concrete basis for understanding, at the micro level, how males and females decide to engage in gendered fields of study and occupations as a result of gender differences in socialisation, goals, motivations and subjective task values (Eccles 2011). Building on this theory, Eccles (2011) suggests two crucial reasons for the under-representation of females in advanced mathematics and cognate disciplines: females are less likely than males to place high subjective task values on mathematics-related fields and to feel confident of their mathematical abilities.

In line with the above-mentioned theories, in this thesis I have adopted a life course perspective which recognises that students' educational choices are affected by opportunities and constraints of social structure, cultural beliefs and normative social practices over the life course (Elder 1998). Specifically, I have examined how educational experiences, occupational expectations, socialisation influences from the family, and the school environment in adolescence contribute to gendered participation in advanced high school mathematics and related university studies. Previous studies of gender segregation in mathematics education have seldom used nationally representative samples of Australian students. Therefore, following the life course approach, I have analysed data from the 2003 cohort of the nationally representative LSAY using multilevel logistic regression models. In this concluding chapter, I highlight the major findings of this thesis and discuss their implications.

8.1 Major findings

8.1.1 Mathematics self-concept as the key to narrowing the gender gap in enrolment in advanced high school mathematics

In Chapter 5, I demonstrated that if girls were as likely as boys to feel confident of their mathematical abilities (that is, have high levels of mathematics self-concept), perform well in mathematics and aspire to mathematically intensive careers at age 15, the gender gap in advanced mathematics enrolment in Year 12 would disappear. My results show that girls achieved almost as much as boys in high school mathematics, but they were significantly less likely than boys to feel confident of their mathematical abilities. I found that reducing gender differences in mathematics self-concept would have the greatest potential to narrow the gender gap in advanced mathematics enrolment. Teenage occupational expectations were less influential than self-concept

and academic achievement in mathematics in explaining gendered participation in advanced high school mathematics.

My finding of the effect of mathematics self-concept on reducing the gender gap in advanced mathematics enrolment corresponds to the expectancy value theory and stratification theory of gender essentialism. Specifically, the finding aligns with the expectancy value theory which suggests that one of the two important reasons that girls often opt out of advanced high school mathematics is that they have lower self-concept in mathematics than boys (Eccles 2011). Because of the influence of the widely shared gender stereotypical belief through gender socialisation that males are naturally more talented in mathematics than females, girls tend to rate their mathematical abilities lower than do boys, as argued by the expectancy value theory (Eccles 2011; Schoon and Eccles 2014). Such a lower self-assessment of mathematical abilities is a major factor leading to less participation by females in advanced high school mathematics, as demonstrated by the studies in Australia, Germany and the United States (Correll 2001; Guo et al. 2015; Parker et al. 2014). The stratification theory of gender essentialism does not illustrate the relation of mathematics self-concept to gendered participation in advanced mathematics directly. However, the theory implies the relation by arguing that the cultural emphasis on individual self-expression encourages the development of gendered affinities (Charles and Bradley 2009). In this situation, girls are more likely to avoid mathematics because it is culturally regarded as masculine and is inconsistent with feminine identities.

To sum up, in Chapter 5 I demonstrated that mathematics self-concept in adolescence had the greatest influence on gender differences in the later pursuit of advanced high school mathematics by Australian youth. Furthermore, my findings imply that gender-biased self-assessment of mathematical abilities reduces girls'

chances of studying advanced mathematics in different student cohorts, countries and education systems.

8.1.2 The importance of occupational expectations and mathematics self-concept to gendered study choice at university

At the next level of education, university, I demonstrated in Chapter 6 that the gender gap in choosing a mathematically intensive university major could be reduced by almost half with the following assumptions: women were as likely as men to aspire to mathematically oriented careers, to have high self-concept in mathematics, to perform as well in mathematics and to study at similar rates in advanced mathematics and physical subjects in secondary school. Among these factors, the expectation of a mathematically oriented career and mathematics self-concept are the most decisive in bridging the gender gap in selecting a mathematically intensive major. This finding is consistent with the expectancy value theory which suggests that men have a higher chance of engaging in mathematically intensive fields of study because they place more subjective task values on those fields, which in turn increase their chances of aspiring to related careers, and they feel more confident of their mathematical abilities than women (Eccles 2011).

I showed that Australian youth tended to aspire to gender-typical occupations and they reproduced their gendered affinities in their university major choices. As suggested by the stratification theory of gender essentialism, Australian youth are inclined to expect gender-typical occupations for their future because the culture embraces and legitimises individual self-expression in making curricular and occupational choices, and young people can aspire to and engage in careers that match their gendered identities (Charles and Bradley 2009). My finding aligns with the recent stratification studies which show that occupational expectations in high school explain

to a large extent gendered engagement in tertiary science education in Australia and the United States (Legewie and DiPrete 2014b; Morgan, Gelbgiser and Weeden 2013; Sikora 2014b; Sikora 2015). More importantly, my thesis is the first study to demonstrate that enhancing girls' expectations of future involvement in mathematically oriented occupations has the potential to reduce gender segregation in mathematics education in Australia.

My results also show that mathematics self-concept in adolescence continues to be influential to gendered participation in mathematically intensive university studies. Early stratification research has argued that when females have lower self-concept in mathematics than males, they are more likely to reduce their interests and efforts in mathematics and cognate disciplines in their educational pathway (Correll 2001). As a result, young women have a lower probability of engaging in mathematically intensive fields of study at the tertiary level than young men (Correll 2001; Parker et al. 2014). To sum up, in Chapters 5 and 6 I presented evidence that enhancing girls' expectations for mathematics-related occupations has a considerable potential to narrow not only the gender gap in advanced high school mathematics enrolment but also the gender gap in choosing a mathematically intensive major at university.

8.1.3 The effect of single-sex schooling experience on students' engagement in advanced mathematics and related disciplines

In Chapter 7, I switched my attention to school characteristics and examined whether specific school characteristics enhanced or reduced the chances of adolescent boys and girls pursuing advanced mathematics and related fields of study. The literature in this area has long years of debate on the extent to which single-sex education counteracts gender stereotypes and promotes females' engagement in mathematics and related disciplines (Signorella, Hayes and Li 2013; Smithers and Robinson 2006;

Spielhofer, Benton and Schagen 2004). Hence, I examined the extent to which the experience of single-sex secondary education affects students' decisions to study advanced mathematics in Year 12 and to choose related majors at university. Many existing studies have been criticised for confounding the advantage of single-sex education with that of selective, better resourced or private schools (Halpern et al. 2011; Smyth 2010). To address this methodological issue, in my analysis I considered the differences in school resources, selective admission policies and availability of qualified teachers between single-sex and coeducational schools.

I demonstrated that single-sex schooling enhanced girls' enrolment in advanced mathematics in Year 12. The advantage of all-girls education is evident in my analysis even after I considered the pre-existing differences between single-sex and coeducational schools in their resources, selectivity in student admissions and teacher quality. This evidence suggests that all-girls schools provide a more favourable environment than coeducational schools for girls to pursue advanced high school mathematics. Previous studies indicate that all-girls schools free girls from the pressures of competition with boys and from having to conform to gender role expectations (Cherney and Campbell 2011; Watson 1997). In addition, early research points out that there may be more female teachers of mathematics in all-girls schools than in coeducational schools to provide effective role modelling (Mallam 1993). Under these conditions, in all-girls schools the prevailing gender stereotypical belief that mathematics is more important and appropriate for boys is weakened.

My results further show that single-sex schooling continues to promote female engagement in mathematically intensive education at university. After taking into account the pre-existing differences between all-girls and coeducational schools, I found that graduates of all-girls schools still had a higher chance of engaging in mathematically intensive studies at university than female graduates of coeducational

schools. This piece of evidence suggests that all-girls schools are able to counteract gender stereotypes in mathematics and provide a supportive environment for girls to pursue advanced mathematics and related disciplines not only in senior secondary school but also at university.

Although my results show that attending an all-boys' school does not have any effect on boys' enrolment in advanced high school mathematics, the experience of single-sex education substantially reduces the probability of young men to choose a mathematically intensive major at university. These results imply that graduates of all-boys schools are less likely to regard mathematics as a male domain and they do not need to engage in mathematics as a means of 'doing masculinity'. Previous studies also indicate that graduates of all-boys schools possibly have less pressure to comply with the social expectations of their traditional gender roles and are more inclined to engage in gender-atypical majors at university than male graduates of coeducational schools (James and Richards 2003; Sullivan, Joshi and Leonard 2010). To sum up, my analysis shows that the experience of single-sex secondary education has the potential to reduce the gender gap in the choice of a mathematically oriented major at university.

8.2 Implications

The results of my thesis imply that gendered participation in mathematically intensive university studies is a continuation of gender differences in occupational expectations and educational experiences in adolescence. The gender gap in enrolment in advanced high school mathematics appears to be smaller than the gender gap in teenage occupational expectations. However, once students leave secondary school, the gender gap in selecting a mathematically intensive major at university widens dramatically as young women are more likely than young men to pursue other degree programs. These results are in accord with the 'leaky pipeline' argument which suggests

that women have a higher propensity to 'leak' from the mathematically intensive pipeline than men (Blickenstaff 2005; Xie and Shauman 2003). The 'leaky pipeline' argument does not consider the sociocultural, institutional and individual factors that account for the leakage of females from the mathematically intensive pipeline. Therefore, in this thesis, I have used mainly the expectancy value theory, the stratification theory of gender essentialism and the life course approach to guide my empirical analysis. I pay attention to how social structures, cultural norms and individual characteristics interact to influence students' decisions to engage in advanced mathematics and related disciplines.

The results of my analysis have reaffirmed my proposition that the significance of individual characteristics that affect students' engagement in advanced mathematics and cognate fields of study are best understood in the broad context of cultural and structural factors across various life stages. In Chapters 5 and 6, I demonstrated that teenage occupational expectations and self-concept in mathematics strongly influence the decisions that males and females make about engaging in advanced mathematics and related disciplines. Males and females are not born with gender differences in occupational expectations and mathematics self-concept. As discussed in section 8.1, males and females develop those gendered patterns in response to the gendered opportunities and constraints of social structure and culture over their life course. With the stratification and life course approaches, we are able to understand how social structures and cultural norms contribute to the development of gendered identities, gendered affinities and gender differences in psychological characteristics.

The findings of my thesis suggest that enhancing girls' self-confidence in their mathematical abilities is one of the two essential means to bridge the gender gap in advanced high school mathematics enrolment and in the choice of a mathematically intensive university major. These findings demonstrate that even if girls and boys

perform at similarly high levels in mathematics, the likelihood that girls will pursue advanced mathematics in high school and related disciplines at university is low. A critical factor is that girls have significantly lower levels of self-confidence in their mathematical abilities than boys. People who frequently interact with adolescents, particularly parents and high school teachers, can help girls to build up and maintain their self-confidence in mathematics. It is important for parents and high school teachers to be aware of their own gender bias, if any, in favour of boys regarding mathematical competence. It would be ideal if parents and high school teachers can evaluate the mathematical abilities of boys and girls equally and have the same expectations for boys and girls in mathematics education. Parents and high school teachers can also occasionally signal to girls that they perform as well as boys in mathematics. High school teachers may further help girls to boost their self-confidence in mathematics by creating a 'mistake friendly' learning environment particularly for mathematics classes to encourage girls' comfortable engagement with mathematics (Prinsley, Beavis and Clifford-Hordacre 2016).

Another important method to further narrow the gender gap in advanced mathematics enrolment in high school and related fields of study at university, as suggested by my findings, is to encourage more girls to aspire to mathematically intensive careers. Occupations that involve mathematics and technical tasks are often stereotypically viewed as offering few opportunities for interacting with other humans and allowing the expression of individual personalities into the work process (Faulkner 2007; Osborne, Simon and Collins 2003). In fact, these stereotypes are not true as many mathematics-related occupations require social interactions and allow creativity. To counteract gender stereotypical beliefs and to let boys and girls obtain accurate career information, career education at school should be strengthened. Adolescents often change their occupational expectations (Rindfuss, Cooksey and Sutterlin 1999), and

therefore career education should be targeted in secondary school to foster girls' understanding of and interest in mathematics-related careers before they decide on their educational specialisations in Year 12.

8.3 Directions for future research

While the inclusion of students' teenage occupational expectations and high school educational experiences in my regression models presented in Chapter 6 eliminates almost half of the gender gap in the choice of a mathematically oriented university major, the other half of the gap remains unexplained by my models. An important goal for future research is to understand in more depth what factors can bridge this remaining portion of the gender gap. Stereotypical beliefs that define the appropriate occupational roles for males and females may not only emerge in teenage occupational expectations and self-confidence in mathematics but also appear in other domains of social life, such as life-style preferences and family plans. Perhaps mathematics-related occupations are perceived as incompatible with certain life styles, such as travelling, interacting with other people, and family plans that not only young women but also some young men may have. Future studies should further explore these factors and identify other factors that are possibly important contributors to the gender gap in selecting a mathematically intensive major at the tertiary level. Identifying them helps bring more equity to Australian mathematics education.

I have provided evidence that the experience of single-sex secondary education enhances female participation in advanced high school mathematics and related university studies but lowers the probability of male engagement in mathematics-related university majors. As I do not have measures for school environment in my analysis, I can only infer the reasons for the effect of attending single-sex schools on students' engagement with mathematics education from the findings of previous studies. Future

research should undertake further investigation to determine the factors that account for the effect of single-sex schooling.

Given the prevalence of gender egalitarian ideology since the 1970s, Australian women have been encouraged to pursue tertiary educational credentials and professional occupations. While many women thrive in their careers, the integration of women into the mathematically intensive sciences has remained slow. The life course analysis in this thesis demonstrates that talented women who could be successful in mathematically intensive fields of study and employment are discouraged from pursuing advanced mathematics and related disciplines early in their educational career. This phenomenon is not only a waste of individual talents and potential but also a loss for society as the Australian economy has a huge demand for skilled workers with strong quantitative skills (Australian Academy of Science 2016; Australian Industry Group 2013). The policy suggestions for increasing female engagement in advanced mathematics made here may not be novel and I am aware that they alone will not bring about gender equality in Australian mathematics education. The under-representation of females in advanced mathematics and related fields of study has deep cultural and structural roots that will not be transformed by a few isolated policy interventions. To fully unleash the potential of females in mathematics, ultimately we need to alleviate the gender stereotypical beliefs and social barriers associated with mathematics learning and careers. An increase in the representation of females in advanced mathematics along the educational pathway would not only lessen gender segregation in fields of study, but it may also enhance the level of gender equality in the labour market.

Appendix 1

Coding of occupations

Table A1.1 ISCO-88 coding of science occupations

ISCO-88 code	Occupation
Mathematically intensive sciences	
1222	Production managers in manufacturing including factory managers
1223	Production managers in construction
1236	Computing services department managers
1237	Research and development department managers
2100	Physical, mathematical and engineering science professionals
2110	Physicists, chemists and related professionals
2111	Physicists and astronomers
2112	Meteorologists
2113	Chemists
2114	Geologists and geophysicists including geodesists
2120	Mathematicians and statisticians
2121	Mathematicians and associated professionals
2122	Statisticians including actuaries
2130	Computing professionals
2131	Computer systems designers and analysts including software engineers
2132	Computer programmers
2139	Computing professionals not elsewhere classified
2140	Architects, engineers and related professionals
2141	Architects, town and traffic planners including landscape architects
2142	Civil engineers including construction engineers
2143	Electrical engineers
2144	Electronics and telecommunications engineers
2145	Mechanical engineers
2146	Chemical engineers
2147	Mining engineers, metallurgists and related professionals
2148	Cartographers and surveyors
2149	Architects engineers and related professionals not elsewhere classified
3000	Technicians and associate professionals
3100	Physical and engineering science associate professionals
3110	Physical and engineering science technicians
3111	Chemical and physical science technicians
3112	Civil engineering technicians
3113	Electrical engineering technicians

(*Table continues*)

Table A1.1 (Continued)

ISCO-88 code	Occupation
Mathematically intensive sciences	
3114	Electronics and telecommunications engineering technicians
3115	Mechanical engineering technicians
3116	Chemical engineering technicians
3117	Mining and metallurgical technicians
3118	Draughtspersons including technical illustrators
3119	Physical and engineering science technicians not elsewhere classified
3130	Optical and electronic equipment operators
3131	Photographers and electronic equipment operators
3132	Broadcasting and telecommunications equipment operators
3133	Medical equipment operators including x-ray technicians
3139	Optical and electronic equipment operators not elsewhere classified
3140	Ship and aircraft controllers and technicians
3141	Ships engineers
3142	Ships deck officers and pilots including river boat captains
3143	Aircraft pilots and related associate professionals
3144	Air traffic controllers
3145	Air traffic safety technicians
3434	Statistical, mathematical etc. associate professionals
Other sciences	
1221	Production managers agriculture and fishing
2200	Life science and health professionals
2210	Life science professionals
2211	Biologists, botanists and zoologists
2212	Pharmacologists, pathologists and biochemists
2213	Agronomists
2220	Health professionals (except nursing)
2221	Medical doctors
2222	Dentists
2223	Veterinarians
2224	Pharmacists
2229	Health professionals except nursing not elsewhere classified
2230	Nursing and midwifery professionals including registered nurses and midwives
2445	Psychologists
3200	Life science and health associate professionals
3210	Life science technicians and associate professionals
3211	Life science technicians including medical laboratory assistant
3212	Agronomy and forestry technicians
3213	Farming and forestry advisers
3220	Modern health associate professionals except nursing
3221	Medical assistants

(*Table continues*)

Table A1.1 (Continued)

ISCO-88 code	Occupation
Other sciences	
3222	Sanitarians
3223	Dieticians and nutritionists
3224	Optometrists and opticians including dispensing optician
3225	Dental assistants including oral hygienist
3226	Physiotherapists and associate professionals
3227	Veterinary assistants including veterinarian vaccinator
3228	Pharmaceutical assistants
3229	Modern health associate professionals except nursing not elsewhere classified
3230	Nursing and midwifery associate professionals
3231	Nursing associate professionals including trainee nurses
3232	Midwifery associate professionals including trainee midwives

Note: Occupations in the mathematically intensive sciences include those related to engineering, computing, and the mathematical and physical sciences. Occupations in other sciences include those related to biology, agriculture, health and the life sciences.

Source: ILO (1990); Sikora and Pokropek (2012a); Y03

Appendix 2

Detailed statistical tables

Table A2.1 Odds ratios and standardised coefficients from two-level logit models for studying advanced mathematics in Year 12 – Model 5 in Table 5.3

	Model 5		
	Odds ratio	Standard error	Standardised coefficient
Fixed effects			
Student characteristics			
Female	0.792	(0.125)	-0.043
Family background			
Socioeconomic status	1.019	(0.107)	0.005
× Female	0.995	(0.149)	-0.001
Mother has a science job	1.376†	(0.088)	0.042
× Female	0.797	(0.233)	-0.023
Father has a science job	1.132	(0.188)	0.017
× Female	0.764	(0.216)	-0.027
Career expectations			
Expected a career in the mathematically intensive sciences at age 15	2.249***	(0.296)	0.113
× Female	0.855	(0.244)	-0.011
Mathematics			
Mathematics achievement at age 15	3.141***	(0.282)	0.379
Mathematics self-concept at age 15	3.440***	(0.241)	0.411
Weighting variables			
Family structure (reference = nuclear family)			
Other family structure	0.752*	(0.093)	-0.046
Immigration status (reference = native students)			
First-generation students	3.843***	(0.577)	0.151
Second-generation students	2.050***	(0.349)	0.085
State/territory (reference = New South Wales)			
Australian Capital Territory	0.408**	(0.118)	-0.276
Northern Territory	0.198***	(0.093)	-0.414
Queensland	0.539**	(0.109)	-0.258
South Australia	0.223***	(0.054)	-0.534
Tasmania	0.428***	(0.098)	-0.240
Victoria	0.461***	(0.093)	-0.358
Western Australia	0.193***	(0.040)	-0.643

(Table continues)

Table A2.1 (Continued)

	Model 5		
	Odds ratio	Standard error	Standardised coefficient
School sector (reference = government school)			
Catholic school	0.842	(0.137)	-0.078
Independent school	1.131	(0.208)	0.051
Constant	0.000***	(0.000)	
Random effects			
Variance between schools	0.410***	(0.101)	

Note: The sample for this multilevel analysis contains 6,760 students in 314 schools with multiple imputations of missing data. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Y03

Table A2.2 Descriptive statistics of all student-level variables included in the analysis of Chapter 6 (Table 6.2)

	Men	Women	Min.	Max.	*N*
Dependent variable					
Entry into a mathematically intensive science degree after completing Year 12 [a]	0.29	0.07	0	1	3,502
Family background					
Socioeconomic status	0.61	0.56	-2.86	2.15	3,493
Mother has a science job	0.17	0.17	0	1	3,396
Father has a science job	0.21	0.19	0	1	3,379
Career expectations					
Expected a career in the mathematically intensive sciences at age 15 [a]	0.32	0.09	0	1	3,248
Mathematics					
Mathematics achievement at age 15 [a]	599.83	572.67	258.79	842.37	3,502
Mathematics self-concept at age 15 [a]	0.57	0.33	-2.12	2.42	3,500
Studied advanced mathematics and physical science [a]	0.19	0.10	0	1	3,229
Studied physical science only	0.26	0.23	0	1	3,229

Note: This table contains weighted estimates before multiple imputations of missing data.
[a] indicates that the difference between men and women in that variable is statistically significant at $p < 0.05$.

Source: Y03

Table A2.3 Factors affecting the choice of a mathematically intensive university degree program: odds ratios and standardised coefficients from two-level logit models (Model 4 in Table 6.3)

	Model 4		
	Odds ratio	Standard error	Standardised coefficient
Fixed effects			
Student characteristics			
Female	0.324***	(0.072)	-0.247
Family background at age 15			
Socioeconomic status	1.048	(0.110)	0.016
× Female	1.139	(0.187)	0.039
Mother has a science job	1.206	(0.208)	0.032
× Female	0.653	(0.176)	-0.057
Father has a science job	0.899	(0.139)	-0.019
× Female	1.057	(0.276)	0.008
Career expectations at age 15			
Expected a career in the mathematically intensive sciences	3.762***	(0.478)	0.232
× Female	1.367	(0.354)	0.030
Mathematics			
Mathematics achievement at age 15	1.039	(0.080)	0.017
Mathematics self-concept at age 15	1.477***	(0.096)	0.155
Studied advanced mathematics and physical science	3.551***	(0.681)	0.192
× Female	0.740	(0.249)	-0.028
Studied physical science only	1.953***	(0.309)	0.126
× Female	0.744	(0.193)	-0.043
Weighting variables			
Family structure (reference = nuclear family)			
Other family structure	1.014	(0.131)	0.002
Immigration status (reference = native students)			
First-generation students	1.502*	(0.242)	0.062
Second-generation students	0.787	(0.127)	-0.036
State/territory (reference = New South Wales)			
Australian Capital Territory	0.936	(0.204)	-0.079
Northern Territory	1.297	(0.407)	0.257
Queensland	1.190	(0.197)	0.286
South Australia	1.063	(0.243)	0.088
Tasmania	1.302	(0.312)	0.299
Victoria	1.129	(0.187)	0.222
Western Australia	1.078	(0.189)	0.118

(Table continues)

Table A2.3 (Continued)

	Model 4		
	Odds ratio	Standard error	Standardised coefficient
School sector (reference = government school)			
Catholic school	0.882	(0.122)	-0.227
Independent school	1.215	(0.155)	0.322
Constant	0.097***	(0.018)	
Random effects			
Variance between schools	0.027	(0.058)	

Note: The sample for this multilevel analysis contains 3,502 students in 310 schools with multiple imputations of missing data. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Y03

Table A2.4 Odds ratios and standardised coefficients from two-level logit models for studying advanced mathematics in Year 12 with the inclusion of school-level variables in Table 7.3

	Model 1			Model 2			Model 3			Model 4		
	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient
Fixed effects												
School characteristics												
Gender composition of school (reference = coeducational school)												
All-girls school	2.241***	(0.472)	0.301	2.207***	(0.504)	0.295	2.377**	(0.639)	0.260	1.594*	(0.333)	0.144
All-boys school	1.160	(0.305)	0.056	1.192	(0.356)	0.066	1.117	(0.370)	0.032	0.800	(0.213)	-0.068
School sector (reference = government school)												
Catholic school				0.787	(0.133)	-0.128	0.722	(0.148)	-0.139	0.837	(0.150)	-0.078
Independent school				1.000	(0.184)	-0.001	0.915	(0.225)	-0.035	1.143	(0.227)	0.055
School policies and resources												
Selective admission to school (reference = no selective admission)				1.105	(0.141)	0.066	1.109	(0.174)	0.055	0.922	(0.131)	-0.045
Teacher shortage				0.899	(0.072)	-0.122	0.903	(0.090)	-0.096	0.944	(0.080)	-0.056
Student characteristics												
Female	0.361***	(0.041)	-0.267	0.361***	(0.041)	-0.267	0.586***	(0.078)	-0.104	0.599***	(0.082)	-0.095
Family background												
Socioeconomic status	1.414***	(0.095)	0.146	1.394***	(0.096)	0.140	0.965	(0.077)	-0.011	0.975	(0.722)	0.008
Career expectations												
Expected a career in the mathematically intensive sciences at age 15							2.218***	(0.289)	0.114	2.226***	(0.285)	0.111
Mathematics												
Mathematics achievement at age 15							2.495***	(0.209)	0.354	2.677***	(0.226)	0.368
Mathematics self-concept at age 15							3.455***	(0.251)	0.428	3.425***	(0.255)	0.410

(Table continues)

Table A2.4 (Continued)

	Model 1			Model 2			Model 3			Model 4		
	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient
Weighting variables												
Family structure (reference = nuclear family)												
Other family structure										0.734*	(0.098)	-0.050
Immigration status (reference = native students)												
First-generation students										3.967***	(0.617)	0.157
Second-generation students										2.004***	(0.349)	0.084
State/territory (reference = New South Wales)												
Australian Capital Territory										0.246*	(0.146)	-0.296
Northern Territory										0.217**	(0.110)	-0.385
Queensland										0.539**	(0.111)	-0.251
South Australia										0.229***	(0.056)	-0.517
Tasmania										0.646†	(0.149)	-0.083
Victoria										0.452***	(0.089)	-0.359
Western Australia										0.192***	(0.038)	-0.634
Constant	0.109***	(0.010)		0.111***	(0.013)		0.026***	(0.005)		0.050***	(0.010)	
Random effects												
Variance between schools	0.515***	(0.138)		0.498***	(0.131)		0.798***	(0.160)		0.416***	(0.114)	

Note: The sample for this multilevel analysis contains 6,083 students in 289 schools with multiple imputations of missing data. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Y03

Table A2.5 Descriptive statistics of all student-level variables included in the analysis of the impact of single-sex schooling on the choice of a mathematically intensive university study in Table 7.4

	Single-sex schools		Coeducational schools		Min.	Max.	*N*
	Men	Women	Men	Women			
Dependent variable							
Entry into a mathematically intensive science degree [a b]	0.23	0.10	0.3	0.06	0	1	3,174
Family background							
Socioeconomic status	0.77	0.72	0.56	0.49	-2.86	2.15	3,165
Career expectations							
Expected a career in the mathematically intensive sciences at age 15 [a b]	0.28	0.10	0.33	0.07	0	1	2,941
Mathematics							
Mathematics achievement [a b]	604.25	582.47	598.66.49	570.15	258.79	842.37	3,174
Mathematics self-concept [b]	0.41	0.26	0.60	0.35	-2.12	2.42	3,172
Studied advanced mathematics and physical science [b]	0.16	0.12	0.20	0.09	0	1	2,922
Studied physical science only	0.25	0.23	0.28	0.25	0	1	2,922

Note: This table contains weighted estimates before multiple imputations of missing data.

[a] indicates that the difference between men from all-boys schools and women from all-girls schools in that variable is statistically significant at $p < 0.05$.

[b] indicates that the difference between men who attended a coeducational school and women who went to a coeducational school in that variable is statistically significant at $p < 0.05$.

Source: Y03

Table A2.6 Odds ratios and standardised coefficients from logit models for the choice of mathematically intensive university education with the inclusion of school-level variables in Table 7.5

	Model 1			Model 2			Model 3			Model 4		
	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient
Fixed effects												
School characteristics												
Gender composition of school (reference = coeducational school)												
All-girls school	1.779**	(0.355)	0.650	1.784**	(0.343)	0.626	1.629*	(0.316)	0.621	1.744**	(0.347)	0.609
All-boys school	0.640**	(0.087)	-0.495	0.651**	(0.092)	-0.457	0.710*	(0.108)	-0.433	0.686*	(0.109)	-0.411
School sector (reference = government school)												
Catholic school				0.843	(0.117)	-0.265	0.914	(0.132)	-0.162	0.875	(0.124)	-0.203
Independent school				1.159	(0.146)	0.210	1.306	(0.184)	0.447	1.250	(0.184)	0.323
School policies and resources												
Selective admission to school (reference = no selective admission)				0.982	(0.104)	-0.036	1.011	(0.115)	0.019	1.045	(0.124)	0.076
Teacher shortage				1.004	(0.064)	0.014	1.015	(0.069)	0.066	1.022	(0.072)	0.086
Student characteristics												
Female	0.134***	(0.192)	-0.480	0.133***	(0.019)	-0.481	0.253***	(0.038)	-0.301	0.246***	(0.036)	-0.306
Family background												
Socioeconomic status	1.072	(0.075)	0.026	1.034	(0.075)	0.012	1.013	(0.083)	0.002	1.060	(0.087)	0.017
Career expectations												
Expected a career in the mathematically intensive sciences at age 15							3.871***	(0.460)	0.231	3.966***	(0.468)	0.234
Mathematics												
Mathematics achievement at age 15							1.041	(0.081)	0.037	1.049	(0.085)	0.042
Mathematics self-concept at age 15							1.479***	(0.096)	0.148	1.448***	(0.096)	0.138

(Table continues)

Table A2.6 (Continued)

	Model 1			Model 2			Model 3			Model 4		
	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient	Odds ratio	Standard error	Standardised coefficient
Studied advanced mathematics and physical science							3.255***	(0.553)	0.173	3.371***	(0.586)	0.175
Studied physical science only							1.745***	(0.228)	0.102	1.785***	(0.232)	0.105
Weighting variables												
Family structure (reference = nuclear family)												
Other family structure										0.971	(0.132)	-0.004
Immigration status (reference = native students)												
First-generation students										1.512*	(0.014)	0.062
Second-generation students										0.824	(0.252)	-0.027
State/territory (reference = New South Wales)												
Australian Capital Territory										0.728	(0.206)	-0.248
Northern Territory										1.419	(0.464)	0.305
Queensland										1.209	(0.205)	0.279
South Australia										1.083	(0.238)	0.100
Tasmania										1.819†	(0.597)	0.362
Victoria										1.103	(0.184)	0.181
Western Australia										1.094	(0.196)	0.108
Constant	0.447***	(0.039)		0.462***	(0.053)		0.122***	(0.019)		0.105***	(0.021)	
Random effects												
Variance between schools	0.016	(0.052)		0.011	(0.053)		0.001	(0.032)		2.46×10^{-33}	(5.34×10^{-33})	

Note: The sample for this analysis contains 3,174 students in 282 schools with multiple imputations of missing data. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Y03

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