Three Empirical Essays on Family Economics

WONG, Man Kit

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Abstract

The dissertation consists of three empirical studies on Chinese household behavior. Essay 1 uses Chinese child twin data to examine the effect of birth weight on performances during childhood and adolescent periods. Essay 1 has three main contributions to literature. First, this essay is the first to use twin data of an Asian developing country to study the birth weight impact. Within-twins results suggest that birth weight has significant effect on physical growth, but no significant effect on school performance, health conditions, and personality. Second, this study is the first to apply threshold regression on twin data to examine the non-linearity effect of birth weight. Overall, there is no evidence to support the argument that the effect is non-linear on medium-term outcomes. Third, this study is the first to test directly whether birth weight effect operates through interaction with post-birth parental inputs. There is no evidence to support that this mechanism works in within-twins results.

Essay 2 uses Chinese adult twin data to investigate birth weight effect, the outcomes of which have been changed to long-term achievements. The OLS results suggest that birth weight has significant positive relationship with earnings, adult height, and health conditions. However, within-twin-pair results indicate that birth weight has significant positive influence only on adult height. Essay 2 also systematically interprets the pattern of bias directions of OLS relative to within-twins estimates across empirical studies on long-term outcomes. For health measures, OLS estimates are consistently biased upward relative to within-twins estimates across empirical studies, suggesting an overall positive correlation between omitted factors and birth weight. On the contrary, the bias direction of OLS relative to within-twins estimates fluctuates across empirical studies on ability-related outcomes, including educational attainment and earnings. This suggests that there are two main types of omitted variable (e.g., endowments and post-birth parental inputs) with each type having different correlation with birth weight.

Essay 3 uses data from the 2000 and 2005 censuses of China. It analyzes trends on the marital behavior of Chinese people during 1970-2004, and the impact of the one-child policy in terms of marriage age, marriage rate, and assortative mating on age. First, this essay finds that from 1990 onwards, more people have preferred to marry at and after their mid-twenties. Interestingly, up to the early 2000s, the prevailing marriage rates of men and women over 35 years old maintained at very high levels (over 90%) despite China becoming more prosperous. Moreover, the positive assortative mating on age was more or less the same from 1970 to 2004. In addition, this essay is the first to compare the marriages of Zhuang people relative to other non-Han people (excluding Man people) around 1989 to implement the difference-in-differences (DiD) estimation. Results from DiD estimations indicate that the one-child policy encourages more people to delay marriages. On the one hand, the policy favors more men at 30 years old or above to marry young women in their twenties. On the other hand, interestingly, it also induces more young men to marry older women.

摘要

此論文包括了三篇關於中國家庭行爲的實證研究。第一篇研究是用中國兒童雙胞胎數據去探討出生體重對人們在兒童和青少年時期表現的影響。本篇對之前的文獻有三個主要的貢獻。首先，本文是第一篇用亞洲發展中國家的雙胞胎數據，去研究出生體重的影響。雙胞胎組內估計顯示出生體重對身體的生長有顯著的影響，但對於學業、健康狀況，以及個性並沒有顯著的影響。其次，本研究是首次應用臨界測量模型於雙胞胎數據上，整體而言，沒有證據支持出生體重對中期表現的影響是非線性的。此外，本文是第一篇直接地探討出生體重的影響是否與父母的投入有交互作用。在雙胞胎組內的估計，沒有任何證據支持這說法。

第二篇研究使用中國成人雙胞胎數據去調查出生體重對於長遠成就的影響。普通最小二乘方(OLS)結果表明出生體重與工資，成人身高和健康狀況有顯著的正關係。不過，雙胞胎組內估計顯示出生體重只對成年身高有正面顯著的作用。其次，本文有系統地分析先前文獻和本篇的實證結果，調查相對於雙胞胎組內估計，OLS 估計的偏差有無顯示一致的方向。於健康方面，在多個實證研究的結果中，本文發現相對於雙胞胎組內估計，OLS 估量一致性的誇大了出生體重的影響，顯示出生體重與忽略因素有正關係。與此相反，與能力有關的成就包括教育成就和收入，相對於雙胞胎組內估計，OLS 估量的偏差，沒有顯示一致的方向。這可能表明，有兩種不同類型的遺漏變量，例如天賦和出生後父母的投入，與出生體重有不同的關係。

第三篇研究是使用中國 2000 年和 2005 年的人口普查數據去討論由 1970 年至 2004 年間，中國人在結婚年齡、結婚率，以及配偶年齡配對方面的趨勢，以及一孩政策對於以上三方面的影響。首先，從 1990 年起，越來越多的中國人喜歡在二十多歲或以後結婚。有趣的是，到了二十一世紀初，即使中國變得更加繁榮，大多數 35 歲以上的男性和女性(超過 90%)都已經結婚。其次，夫妻之間的年齡配對，依然維持了差不多的模式。此外，本文是首次透過比較壯族與其他非漢族(不包括滿族)在 1989 年前後的婚姻的變化，去實行分歧中的差異(Difference-in-Differences)估量。其結果指出一孩政策鼓勵男女雙方推遲結婚。一方面，一孩政策吸引更多男性在三十歲或以上的年紀結婚，他們仍然娶一個 20 多歲的年輕女性；另一方面，有趣的是，一孩政策還吸引更多年紀較輕的男性和較其年長的女性結婚。

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Chapter 1
Introduction

This dissertation consists of three empirical studies on Chinese household behavior. The first two essays are interrelated, as they study the impact of birth weight on medium- and long-term outcomes using Chinese twin data. The third essay attempts to analyze the trends on marital behavior of Chinese people from 1970 to 2004, and the impact of the one-child policy in terms of marriage age, marriage rate, and assortative mating on age.

Birth weight is regarded as a good indicator of pre-birth nutrient intake. Many early studies on birth weight effect use the OLS regression, and their results support the importance of birth weight on outcomes in the short to long term (McCormick et al., 1990; Corman and Chaikind, 1998; Currie and Hyson, 1999; Barbara et al., 2002; Richards et al., 2002; Case et al., 2005). However, OLS estimates may be subject to omitted variable bias since birth weight is correlated with genetic and other family factors, which may not be controlled for in OLS regression. In order to remove omitted variable bias, recent studies prefer to use twin data to conduct within-twins fixed effects regression (Behrman and Rosenzweig, 2004; Almond et al., 2005; Black et al., 2007; Oreopoulos et al., 2008; Royer, 2009).

Despite numerous twins-based studies analyzing the impact of birth weight, no twins-based analysis has been conducted for developing countries, especially in the Asian region. Moreover, three prevailing mechanisms of birth weight effect exist: own, proxy, and interactive effects. First, higher birth weight of an infant suggests higher endowment in two aspects: health and ability. Hence, birth weight is expected to have an own effect on the performance of an individual. Second, higher birth weight represents infants as having inherited better, yet unobserved, family endowments (e.g., genes). Thus, birth weight impact, as manifested in OLS results, may be a proxy of the influences from these omitted family endowments. In this dissertation, this is referred to as the "proxy effect." Third, birth weight may interact with intermediary factors (i.e., post-birth parental inputs), which is called the "interactive effect" in this dissertation. OLS estimates are likely to contain these three effects jointly. Within-twins estimates are believed to remove the proxy effect; however, may contain both own and interactive effects. Thus, it is uncertain if within-twins results in prior literature fully reflect the own effect on future performances. Recent twins-based studies only briefly discuss this subject, leaving such important issue for future work. Motivated by these gaps, the first two essays attempt to use Chinese twin data to shed further light on past literature.

Essay 1 uses Chinese child twin data to examine birth weight effect on medium-term outcomes during childhood and youngster periods. Overall, this essay has four contributions to literature.

First, this essay is the first to use twin data from an Asian developing country in the study on the impact of birth weight. OLS results suggest that birth weight has a significant positive relationship with obtaining academic awards, physical growth, health conditions, and character. According to within-twins results, Chinese children born with higher birth weight are taller and heavier, and do more household chores. However, within-twins estimates are insignificant on school performances, as well as other measures of health conditions and personality.

Second, this study is the first to apply the threshold regression developed by Hansen (1999) on twin data. In investigating the non-linearity effect of birth weight, the present study finds that threshold regression is more reliable than spline regression, which has been used by previous twins-based studies. Overall, the present results support the argument that birth weight impact is linear on medium-term outcomes, and further confirm that within-twins results can be generalized for the whole population.

Third, this study is the first to test directly the "interactive effect" mechanism. No prior literature tests directly whether the influence of birth weight operates through interaction with post-birth parental inputs. The present data contain information on inputs of parents towards twins, which allows for testing of this mechanism. As a whole, based on the Chinese child twin sample used by the current work, there is no evidence to support the argument that within-twins estimate contain an interactive effect. Furthermore, in the present study, OLS estimates are larger than within-twins estimates on several measures of medium-term performance. This implies that the positive proxy effect exists, leading to an upward bias of OLS estimates.

Fourth, this essay examines the findings by Currie et al. (2008), wherein estimates of birth weight dummies become smaller when early health measures are added into sibling fixed effects regression. Based on results, Currie et al. (2008) propose that long-term impact of birth weight occurs partly because birth weight is predictive of future health conditions. However, using the present Chinese child twin sample, unlike in the findings of Currie et al. (2008), the within-twins estimates of birth weight measures remain nearly the same, with or without controlling for any early sickness measure.

Essay 2 continues by investigating the influence of birth weight using a Chinese adult twin data set. In this case, the outcomes of interest change to long-term achievements, including educational attainment, earnings, adult height, body mass, health conditions, and birth weight of the next generation.

The present OLS results suggest that birth weight has a positive and significant relationship with earnings, height, and health conditions in the long term. In contrast, within-twin-pair results indicate that birth weight only has a significant positive influence on height.

Moreover, there is little evidence from spline and threshold regressions to support that birth weight effect is non-linear on long-term outcomes, except for educational attainment.

In addition, Essay 2 systematically interprets the pattern of bias directions of OLS relative to within-twins estimates, both from prior empirical literature and this study, in terms of two major types of outcomes (i.e., health-related and ability-related). Except for Behrman and Rosenzweig (2004), previous studies seldom interpret why OLS estimates are biased either upward or downward relative to within-twin estimates for a specific outcome. For long-term health measures, OLS estimates are biased consistently upward relative to within-twins estimates across empirical studies, suggesting that omitted health-related factors and birth weight are positively related. Nevertheless, the bias direction of the OLS relative to within-twins estimates fluctuates across empirical studies, as in the case of ability-related outcomes, such as educational attainment and earnings. OLS estimates are biased downward in some studies (e.g., Behrman and Rosenzweig, 2004), while they are biased upward in other studies (e.g., Oreopoulos et al., 2008) for ability-related outcomes. Such inconsistency suggests that two main types of omitted variable exist, with each type having different correlation with birth weight, and the resulting overall bias direction of OLS estimates relies on which type of omitted variable bias dominates.

By linking the findings of Essays 1 and 2, and by using Chinese twin samples, the present within-twin results indicate that birth weight has significant effects on the growth of an individual during childhood, as well as on height in the long term. In contrast, within-twins results in prior literature often mention that birth weight has significant impact on educational achievement, earnings, and birth weight of the next generation.

Unlike the preceding two essays on birth weight issues, Essay 3 attempts to examine the marital behavior of the Chinese people using data from the 2000 and 2005 censuses of China. Essay 3 has two main objectives. First, it analyzes the trends in marriage age, marriage rate, and assortative mating on age for the Chinese from 1970 to 2004, a period of policy changes and rapid economic growth. Prior literature (Xu et al., 2003; Yang and Chen, 2004) focuses on marriage rate and marriage age from 1970 to the early 1990s. The present study is the first to use large-scale Chinese national data covering a lengthy discourse on these aspects. Second, it studies the impact of the one-child policy on marriage age, marriage rate, and assortative mating on age using a difference-in-differences analysis. Previous studies mainly examine the impact of the policy on other fields, such as sex selection at birth, the welfare of women in the family, quantity and quality tradeoff on children, and so forth (Short et al., 2001; Li, 2003; Yang, 2007; Rosenzweig and Zhang, 2009). As households are allowed to have only one child, and females are usually only allowed to be pregnant once, the policy is expected to change the marital behavior of Chinese people. As far as we know, this study is the first to examine such policy influence on these areas.

Consistent with the findings of Yang and Chen (2004), the present results show that the Chinese people delayed their marriages from early to mid-twenties under the government's campaign in the 1970s; however, they then reverted to marrying in their early twenties in the 1980s. From 1990 onwards, more people preferred to marry during or after their mid-twenties. Interestingly, the prevailing marriage rates of men and women over 35 years old maintained at very high levels (over 90%) up to the early 2000s despite China becoming more prosperous. Such phenomenon is different from those in developed countries wherein they are more likely to remain single when they become more affluent. In addition, the mean age gap between spouses from 1970 to 2004 fluctuated within ± 1 year. The present results also indicate that positive assortative mating on age is maintained more or less the same during 1970-2004. The above-mentioned findings suggest that despite the fact that more Chinese people prefer to delay marriage, their traditions regarding willingness to marry and assortative mating on age have been preserved. This phenomenon should be studied further in order to examine the underlying reasons for such persistence.

Next, in investigating the influence of the one-child policy, this essay is the first to compare the marriages of Zhuang people to other non-Han people (excluding Man people) around 1989 to implement the difference-in-differences estimation. This comparison is believed to be more definitive than that of the Han versus non-Han in prior literature. Present findings indicate that the policy encourages more men and women to delay their marriages. Moreover, the policy affects the assortative mating on age. Interestingly, more young men in their late teens to mid-twenties marry older women. But, most of men who marry in their thirties or older still prefer to marry younger women in their twenties. Overall, the positive mean age difference between spouses in their first marriages becomes larger, rather than smaller, after being subjected to the one-child policy.

Chapter 2

Impact of Birth Weight on Medium-Term Outcomes: Evidence from Chinese Child Twins

2.1. Introduction

2.1.1. Background

Birth weight is an important indicator of nutrition intake during pregnancy. Many early studies (McCormick et al., 1990; Corman and Chaikind, 1998; Currie and Hyson, 1999; Barbara et al., 2002; Richards et al., 2002, and Case et al., 2005) use OLS regression to investigate the impact of birth weight. Their results support the importance of birth weight in future performances, such as infant mortality, educational achievement, and long-term health conditions. These findings have encouraged government bodies to enhance the welfare of pregnant women because infant health is important for the future of children. For instance, the US government has carried out actions to improve the health of babies in recent years based on the belief that infant health can affect future achievements. However, results from OLS regressions do not necessarily mean that birth weight has a causal influence on later outcomes, from short term to long term.[1] Birth weight is correlated with genetic and other family factors that may not be observable. If OLS regression fails to control these relevant but unobservable factors, the OLS estimate of birth weight is subjected to omitted variable bias. For instance, low birth weight is a result of poor prenatal circumstances such as maternal smoking habit, low family incomes, and so forth. These factors not only affect the infant weight, but also future development of the child.

In order to address the omitted variable bias, recent studies have switched to twin data in carrying out within-twins fixed effects regression in the estimation of birth weight effect. Almond et al. (2005) use large-scale twin data in the US and find that the within-twins estimates of birth weight are much smaller than OLS estimates on short-

[1] In this study, short-term outcomes refer to the performances of infants born within 1 year, medium-term outcomes refer to the performances of an individual aged between 6 and 18, and long-term outcomes refer achievements as adults.

term outcomes, including one-year mortality, five-minute Apgar score, and hospital costs, suggesting that the causal effect of birth weight is rather small. However, some recent studies (Behrman and Rosenzweig, 2004; Black et al. 2007; Oreopoulos et al., 2008) use other twin data sets for within-twins results. These studies suggest that birth weight has significant positive impact on medium- and long-term outcomes, such as total physician visits between ages 12 and 17, probability to reach Grade 12 by age 17, educational attainment, earnings, and so forth.

2.1.2. Conceptual Issues on the Mechanisms that Underlie the Birth Weight Effect

With these new findings on twin data, a heated debate has emerged in relation to birth weight effects on short-, medium-, and long-term outcomes. Three proposed mechanisms prevail in literature (although they have not been discussed systematically in one place before): (1) own effect, (2) proxy effect, and (3) interactive effect.

"Own effect" refers to the direct effect brought about by the birth weight. The birth weight itself has positive direct influence on later outcomes. This favorable effect is unrelated to the genetic factor or any other post-birth mediating complementary factors. Birth weight represents inborn endowment in two main aspects: health and ability. Cunha and Heckman (2007) propose that health human capital is complementary to skills, which in turn leads to higher skills. The ability gap between individuals opens up at early ages. Currie et al. (2008) further propose that higher birth weight could foster the cognitive development of a child. Such effect accumulates over time. Thus, children born with lower birth weight in the early period are unable to catch up. Worse, their performance is likely to worsen continuously in the future.

"Proxy effect" asserts that the effect of birth weight found in the OLS results mainly comes from unobserved genetic components and other family factors that are embedded once individuals are born. Such unobservable factors are uncontrolled for in the OLS regression. Thus, the significant relationship between later outcomes and birth weight found in the OLS regressions is spurious. For example, individuals born with higher birth weight claim better genes inherited from parents. Thus, their better performance in the future points to their higher intelligence, rather than their higher birth weights. Hence, birth weight functions as a proxy or signal and its significant impacts in the OLS results are mainly derived from unobservable genetic and other family factors. In this case, the policy of enhancing infant birth weight may not be effective. Recent studies prefer to use twin data in order to implement within-twin-pair regression, which removes unobserved family factors common to twins. The within-twins estimate is expected to be free of this "proxy effect."

The aforementioned scenario illustrates the possibility of a positive proxy effect. However, the proxy effect can be positive or negative, depending on the kinds of omitted factors and their relationship with birth weight. Table 2.1 summarizes the view of prior studies towards birth weight representation and possible omitted factors correlated with birth weight. In general, birth weight is regarded as a good measure of infant health and prenatal/fetal nutrient intake. However, extant literature rarely specifies the details of the omitted factors, which are usually grouped as unobservable family factors (e.g., genes).

For simplicity, in the present study, unobserved family endowments are classified into two main types: by health and by ability. Generally, health-related omitted endowment and birth weight are positively related. However, unobserved ability consists of different dimensions, with each dimension having its own correlation with birth weight. For instance, schooling ability and birth weight may be related negatively, suggesting that heavier babies may have lower talent in learning. This possibility is raised by Behrman and Rosenzweig (2004) to explain why OLS estimates of birth weight are biased downward relative to within-twins estimates on educational attainment and earnings.[2] However, other dimensions of ability, such as persistence, could be related positively with birth weight. For achievements in situations where persistence is more important than learning ability, the OLS estimate of birth weight would be biased upward. Thus, the proxy effect can be positive or negative, depending on omitted family factors and their relationship with birth weight.

[2] Another possibility raised by Behrman and Rosenzweig (2004) is that parents compensate on their child born with lower birth weight across households.

"Interactive effect" means that the birth weight effect operates through interactions with post-birth parental inputs. For instance, developing a child born heavier yields a higher marginal benefit than a child born lighter, thus, parents might invest more on the child born heavier, leading to a positive significant relationship between birth weight and future performances. In this case, OLS estimates of birth weight could be significant due to the positive interactive effect. Additionally, if parents perceive that one twin is better because the child is born with higher birth weight and they reinforce this particular twin, within-twins regression would not be able to remove this interactive effect when parental inputs between twins, which are correlated with birth weight between twins, are not controlled for in the regression. Possibly, within-twins estimate of birth weight is significant even though the own effect is small because within-twins estimates reflect both positive own and interactive effects.[3] Similar to the proxy effect, the interactive effect may be negative when parents compensate on a child born with lower birth weight.

2.1.3. Motivations and Objectives

Despite numerous twins-based studies analyzing the impact of birth weight on short- and long-term outcomes, only the study by Oreopoulos et al. (2008) uses Canadian twin data to study birth weight impact on academic outcomes and health conditions in the medium term (i.e., childhood and adolescent periods). Which mechanism works is important to policymaking. Within-twins estimate is believed to be free of a proxy effect, but may still contain an interactive effect. If the birth weight effect found in previous twins-based empirical studies is attributed largely to the positive interactive effect, it may not be worthwhile for the government to spend much resource on enhancing the birth weight of infants. Unfortunately, recent twins-based studies only briefly discuss this issue and leave such important issue to subsequent works. These gaps have motivated us to use Chinese child twin data to explore further the birth weight effect on medium-term outcomes, and to test whether birth weight mainly

[3] Almond et al. (2005) use this mechanism to explain why within-twins estimates are much smaller than the OLS estimates on short-term health measures in their study while other twins-based studies find significant birth weight effects on medium- and long-term outcomes (such as Black et al., 2007, Oreopoulos et al., 2008).

operates through interactions with reinforcing post-birth parental inputs. The specific objectives of this chapter are as follows.

The first objective of this chapter is to utilize Chinese child twin data to examine the influence of birth weight on academic performance, physical growth, health conditions, and character in the medium term.

The second objective is to examine the non-linearity effect and threshold level of birth weight on medium-term outcomes. Most twins come disproportionately from the lower end of birth weight distribution.[4] If birth weight effect is non-linear and concentrates in the range of less than 2,500 grams,[5] estimation based on twin data may overstress the importance of birth weight on the general population that is dominated by singleton births. It is important to clarify this non-linearity concern of the birth weight effect. A common method used in recent twins-based studies is spline (piecewise linear) regression. Unfortunately, this method poses a weakness in that the knot point is assumed by researchers when the number of segments and the values of knot points are actually unknown. In the present study, we use a more reliable method, threshold estimation, to test the non-linearity effect in terms of medium-term outcomes. The advantage of this method is that the threshold of birth weight is determined, rather than pre-determined, in the estimation. To our knowledge, this approach is applied on twin data for the first time in the current study.

The third objective is to utilize information on parental inputs on the child twin data set in order to test the "interactive effect" mechanism directly. Researchers generally presume that twins, especially identical twins, share common unobservable genetic and other family factors, and hence, within-twins estimation can remove the proxy effect. However, it is possible that a twin sibling born with higher birth weight in a household tends to be healthier and can grow up faster compared with the other

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[4] The mean birth weight for twins is approximately 2,500 grams only

[5] An infant born with weight less than 2,500 grams (5.5 pounds) is defined as low birth weight by the World Health Organization (WHO) Such definition is based on epidemiological evidence that infants born weighing less than 2,500 grams are approximately 20 times more likely to die than babies born weighing 2,500 grams or above Some studies (such as Case et al., 2005) only compare outcomes of individuals born with birth weight less than 2,500 grams and individuals born with weight 2,500 grams or above This is because the researchers believe that the benefit of increasing birth weight concentrates in the range of less than 2,500 grams only

sibling. Parents may treat each twin differently in the course of growth. Parents reinforcing the stronger twin may explain why a sibling born with higher birth weight outperforms the other sibling. In this case, unfortunately, within-twins regression fails to remove the interactive effect because post-birth parental inputs are correlated with birth weight and are different between twins. As far as we know, no prior literature has investigated whether birth weight interacts explicitly with post-birth parental inputs between twins. In turn, there is no guarantee that within-twins estimate could identify the own birth weight impact. The Chinese child twin data set contains information on parental inputs on children. Thus, this study can examine explicitly whether parental inputs vary in response to the difference in birth weights between twins.

The fourth objective is to examine whether adding an early sickness measure can reduce magnitudes of estimated birth weight effects.[6] Currie et al. (2008) find that sibling fixed effects estimates of birth weight dummies diminish on medium-term outcomes when early health measures are controlled for, although the pattern of significance in birth weight dummies remains similar. The authors propose that part of the long-lasting impact of birth weight may occur by predicting future health conditions. Hence, the Chinese child twin sample is used according to this method in order to observe probable similar qualitative results.

2.1.4. Major Findings and Contributions

This chapter contributes to literature in four ways. First, this study is the first to use twin data from Asian developing countries for the analysis of birth weight effect on outcomes in the medium term. OLS results suggest that birth weight has significant impact on school performance, physical growth, health conditions, and character. Within-twins results indicate that birth weight has significant impact on physical growth and performing household chores, but no significant effect on school performance and other measures of health conditions and character. Overall, based on

[6] The sample size and information on sickness record of children of this study are rather limited relative to Currie et al. (2008).

within-twins findings, Chinese children born with higher birth weight are taller, heavier, and perform more household chores.

Second, this study is the first to apply threshold estimation on twin data. According to the results of spline and threshold regressions, overall, there is no evidence to support that birth weight effect is non-linear on medium-term outcomes. Findings from the present work indicate that within-twins results can be generalized to the whole population.

Third, this study is the first to test the "interactive effect" mechanism directly. As a whole, using the Chinese child twin sample, no evidence supports the idea that within-twins estimate contains the interactive effect. Overall, OLS estimates tend to be biased upward relative to within-twins estimates on several measures of medium-term performance. This suggests that the positive proxy effect exists, leading to significant OLS coefficients of birth weight measures.

Fourth, different from Currie et al. (2008), the estimated coefficients of birth weight measures remain almost the same with or without controlling for an early sickness measure using the sample in this present work. Such findings may cast doubt on the conjecture of Currie et al. (2008).

The rest of this chapter is organized as follows. Section 2.2 reviews and discusses several recent relevant studies. Section 2.3 describes the Chinese child twin data set of the present work. Section 2.4 introduces the methodology. Section 2.5 reports the results and interprets the implications. Section 2.6 summarizes the findings and implications.

2.2. Literature Review

Studies on the relationship between birth weight and outcomes from short to long term have been carried out for a long time. Many early studies using OLS regression have found significant birth weight impacts on later achievements. In the short term, babies born with low birth weight have higher infant mortality rate than babies with birth weight higher than 2,500 grams (McCormick, 1985). In the medium term, children born with low birth weight are more likely to have difficulty in terms of school performance (McCormick et al., 1990; Corman and Chaikind, 1998; Barbara et al., 2002; Richards et al., 2002). In the long term, based on extant literature, children born with lower birth weight have lower educational achievements, lower earnings, and poorer health conditions (Currie and Hyson, 1999 and Case et al., 2005). However, as mentioned earlier, the OLS estimate of birth weight is likely to be subjected to omitted variable bias, and the estimated impact may not be the own effect of birth weight.

To overcome the omitted variable bias, some researchers have switched to use siblings data (e.g., Conley and Bennett, 2000; Johnson and Schoeni, 2007), implementing the sibling fixed effects approach to compare the outcomes of siblings born with different birth weights. However, this method can only control part of genetic factors and fails to control time-varying factors. For example, maternal behavior may be different for each pregnancy. Hence, several economists adopt the within-twins approach to analyze the impact of birth weight because twin comparison, especially that of monozygotic twins, is likely to identify the own effect. For instance, Almond et al. (2005) use twins born in the US from 1995 to 2000 to compute the effect of birth weight on hospital costs, five-minute Apgar score, ventilator incidence, and infant mortality rates. According to Almond et al. (2005), the estimated effects of birth weight are significantly smaller in within-twins regressions than in the pooled OLS regressions. In addition, several studies use twin data to analyze birth weight effect on long-term outcomes (Behrman and Rosenzweig, 2004; Black et al., 2007). Relative to numerous studies on birth weight effect on short- and long-term performances, only one study focuses on twin data and medium-term outcomes. However, several studies exist on sibling data that estimate birth weight impact on school performance and health conditions over childhood and adolescent periods. The following segments briefly summarize the main findings of studies using twin or sibling data.

The study by Oreopoulos et al. (2008) may be the only one to use twin data to analyze the impact of birth weight on outcomes in the medium term. Twin and sibling data of births between 1978 and 1985 in Canada are used to analyze birth weight effect on short-, medium-, and long-term performances. This study uses administrative data from the Population Health Research Data Repository at the Manitoba Centre for Health Policy (MCHP) in Canada. According to within-twin-pair results, birth weight has significant negative effect on the number of physician visits for children between 12 and 17 years old, and the probability of requiring social assistance after reaching 18 years old. For school outcomes, some evidence supports that birth weight has a significant positive effect on the probability to reach Grade 12 by age 17. Little evidence supports birth weight having a significant impact on language arts standard test scores of Grade 12.

Johnson and Schoeni (2007) use Panel Survey of Income Dynamics (PSID) observations for children born between 1951 and 1975 in the US, consisting of 0–16 year olds in the first wave interview in 1968, and children born between 1968 and 1975 in latter waves. They use passage comprehension reading (for children aged 6 or above), letters/words reading (for children aged below 6), broad reading summation, and Woodcock-Johnson mathematics scores (for children aged below 6) as measures of cognitive achievement of children. Results from sibling fixed effects regressions suggest that low birth weight has significant negative effect on passage comprehension reading and mathematics scores and significant positive effect on probability of dropping out of high school.

Currie et al. (2008) use a large sibling data set with approximately 50,000 children born between 1979 and 1987 from Manitoba, Canada, with after-birth follow-up record up to year 2006. Their study covers several medium-term outcomes for measures on language arts standardized test scores in Grade 12, choice of taking college-preparatory mathematics course in high school, choice of reaching Grade 12 by age 17, and choice of applying for social welfare upon reaching 18 years old. Moreover, the hospital records consist of birth weight, congenital anomalies, and prenatal problems. In order to examine the influence of congenital anomalies, their sample includes observations with congenital defects. In addition, the effects of asthma, major injuries, attention deficit hyperactivity disorder (ADHD), conduct disorders, and the other major health problems classified by Adjusted Clinical Group (ADG) software are examined. In particular, the aforementioned after-birth health problems are separated by the age range: 0–3, 4–8, 9–13, and 14–18 years old for preschool years, early elementary school, early adolescence, and late teen years, respectively. Based on results from sibling fixed effects estimation, Currie et al. (2008) find that children born with lower birth weight are more likely to obtain welfare aid when reaching 18 years old, have lower language scores (only significant at the lowest birth weight category), and are less likely to reach Grade 12 by age 17. They further add congenital and early health measures for 0–3-year-olds in the regression. The pattern of significance of birth weight dummies is nearly the same as those without these additional control variables; however, the magnitude of estimated birth weight effects diminishes in general. Currie et al. (2008) propose that low birth weight is predictive of future health conditions, and that part of low birth weight impact is linked to later health conditions.

All these studies use data from Western developed countries. Moreover, these studies have taken the fixed effects approach for granted (i.e., within-twins or sibling fixed effects), ignoring the possibility of an interactive effect. As noted earlier, it is possible that estimates from within-twins or sibling fixed effects regressions cover both own and interactive effects. This study hopes to shed further light on these matters.

2.3. Data

The data set for this study is obtained from the Chinese Child Twins Survey (CCTS). This data set has been used in Rosenzweig and Zhang (2009).[7] The survey was designed and supervised by Professor Junsen Zhang and was carried out by the Urban Survey Unit (USU) of the National Bureau of Statistics (NBS) in late 2002 and early 2003 in the Kunming District of China. Kunming is the capital of Yunnan Province, located in the far southwestern part of China.[8] The CCTS covers all households with twins aged 7 to 18 and a sample of households with non-twins in the same age range. The families with twins were identified by USU, which used the 2000 population census for Kunming to sort out households with children having the same birth year and month for the 7–18-year-olds. According to the addresses provided by the census office, these potential families were visited to determine whether the children were

[7] The objectives, methodology, and the targeted outcomes of interest of the current study are largely different from Rosenzweig and Zhang (2009) The differences between the present study and their paper are briefly discussed in Section 2.4.

[8] In Kunming, the one-child policy is enforced in urban households. Rural households are exempted from the policy and can have two children at maximum even if the first-born child is a male

twins. Once confirmed, relevant family members were interviewed. To allow for comparison with the twin sample, for every child twin household identified, the fourth household on the right hand side of the same block was surveyed to represent a non-twin child household. If the fourth household was not suitable for interview, interviewers switched to the fifth, sixth, and so forth.

This survey covered a broad range of information on various aspects, including parental expenditures on children, parental coaching and teaching attributes, and children's performances in school, physical growth, health conditions, and character. During the visit, parents and children were interviewed separately for specific sections. The questionnaire comprised 10 parts, labeled from A to J. Sections A to C and E to F contained questions specifically targeted to parents: family attributes, such as educational achievement, earnings, expenditures, parent's evaluation on performance of twins, and so forth. Section D was related to the characteristics of children in school, and was answered by both parents and children. The other sections, focusing on parent-child interactions, and performances of the children in school and at home, were answered by children. Furthermore, children themselves were separated in different rooms when answering the specific questions in Sections G to J of the questionnaire. Such arrangement was aimed to obtain responses that were more accurate.

The following requirements were used to classify identical twins in the child twin data set: same sex, same hair color, same eye color, and very similar appearance. Consequently, 931 identical twin pairs were contained in the child twin data set. Some observations have missing data on required variables for analysis, and thus were dropped from identical twin sample.[9] The final sample used for analysis includes 547 twin pairs (1,094 observations).

Generalizability of Twins-Based Estimation

[9] In the data set, information on several diseases and malfunctions in body that the respondents had suffered from is presented. For illnesses with distinct features on appearance or behavior, including stammering, hyperactive behavior, brain disorders, monophobia, deafness, blindness, broken leg, and plastic surgery defect, if either or both siblings had suffered from these illnesses, they were excluded from our sample. A total of 42 observations were dropped.

The usefulness of the estimates from within-twin-pair regression relies on whether the empirical results can extend to the general population dominated by singleton births. The average values of key attributes in twin and singleton samples are reported for comparison. Table 2.2 summarizes the descriptive statistics of identical twins, whole twins (identical and non-identical), and non-twins from the present survey. As shown in Column (1), birth weight of each identical twin was approximately 2,400 grams on average, slightly less than the upper bound of low birth weight. The mean age of the children was approximately 11 years. Using the US representative sample as basis, under the same age and gender group, the height and weight of Chinese child twins were approximately one standard deviation lower than those of the US sample in relation to the mean of z-score of height-for-age (HAZ) and weight-for-age (WAZ). On the average, the parents had 9 years of schooling. The fathers had mean earnings of 700 RMB per month, while the mothers had mean earnings of 476 RMB per month. By comparing the mean statistics in Columns (1) and (2), we find that all the attributes of identical child twins were almost the same as those of whole child twins, including both identical and non-identical twins.

A comparison of the mean values in Columns (1) and (3) shows that the average birth weight of singletons was approximately 3,100 grams, which was 700 grams higher than that of identical twins. For HAZ and WAZ, singletons were approximately 0.9 and 0.6 standard deviations lower than those of the US representative sample. Apparently, singletons tend to grow up slightly faster, and are taller and heavier, than twins under the same age and gender group. Although twins were found to be physically weaker than singletons in childhood, the educational level and monthly earnings of the parents of singletons and identical twins were very close. Thus, the difference in average physical growth between twins and singletons in childhood is likely because, on the average, children from twin births were born with lower birth weight compared with singleton births.

Twins vs. Singletons Births

According to the descriptive statistics shown in Table 2.2, the major difference between twin and singleton children is birth weight. Other twin studies also report such a pattern. As the mothers of twins bear two babies simultaneously, the average weight of each twin is less than that of singletons at birth. Figure 2.1 plots the birth weight distributions of singletons and identical twins, showing that approximately 50% of twins born less than 2,500 grams. Nevertheless, the shapes of the dispersion of birth weight are very close over identical twin and singleton samples. Shifting the twin distribution to the right by approximately 600 grams reveals a large overlap between the two distributions.

To investigate further the external validity of using twin data, the relationship between birth weight and medium-term outcomes is plotted across twin and singleton samples, as shown in Appendix Figures 2.1 to 2.7. The patterns of the relationship between each outcome and birth weight are similar over child twin and singleton samples,[10] suggesting that results from the twin data may be generalizable to the whole population. Black et al. (2007) and Royer (2009) also plot such kind of figures and make similar judgments.

How and Why Birth Weight Differs between Twins

In the distribution of birth weight difference within identical child twins (Figure 2.2), only 14% of twin pairs have the same birth weight; 29% have 100 or less than 100 grams weight difference; approximately 26% have 100–200 grams difference; approximately 23% have 200–500 grams difference; and the remaining 8% have more than 500 grams difference. This dispersion allows us to obtain the variation in the size of birth weight within twins to implement within-twins estimation.[11]

One concern is the exogeneity of birth weight difference between twins. According to a WHO report, the two common reasons for low birth weight of infants are short gestational length and low fetal growth rate (intrauterine growth retardation or IUGR). As gestation length is equal between twins, the difference of birth weights within a twin pair is mainly due to differences in fetal growth rates. This means that the nutritional intakes for twin siblings are different when they are inside the womb; their

[10] The volatility in the low and upper ends of the birth weight distribution is due to rarity of such data with two ends.

[11] To test the sensitivity of the empirical results to any outliers, the observations in which the absolute difference in birth weight between twins exceeds 3 standard deviations from the mean of the absolute difference are excluded. As a result, a total of 24 observations are dropped, accounting for 2.2% of the original sample (1,094 observations) The within-twins results for the impact of birth weight on medium-term outcomes and the relationship between parental inputs and birth weight (not shown) are almost the same with or without excluding these 24 observations. Thus, the results are not sensitive to any outliers

different locations inside the womb can in fact affect nutrient absorption. If the location of the umbilical cord attached to the placenta of one twin is better, then, despite having the same genes, this sibling will receive more nutritional intake and blood perfusion, resulting in difference in birth weights. Furthermore, as the positioning of twin siblings is random, the resulting birth weight difference between twins is exogenous from other observable and unobservable family factors.

2.4. Methodology

2.4.1. OLS, Within-Twin-Pair Regressions, and Medium-Term Outcomes

In this section, the empirical framework in estimating birth weight effect is illustrated, and measures of medium-term outcomes are introduced. In particular, in response to the possible mechanisms that underlie birth weight impact (own effect, proxy effect, and interactive effect), we discuss whether OLS and within-twins regressions could identify the own effect of birth weight.

OLS Regression

For simplicity, the following equation uses BW to represent the measure of birth weight.[12]

$$y_{ij} = \beta BW_{ij} + \delta_1' f_i + \delta_2' p_{ij} + \alpha' X_i + \varphi' Z_{ij} + \varepsilon_{ij}, \qquad (2.1.1)$$

where i refers to a family; j refers to a specific child in a family; y_{ij} is the outcome of sibling j in family i; BW_{ij} is the birth weight measure; f_i is a set of unobservable family characteristics, including genetic factors which are correlated with birth weight; p_{ij} is a set of post-birth parental inputs on sibling j in family i; X_i refers to a set of other observed family factors; Z_{ij} is a set of observed individual variables that affect the outcome, such as age, gender,[13] birth order,[14] and so forth; and ε_{ij} is the error term that is assumed independent from all the other variables in the equation.

[12] This study has three measures of birth weight One is the weight at birth directly. Another is log birth weight The third proposed measure of birth weight is a dummy variable that equals 1 for birth weight less than 2,500 grams, otherwise, it is 0.

[13] Gender is a dummy variable that equals 1 if the twin is a male; otherwise, it is 0

[14] Birth order is a dummy variable that equals 1 if the twin is born first; otherwise, it is 0.

The coefficient of interest is β, which measures the own effect of birth weight on outcomes, holding all other observable and unobservable factors constant. If f_i and p_{ij} cannot be controlled, then the OLS estimate (β_{OLS}) is biased and captures the joint effect, including (1) own effect, (2) proxy effect, and (3) interactive effect.

$$\beta_{OLS} = \beta + \delta_1 \frac{\operatorname{cov}(BW_{ij}, f_i)}{\operatorname{var}(BW_{ij})} + \delta_2' \frac{\operatorname{cov}(BW_{ij}, p_{ij})}{\operatorname{var}(BW_{ij})}. \qquad (2.1.2)$$

Within-Twins Regression

As identical twins have identical genes, common family background, and the same neighborhood, they are expected to have the same f_i.[15] In addition, parents likely treat them very similarly. Thus, p_{i1} and p_{i2} are expected to be invariant within twins inside household i.

The within-twin-pair fixed effects estimation is specified as follows:

$$y_{i1} = \beta BW_{i1} + \delta_1' f_i + \delta_2' p_{i1} + \alpha' X_i + \varphi' Z_{i1} + \varepsilon_{i1} \qquad (2.1.3)$$

$$y_{i2} = \beta BW_{i2} + \delta_1' f_i + \delta_2' p_{i2} + \alpha' X_i + \varphi' Z_{i2} + \varepsilon_{i2}. \qquad (2.1.4)$$

The result of first difference of Equations (2.1.3) and (2.1.4) is

$$y_{i1} - y_{i2} = \beta\left(BW_{i1} - BW_{i2}\right) + \varphi' (Z_{i1} - Z_{i2}) + \varepsilon_{i1} - \varepsilon_{i2}. \qquad (2.1.5)$$

The within-twin-pair estimate (β_{FE}), which is unbiased, measures the own effect of birth weight.

However, some researchers propose that the within-twins estimate may still be biased because parental inputs (which may not be observed or available in the data set) may be interacted with birth weight. For instance, parents can reinforce a twin born with

[15] Fraga et al (2005) point out that identical twins have the same DNA in their neurons (genotype) but do not have the same experience such as environmental factors, leading to differences through epigenetic in gene expression (phenotype) Epigenetic factors refer to the chemical markers that attach to genes and affect how they are expressed through slowing or shutting the genes off or increasing their output despite there is no change in the underlying DNA sequence. The epigenetic changes in neuron function affect neurobiological pathways that affect health (physical and mental), behavior and learning The impacts of epigenetic on gene function begin at conception and utero development, and then continue after birth (Shonkoff, 2009). In the child twin sample, both twins lived together with their parents and had the same living environment Thus, epigenetic differences between child twins are likely to be negligible and would not affect the interpretation of the empirical results in this chapter

higher birth weight (more talented). In this case, within-twins estimate may cover both own and interactive effects. That is,

$$\beta_{FE} = \beta + \delta_2' \frac{\text{cov}(\Delta BW_{ij}, \Delta p_{ij})}{\text{var}(\Delta BW_{ij})}, \text{ where } \text{cov}(\Delta BW_{ij}, \Delta p_{ij}) \neq 0. \qquad (2.1.6)$$

This remaining bias is discussed further in Section 2.4.3.

Measures of Medium-Term Outcomes

In the next segments, we introduce three categories of medium-term outcomes: (i) school performance, (ii) physical growth and health conditions, and (iii) character.

(i) School Performance

The first category is related to school outcomes, including Chinese language marks, z-score of Chinese language marks, mathematics marks, z-score of mathematics mark, and the number of "three-good student" awards received. Chinese language and mathematics scores range from 0 to 100. However, as the children attended different schools and the school quality was different, especially across urban and rural regions, the scores used here may not be a good indicator of the performance because they do not have a standard scale.[16] To lessen the problem, we generated z-scores of Chinese language and mathematics marks by primary-secondary level and rural-urban region.[17] In addition, the data set of the present study recorded the number of "three-good student" awards received (i.e., award given to a student who performs well in each of the following aspects: moral and character, academic performance, and health status).

(ii) Physical Growth and Health Conditions

The second category focuses on the physical growth and health conditions of children consisting of z-scores for height-for-age (HAZ), weight-for-age (WAZ), body mass index-for-age (BAZ),[18] underweight,[19] obese,[20] and frequency of hospital visits for the

[16] Despite the data set having records of middle school examination, the observations were too few for analysis.

[17] The original score subtracts the specific mean and then divides by specific standard deviation in primary-urban sample, primary-rural sample, secondary-urban sample, and secondary-rural sample separately.

[18] $Body\,Mass\,Index(BMI) = \left(\frac{Weight\ in\ Ki\log rams}{(Height\ in\ centimers)^2} \right) \times 10{,}000$

previous academic semester. HAZ, WAZ, and BAZ are common indicators in measuring physical growth of children. For instance, HAZ measures the number of standard deviations of height of a child deviating from the average height in a specific group by age and gender. Underweight and obese dummies are classified by BAZ. Frequency of hospital visits measures the frequency of visiting physicians (0, 1, 4, 7, and 10 times in the last school semester).

(iii) Character

The third category focuses on the character of children. It includes three indices: "good character," "bad character," and "do household chores." It is interesting to examine the impact of birth weight on these noncognitive measures. Prior literature using twins or sibling data mainly examines the outcomes of cognitive development such as academic performance and physical health during childhood and adolescent period. Indeed, Cunha and Heckman (2007) point out that skills and abilities have multiple dimensions and non-cognitive skills (such as perseverance, self-control, self-esteem and so forth) could foster cognitive skill.[21] Early studies (McCormick et al., 1990; Corman & Chiakind, 1998) use cross-sectional data to study the impact of birth weight on behavior problems. For instance, McCormick et al. (1990) use the U. S. data from 1981 National Health Interview Survey and find that very low birth weight children have higher probability to have school difficulty and behavior problems. Thus, this study aims to carry out within-twins estimation to identify the own effect of birth weight on the following non-cognitive measures.

The data set of the present study contains 19 questions on the strength and weakness in character of twin siblings, such as being bad-tempered, worried, anxious and subversive, cautious, persistent, and so forth.[22] Parents answered these questions

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The BMI value is plotted on the BAZ growth charts generated by the Centers for Disease Control and Preventions (CDC) to get a percentile ranking The percentile displays the relative position of children among a group with same sex and gender

[19] Underweight is a dummy variable that equals 1 if BAZ of the child is less than the 5[th] percentile based on the BAZ growth charts, otherwise, it is 0.

[20] Obese is a dummy variable that equals 1 if BAZ of the child is greater than the 5[th] percentile based on the BAZ growth charts; otherwise, it is 0

[21] Several prior studies (Bowles et al., 2001, Cunha and Heckman, 2008, Cunha and Heckman, 2009) also find that noncognitive abilities have significant influences on long-term achievements such as educational attainment, earnings, and so forth.

[22] Good characters include "be obedient for adult's request," "having at least one good friend," "in general liked by other children," "be cautious," and "be persistent and focus for a long time" Bad

based on child performance over the past six months. There were three possible answers: completely not matched, some matched, and perfectly matched. If the answer was "perfectly matched," then the child is regarded as having this attribute. We summed up the good personality traits to generate the good character index ranging from 0 to 5. Similarly, the bad character index is composed of several bad personality traits ranging between 0 and 15. The do household chores index gauges how often the child does household chores. The questionnaire asked children regarding the frequency of doing the following tasks: packing schoolbag, making bed, tidying up room, washing clothes, preparing dinner, cooking dishes, washing dishes, and cleaning up room. Children were requested to answer 1 (everyday), 2 (often), 3 (sometimes), 4 (seldom), or 5 (never) for each task. If the child answered 1 (everyday) or 2 (often) for a task, then a score of 1 is given to this task; otherwise, 0. These scores were added to obtain the do household chores index ranging between 0 and 8. This index is expected to measure the virtue of the child at home.

2.4.2. Threshold Estimation and Test of Non-Linearity Impact of Birth Weight on Medium-Term Outcomes

In Section 2.3, the outcomes are found to be similar between singletons and twins over the birth weight distribution. The findings support the generalizablity of estimation from the twin data. However, another concern for the usefulness of the estimation from twin data comes from the potential non-linearity influence of birth weight on later outcomes. Most of the birth weight of twins falls within the lower range of birth weight distribution. For instance, birth weight may have significant influence only when it is less than 2,500 grams. Holding this belief, the estimates of birth weight from twin data tend to exaggerate the impact on general population dominated by singleton birth. Some studies, such as that by Case et al. (2005), merely examine the impact of low birth weight.

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characters consist of "be unstable and hyperactive," "always complain uncomfortable such as having headache," "be bad tempered," "be lonely," "be worried by many things," "be anxious and subversive," "always fight and argue with other kids," "always be unhappy," "easily get distracted," "easily lose confidence in new environment," "always tell lies," "be bullied by other children," "steal things at home, in school, or other places," and "be frightened easily by many things "

As noted before, low birth weight (LBW) is defined by the WHO as weight of less than 2,500 grams (5.5 pounds). The cut-off point at 2,500 grams is based on epidemiological evidence on infant mortality. However, this knot point may be unsuitable for subsequent studies on later outcomes. Black et al. (2007) claim that continuous measures (e.g., log birth weight) fit the data much better than a dummy variable of low birth weight on long-term outcomes. Their findings have aroused our interest in examining the validity of the common knowledge of 2,500 grams as a watershed for medium-term outcomes.

To our knowledge, no prior literature examines the non-linearity effect of birth weight on medium-term outcomes; thus, examining this issue using Chinese child twin sample is worthwhile. Moreover, recent studies have opted to use spline regressions to test the non-linearity effect of birth weight. As noted earlier, the major limitation of spline regressions is that the value of the knot(s) and the number of knots should be known in advance. The reliability of birth weight estimates from spline regressions remains in question because the results are highly affected by the initial settings of the value and the number of knot points. Thus, in addition to spline regressions, the present study applies the threshold estimation developed by Hansen (1999) on twin data to estimate the threshold level of birth weight on medium-term performances. The following shows that the test of single threshold against zero threshold is equivalent to test whether the slope coefficients are equal across two segments of birth weight distribution. If the null hypothesis of no threshold is not rejected, the estimated coefficients are not significantly different across two regimes, in turn providing evidence to support the linear impact of birth weight. The test of existence of threshold(s) can be regarded as a test of non-linearity effect of birth weight. Briefly, we will introduce the methodology and hypothesis testing.[23]

Hansen (1999) has developed a threshold regression method for non-dynamic panel data with individual specific fixed effects. The resulting estimated threshold levels are more reliable than other methods since the threshold is a global optimum. In Hansen's original framework (1999), i refers to an individual, j refers to time, and fixed effect

[23] For details, see Hansen (1999).

refers to individual heterogeneity; in the framework of this study, i refers to a family, j refers to twin siblings, and fixed effect refers to family specific effect.

The structural equation that we are interested in is

$$y_{ij} = \begin{cases} \beta_1 BW_{ij} + \delta_1' f_i + \delta_2' p_{ij} + \alpha' X_{ij} + \varphi' Z_i + \varepsilon_{ij} \; if\, BW_{ij} \le \gamma \\ \beta_2 BW_{ij} + \delta_1' f_i + \delta_2' p_{ij} + \alpha' X_{ij} + \varphi' Z_i + \varepsilon_{ij} \; if\, BW_{ij} > \gamma \end{cases}, \qquad (2.2.1)$$

where i denotes a specific household; j (= 1, 2) refers to the sibling inside a household, and the control variables are the same as those in Section 2.4.1.

Intuitively speaking, if the birth weight effect is more significant and larger on the lower end (i.e., $\gamma = 2500$), then β_1, which corresponds to the range of ≤2,500 grams, is significantly greater than β_2, which corresponds to the range of > 2,500 grams. This indicates that the marginal benefit of increasing birth weight for ≤2,500 is more significant and larger than for those >2,500 grams.

To remove f_i and p_{ij}, which are supposed to be equal for twins within a family (i), the family-specific means are taken off,

$$y_{ij}^* = \beta' BW_{ij}^*(\gamma) + \alpha' X_{ij}^* + e_{ij}^*, \qquad (2.2.2)$$

where $y_{ij}^* = y_{ij} - \bar{y}_i$, $\beta = \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix}$, $BW_{ij}^*(\gamma) = BW_{ij}(\gamma) - \overline{BW}_i(\gamma)$,

$\overline{BW}_i(\gamma) = \frac{1}{2}\sum_{j=1}^{2} BW_{ij}(\gamma) = \begin{pmatrix} \frac{1}{2}\sum_{j=1}^{2} BW_{ij} I(BW_{ij} \le \gamma) \\ \frac{1}{2}\sum_{j=1}^{2} BW_{ij} I(BW_{ij} > \gamma) \end{pmatrix}$, $I(\cdot)$ is an indicator function,

$X_{ij}^* = X_{ij} - \bar{X}_i$, and $e_{ij}^* = e_{ij} - \bar{e}_i$.

For any given γ, the slope coefficients (β) in Equation (2.2.2) can be estimated by the OLS regression.

The estimated optimal $\hat{\gamma}$ is the one that minimizes the sum of squared errors. To implement the minimization, distinct values of birth weight in the sample are first sorted. Next, smallest and largest 5% distinct values of birth weight are excluded. The remaining values constitute the possible values of γ. For each value of birth weight within the remaining pool, regression is implemented and the sum of squared errors is computed. The minimum value of the sum of squared errors yields the optimal estimated $\hat{\gamma}$.

The next step is to test the existence of a threshold. The null hypothesis of no threshold effect is expressed in the following linear constraint: $H_0 : \beta_1 = \beta_2$.[24] This test is same as testing for the presence of non-linear influence on birth weight.[25] The null hypothesis is rejected if the p-value is smaller than the pre-determined critical value. If the null hypothesis is rejected, the presence of a threshold effect of birth weight is supported, showing evidence of the non-linearity effect of birth weight. Furthermore, if a threshold effect of birth weight exists, the value of threshold may not cluster at 2,500 grams. Thus, the above-mentioned threshold regression method not only tests the existence of a threshold effect, it also gives the estimate of the threshold of birth weight with respect to each of medium-term outcomes.

2.4.3. Tests on the "Interactive Effect" Mechanism

As previously noted, there are three main possible mechanisms underlying the significance of birth weight estimate in OLS and within-twins regressions. First, birth weight itself has own positive influences. Second, birth weight effect is a proxy for the impact from unobserved genetic or other family factors. Third, birth weight interacts with post-birth parental inputs.

In general, the OLS estimate is biased, and the OLS estimated impact is a joint effect including own, genetic, and interactive effects. Recall,

$$\beta_{OLS} = \beta + \delta_1' \frac{\text{cov}(BW_{ij}, f_i)}{\text{var}(BW_{ij})} + \delta_2' \frac{\text{cov}(BW_{ij}, p_{ij})}{\text{var}(BW_{ij})}. \qquad (2.1.2)$$

[24] It is possible that there is more than one threshold. The null hypothesis becomes single threshold against double thresholds.
[25] As the true threshold γ is unidentified in the null hypothesis, the classical tests do not have standard distributions and are not applicable in this case. Hansen (1996) proposes that bootstrapping can be used to simulate the asymptotic distribution of the likelihood ratio test.

Generally, identical twins have the same genes and similar family background; thus, the proxy effect is likely to be removed in within-twins regression. If parents treat twins similarly, within-twins estimate is likely to identify the own effect. However, it is possible that the parents may treat the twins differently in childhood; that is, from the point of view of the parents, their children are not "identical," even if their genes are the same. Almond et al. (2005) propose that the long-lasting effect from within-twins result is driven by reinforcing post-birth parental inputs on a specific twin born heavier. In this case, within-twins estimate is biased upward as it contains not only the own effect but also the positive interactive effect. In contrast, parents may compensate on a twin born with lower birth weight; thus, there is a negative correlation between post-birth parental inputs and birth weight. In this case, within-twins estimate is biased downward. Recall,

$$\beta_{FE} = \beta + \delta_2 \frac{\text{cov}(\Delta BW_{ij}, \Delta p_{ij})}{\text{var}(\Delta BW_{ij})}, \text{ where } \text{cov}(\Delta BW_{ij}, \Delta p_{ij}) \neq 0. \qquad (2.1.6)$$

To the best of our knowledge, no prior study has examined the "interactive effect" mechanism directly,[26] and no prior study has investigated whether twins are cared for by parents identically. The advantage of the child twin data set in the current study is that it consists of several parental inputs towards twins, including parental coaching, parental teaching, and parent's monetary expenses. The data provide a good opportunity to examine whether parents care for twins differently with respect to the difference in birth weight. If birth weight mainly mediates its effect through such interaction, parents would expectedly spend resources differently on children born with different birth weight. Thus, this study examines whether parents provide more or less the same care for the child born with higher birth weight. Although the present study cannot examine all parental inputs, there is a reasonable expectation that both observable and unobservable parental inputs are correlated with birth weight, and that

[26] To test the possibility of "interactive effect", some studies separate the whole twin sample based on some criteria including educational attainment of the mother (with twelve or more years of schooling), family income, birth order of children (Black et al., 2007), and family size (Royer, 2009). This is based on the belief that parents in better-off families (in which parents are higher-educated or family size is smaller) are more likely to compensate on a twin born with lower birth weight. Within-twins estimates are expected to be smaller in better-off households if there is sizeable influence of birth weight coming from the interaction with parental inputs. These two studies claim that no definite judgment can be made from the results across sub-samples (not shown).

the birth weight effect is driven by both observable and unobservable parental inputs based on the "interactive effect" mechanism. The inputs of parents are separated into three main categories:[27]

(i) Parental Coaching

The first set of inputs focuses on parent-child communication and parental guidance towards the behavior and performance of the children. The set comprises several indices: parent-child contact (ranging from 6 to 30), parental punishment (7 to 21), parental ignorance (2 to 6), and two indices for parental reaction towards their child's disappointing academic performance [i.e., scolding (4 to 20) and concerning (4 to 20)]. As for the relevant questions asked in the interview that could generate the above-mentioned variables, the answer was given by the children individually in a separate room in order to obtain replies that were more reliable.

For instance, the parent-child contact index is a sum of the frequency of events that occurs between the child and their parents, including discussing an issue with parents, sharing with parents the events that happened in school, sharing own ideas, dining with parents, playing games with parents, and watching TV with parents. In each event, the child was asked to answer 1 (never), 2 (seldom), 3 (sometimes), 4 (often), and 5 (everyday). The values were added to generate the parent-child contact index ranging from 6 to 30. The higher the value of the index, the more frequent the contact between the child and parents.

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[27] Rosenzweig and Zhang (2009) use the same Chinese child twin data set to investigate the potential weakness of using twinning as exogenous instrument for testing the quantity-quality (Q-Q) trade-off hypothesis parents may allocate resources differentially across their children in response to the difference in ability among siblings. Their focus and the objective of the current study are very different Their study aims to build up a theoretical model with empirical evidence to support that parents are likely to reinforce the more talented child. Thus, the method of prior studies using twinning on parity N to estimate the influence of family size on the quality of children on parity N-1 is problematic and the estimated effect is undervalued The main role of adding birth weight is to serve as a control variable of endowment of twins The objective of the current study is to examine the influence of birth weight on the medium-term outcomes and whether parents treat identical twins differently with respect to the difference in birth weight In addition, most of the variables used in the current study are different from the variables used by Rosenzweig and Zhang (2009). Apart from Chinese language score, mathematics score, and health measures, the current study also covers other measures such as the number of "three-good student" award, and measures of character as the dependent variables In addition, aside from school, clothing, and total expenses, measures of coaching are also taken into account as parental inputs Furthermore, the sample in the current study only includes identical twins

The parents were also asked regarding their reactions when a child did not obey a parental order (i.e., scolding, reducing allowances, and so forth). Each child was asked to answer 1 (seldom or never), 2 (sometimes), or 3 (often) to each response. The punishment index (7 to 21) is the sum of the responses of each child to the following actions: "scold you," "stomp feet," "spank you," "ground you," "order you do housework," "reduce your allowance," and "do not allow watching TV or set limitation on watching TV." Ignorance index (2 to 6) is the sum of the child responses to these two reactions: "ignore you" and "tell you to go to your bedroom."

The last two indices are generated from the children's answers for questions related to reactions of parents when they were dissatisfied with children's academic performance. To each response, a child had five possible answers, ranging from 1 (never) to 5 (very possibly). The scolding index (4 to 20) is the sum of the answers to the following reactions of parents with regard to punishment (i.e., "blame you," "punish you," "tell you to spend more time to study," and "restrict your non-academic activities"). Similarly, the concern index (4 to 20) is the sum of the answers to the reactions of parents, such as "discuss with you the cause of the problem," "wait and let you improve," "spend more time tutoring you," and "contact your school teacher."

(ii) Parental Tutoring on Schoolwork

Apart from the above-mentioned parental coaching measures, the present study concentrates on the parental tutoring inputs on the studies of the children. Children were asked on the frequency of the following kinds of assistance provided by the parents: tutoring after class, checking homework, and assigning extra homework. The binary indicator for each measure equals 1 if the child replied that parents employ these actions 1–3 times every week or more; otherwise, it is 0.

(iii) Parents' Monetary Expenses

The monetary spending of parents on their children was also examined using these three measures: clothing expenses, school expenses (sum of school tuition, buying books, stationery, home tutor expenses, training class expenses, and hostel fee), and total expenses (sum of clothing, school, and other expenses).

2.4.4. Test on Birth Weight Effect through Early Health Conditions

Currie et al. (2008) suggest that part of the birth weight effect occurs because it is predictive of later health conditions. In this case, the within-twins estimated birth weight effect is expected to decrease upon the addition of early health measures in the regression. The child twin data set of the present study consists of a few common sicknesses occurring in early childhood, including continuous diarrhea, serious lack of calcium, asthma, whooping cough, fracture, and heart disease. As the sample size is small, a dummy variable equal to 1 is used if the child suffered from at least one of the above-mentioned sicknesses from infancy period up to 5 years old. This dummy variable in the within-twin-pair estimation allows for the investigation of the significance and magnitude of the birth weight estimates, and if these are affected when early health conditions are controlled.[28]

2.5. Results

2.5.1. Results of Birth Weight Impact on Medium-Term Outcomes

In this section, the empirical results of the influence of birth weight on medium-term outcomes are interpreted based on the child twin sample of 1,094 observations (547 pairs). The regression results are summarized in Table 2.3.

First, in the case of Chinese language mark, mathematics mark, and corresponding z-scores, both OLS and within-twin-pair estimates of birth weight are insignificant. For the number of "three-good student" awards received, children with higher weight at birth have higher chance of receiving more awards based on the OLS results. However, the estimates are insignificant and smaller in the within-twin-pair approach. These results suggest that birth weight is related positively to certain good attributes of the parents (e.g., genes) and neighborhood environment, leading to an upward bias in OLS estimation. Qualitatively, such findings are similar to the findings of Oreopoulos et al. (2008) in which the OLS estimates are significant and larger;

[28] In addition, a dummy variable for the child suffered from at least one kind of the above-mentioned illnesses after 5 years of age will also be added as a control variable.

however, fixed effects (FE) estimates (within-twins and sibling FE) are almost insignificant and smaller on a standard language art score in Grade 12.

Next, the results on physical growth and health conditions are discussed. For the z-score of height-for-age, the within-twin-pair results indicate that there is a significant positive effect of birth weight on height and the magnitude of the estimates is slightly less than the OLS estimates. For z-scores of weight and BMI, both the OLS and within-twins estimated coefficients of birth weight are similar and significantly positive. In addition, in the case of the probability of being underweight, despite the OLS estimates are significantly positive, within-twin-pair estimates are insignificant. For the probability of being obese, the OLS estimated coefficients of birth weight and log birth weight are insignificant while within-twin-pair estimated coefficients of birth weight and log birth weight are positive and marginally significant at the 10% level.[29] Furthermore, OLS results suggest that birth weight has a significant negative impact on the frequency of hospital visits; however, the within-twins results indicate no significant effect because all within-twins estimates are smaller and insignificant. This finding is similar to that of Almond et al. (2005): pooled OLS estimation overstresses the low birth weight effect on short-term health conditions and hospital costs.

Third, as far as we are aware, the current study is the first twin study to examine the birth weight effect on the characters of children. In the case of bad character index, OLS results suggest that a child born with lower birth weight behaves worse than does a child born with higher birth weight. However, no significant birth weight impact on the good and bad character indices within-twins results can be found. In addition, interestingly, both the OLS and within-twin-pair results support that children born with higher birth weight do more household chores.

As a whole, according to the within-twins results, there is no evidence to support that birth weight has a significant impact on academic performance. Moreover, birth weight is noticeably beneficial for the development of physical growth in childhood, reflected in z-score of height, weight, and BMI. On the average, a child born with

[29] For the underweight dummy, the results in logit and FE logit regressions are qualitatively close to the results in the OLS and within-twins regressions. For the obese dummy, both logit and FElogit estimates of birth weight measures are insignificant.

higher birth weight tends to grow faster, and be taller and heavier in comparison to a child with lower birth weight. Interestingly, OLS and within-twins estimates are quite close in these growth measures. In addition, children born with higher birth weight perform more household chores. Furthermore, the OLS regression overstates the birth weight effect on school performance, other measures of health conditions, and personality trait in the medium term.

One point should be reminded that the above findings are subject to measurement error bias. Let $BW_{ij} = BW_{ij}^{*} + e_{ij}$. BW_{ij}^{*} is the true birth weight. e_{ij} is the measurement error. Suppose the classical errors-in-variables (CEV) assumption is satisfied, that is, the measurement error is uncorrelated with BW_{ij}^{*}. The OLS estimate of birth weight will be closer to 0. This is called the attenuation bias. Within-twins estimation can remove the unobserved factors through differencing within twins, however, this method tends to exacerbate the measurement error bias.[30] In our child twin sample, the birth weight records of child twins were reported by their parents. As the records provided by twins' parents are quite reliable, the measurement error bias seems not to be a big problem. Furthermore, Currie (2009) mentions that the measurement error tends to be random in birth certificate data while the measurement error in maternal reports tends to be nonrandom and thus the estimates from regressions controlling for mother fixed effects will be larger since the bias from mother-specific measurement error is removed. In this case, if twins' parents overstate or understate the birth weight of each twin by the same amount systematically, then $e_{i1} = e_{i2}$. For the within-twins estimation, we have

$y_{i1} - y_{i2} = \beta\left(BW_{i1}^{*} - BW_{i2}^{*}\right) + \varphi'(Z_{i1} - Z_{i2}) + \varepsilon_{i1} - \varepsilon_{i2} - \beta\left(e_{i1} - e_{i2}\right)$. Under this situation, the measurement error may be eliminated in the estimation.

[30] See Griliches (1979) and Bound and Solon (1999).

2.5.2. Results of Spline and Threshold Regressions on Medium-Term Outcomes

This section reports on the results of spline and threshold regressions of birth weight's impact on outcomes in the medium term. Table 2.4 shows the results of spline regressions with a knot point at 2,500 grams. According to the F-test results of the OLS regressions, birth weight has a non-linear impact on WAZ, BAZ, and the probability of being underweight and obese. However, within-twin-pair estimates of birth weight are not significantly different across two segments.

To examine the validity of the benchmark point at 2,500 grams and to have a more reliable test on non-linearity, the threshold approach proposed by Hansen (1999) is applied on twin data. Table 2.5 reports the results of the likelihood ratio test for the existence of the threshold effect. According to the bootstrapped p-value, there is no evidence to support the non-linearity effect of birth weight since all corresponding p-values are greater than 0.10 in the single threshold model.

In brief, to our knowledge, this is the first study to apply threshold estimation on twin data. Overall, there is no evidence to support that the effect of birth weight is non-linear on medium-term outcomes. Thus, the within-twins results in Section 2.5.1 do not overestimate the impact of birth weight, and can be generalized to the whole population.

2.5.3. Analysis of the "Interactive Effect" Mechanism

As previously noted, the rationale of using twin data for within-twins regression is to remove unobservable omitted factors, which are presumed to be identical between twins. However, do parents really treat twins identically? In particular, would the birth weight effect operate through the interaction with post-birth parental inputs? Do parents reinforce a twin born with higher birth weight or compensate on a twin born with lower birth weight? "Interactive effect" mechanism is tested and the results are reported below. A comparison and interpretation of OLS and FE results of prior studies regarding the birth weight effect on health conditions and academic score over childhood and adolescent period is also presented.

First, according to the OLS results shown in Columns (1) to (3) of Table 2.6, birth weight estimates are insignificant on parental coaching and teaching measures. Nevertheless, OLS estimates of birth weight and log birth weight are significantly negative, while the estimate of the LBW dummy is significantly positive for children's school expenses and total expenses. This means that parents spend more money on children born with lower birth weight across households. However, according to within-twins results shown in Columns (4) to (6), all estimated birth weight coefficients are insignificant in the case of parental coaching measures, tutoring measures, and parent's monetary expenses, except for the punishment and concern indices. This means that parents do not provide more contact, devote more teaching effort, or spend more money on a twin born with higher or lower birth weight inside households. But, parents are less likely to punish a twin born with low birth weight, even if the child does not obey a parental order and parents are also less likely to be concerned with this child even if the child's performance is disappointing inside the family.

As a whole, the above findings support that parents treat twins born with different birth weight similarly inside households. Hence, no evidence supports that within-twins estimate contain the interactive effect. In contrast, the pooled OLS results indicate that parents spend more money (school expenses and total expenses) on children with lower birth weight across families. The findings may support the argument of Behrman and Rosenzweig (2004) that birth weight and post-birth parental inputs are negatively related across households.[31] The following segments compare and discuss the OLS and FE (within-twin-pair or sibling FE) results in relevant studies, including Johnson and Schoeni (2007), Currie et al. (2008), and Oreopoulos et al. (2008), on health conditions and academic score in the medium term.

[31] As noted earlier, Behrman and Rosenzweig (2004) propose two possibilities. Another possibility is that there is a negative correlation between birth weight and unobserved ability.

Table 2.7 displays the empirical results of Johnson and Schoeni (2007) and Oreopoulos et al. (2008) on health measures.[32] Their findings display a consistent pattern that OLS regressions tend to overstate the effect of birth weight on medium-term health conditions.

Table 2.8 displays OLS and FE findings of birth weight effect on academic scores in two prior studies.[33] In Oreopoulos et al. (2008), as a whole, there are consistent results from twin and sibling samples that support OLS estimates being upwardly biased relative to within-twins or sibling FE estimates on language art scores. This suggests that omitted factor and birth weight are positively related. However, on language art score in Currie et al. (2008), the OLS estimate of lowest birth weight dummy is smaller (less negative) than within-twins estimate,[34] which implies the omitted factor and birth weight is negatively related over this range.

As illustrated earlier, the OLS estimate is likely to reflect own, proxy, and interactive effects jointly. If the interactive effect is negative (due to compensating parental behavior), it is possible to find that OLS estimate is smaller.[35] In developed countries with better public welfare, parents may be more likely to compensate on weaker children. Further study on this issue is worthwhile and interesting.

2.5.4. Results of Birth Weight Estimates Controlling Later Health Conditions

The within-twins results for birth weight estimates when adding sickness dummies in regressions are shown in Table 2.9. Panel (a) displays within-twin-pair estimates of log birth weight and LBW dummy in which sickness dummies are not added. Panel (b) displays within-twin-pair estimates of log birth weight and LBW dummy when "early

[32] In the present study, OLS results also overstate the birth weight effect on the probability of being underweight and frequency to hospital.

[33] Johnson and Schoeni (2007) do not display the OLS results on cognitive measures; thus, no comparison can be made.

[34] Currie et al. (2008) suggest the results on the effect of birth weight less than 1,000 grams are hard to justify as there are few surviving children in this category

[35] Recall, $\beta_{OLS} = \beta + \delta_1' \frac{\text{cov}(BW_{ij}, f_i)}{\text{var}(BW_{ij})} + \delta_2' \frac{\text{cov}(BW_{ij}, p_{ij})}{\text{var}(BW_{ij})}$ (2 1.2)

sickness dummy" and "later sickness dummy" are added in the regressions sequentially.[36] Overall, there is no evidence to support that adding an early health measure affects the significance and magnitude of within-twins estimates of birth weight on medium-term outcomes using our sample.

2.6. Concluding Remarks

In the present chapter, the birth weight effect on medium-term outcomes is examined, including school performance, physical growth, health conditions, and character. This study is the first to use Chinese child twin data to study the birth weight effect. OLS results suggest that birth weight has a significant relationship with the number of "three-good student" awards, as well as several measures of physical growth, health conditions, and character. However, based on within-twins results, birth weight is found to have significantly positive influence on HAZ, WAZ, BAZ, and do household chores index, but no significant effect on school performance and other measures of health conditions and character.

Moreover, this paper is the first to apply threshold estimation on twin data to test the non-linearity effect of birth weight. There is no evidence to support that the impact of birth weight is non-linear on medium-term outcomes. Thus, the results from twin data would not overstate the birth weight impact to general population dominated by singleton births.

In addition, this study summarizes the proposed mechanisms of previous studies for the birth weight effect on future outcomes systematically in one place: own effect, proxy effect, and interactive effect. A major contribution of this study is that it is the first to test the significance of the interactive effect directly as the child twin sample contains information of parental inputs on child twins. Using the sample of this study, no evidence supports that the "interactive effect" mechanism works in within-twins estimation. The findings of this study further consolidate the belief that within-twins

[36] Recall, "early sickness dummy" equals 1 if the child suffered at least one kind of the sicknesses, including continuous diarrhea, serious lack of calcium, asthma, whooping cough, fractures, and heart disease from birth up to 5 years old. "Later sickness dummy" equals 1 if the child suffered at least one of the above illnesses after 5 years old to the date of interview

estimate identifies the own birth weight effect. Meanwhile, the OLS estimates tend to be biased upward and overstate the importance of birth weight on several medium-term performances. This suggests that positive proxy effect exists, resulting in the significance of OLS coefficients.

Furthermore, using Chinese child twin sample, this paper cannot replicate the findings of Currie et al. (2008) that the estimated impact of birth weight falls when controlling early health conditions in regression. Since information on early sickness is limited and the sample size is small in the present study relative to the data used in Currie et al. (2008), further study with more comprehensive data is desirable on this aspect.

The results for within-twins results strongly support birth weight as having a significant favorable impact on the growth of children during childhood. It would be worthwhile for the Chinese government to devote more resources on enhancing infant's weight at birth.

References for Chapter 2

Almond, D., Chay, K. Y. & Lee, D. S. (2005). The costs of low birth weight. *Quarterly Journal of Economics, 120*(3), 1031-1083.

Ayalew, T. (2005). Parental preference, heterogeneity and human capital inequality. *Economic Development and Cultural Change, 53*(2), 381-407.

Barbara, J., Power, C. & Hertzman, C. (2002). Birth weight, childhood socioeconomic environment and cognitive development in the 1958 British cohort study. *British Medical Journal, 325*(7359), 305-311.

Behrman, J. R., Pollak, R. A. & Taubman, P. (1982). Parental preferences and provision for progeny. *Journal of Political Economy, 90*(1), 52-73.

Behrman, J. R. & Rosenzweig, M. R. (2001). The returns to increasing body weight. *Penn Institute for Economic Research Working Paper,* 01-052.

Behrman, J. R. & Rosenzweig, M. R. (2004). Returns to birthweight. *Review of Economics and Statistics, 86*(2), 586-601.

Behrman, J. R., Rosenzweig, M. R. & Taubman, P. (1994). Endowments and the allocation of schooling in the family and in the marriage market: The twin experiment. *Journal of Political Economy, 102*(6), 1131-1174.

Black, S. E., Devereux, P. J. & Salvanes, K. G. (2005). From the cradle to the labor market? The effect of birth weight on adult outcomes. *NBER Working Paper,* 11796.

Black, S.E., Devereux, P. J. & Salvanes, K. G. (2007). From the cradle to the labor market? The effect of birth weight on adult outcomes. *Quarterly Journal of Economics, 122*(1), 409-439.

Bowles, S., Gintis, H. & Osborne, M. 2001. The determinants of earnings: A behavioral approach. *Journal of Economic Literature, 39*(4), 1137-1176.

Case, A., Fertig, A. & Paxson, C. (2005). The lasting impact of childhood health and circumstance. *Journal of Health Economics, 24*(2), 365-389.

Conley, D. & Bennett, N. G. (2000). Is biology destiny? Birth weight and life chances. *American Sociological Review, 65*(3), 458-467.

Conley, D. & Bennett, N. G. (2001). Birth weight and income: Interactions across generations. *Journal of Health and Social Behavior, 42*(4), 450-465.

Conley, D., Strully, K. & Bennett, N. G. (2003). A pound of flesh or just proxy? Using twin differences to estimate the effect of birth weight on life chances. *NBER Working Paper,* 9901.

Corman, H. & Chiakind, S. (1998). The effect of low birthweight on the school performance and behavior of school-aged children. *Economics of Education Review, 17*(3), 307-316.

Cunha, F. & Heckman, J. (2007). The technology of skill formation. *American Economic Review, 97*(2), 31-47.

Cunha, F. & Heckman, J. (2008). Identifying and estimating the technology of cognitive and noncognitive skill formation. *Journal of Human Resources 43*(4), 738-782.

Cunha, F. & Heckman, J. (2009). The economics and psychology of Inequality and human development. *Journal of the European Economic Association, 7*(2–3), 320-364.

Currie, J., Stablie, M., Manivong, P. & Roos, L. (2008). Child health and young adult outcomes. *NBER Working Paper,* 14482.

Currie, J. (2009). Healthy, wealthy, and wise: Socioeconomic status, poor health in childhood, and human capital development. *Journal of Economic Literature, 47*(1), 87-122.

Currie, J. & Hyson, R. (1999). Is the impact of health shocks cushioned by socioeconomic status? The case of low birth weight. *American Economic Review, 89*(2), 245-250.

Ermisch, J. & Francesconi, M. (2000). Educational choice, families, and young people's earnings. *Journal of Human Resources*, *35*(1), 143-176.

Fraga, M.F., Ballestar, E., Paz, M.F., Ropero S., Setien, F., Ballestar, M.L., Heine-Suñer, D., Cigudosa, J.C., Urioste, M., Benitez, J., Boix-Chornet, M., Sanchez-Aguilera, A., Ling, C., Carlsson, E., Poulsen, P., Vaag, A., Stephan, Z., Spector, T.D., Wu, Y., Plass, C. & Esteller, M. (2005). Epigenetic differences arise during the lifetime of monozygotic twins. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(30), 10604-10609.

Griliches, Z. (1979). Sibling models and data in economics: Beginnings of a survey. *Journal of Political Economy*, *87*(5), S37-S64.

Hansen, B. E. (1996). When a nuisance parameter is not identified under the null hypothesis. *Econometrica*, *64*(2), 413-430.

Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing and inference. *Journal of Econometrics*, *93*(2), 345-368.

Johnson, R. C. & Schoeni, R. F. (2007). The influence of early-life events on human capital, health status, and labor market outcomes over the life course. *Institute for Research on Labor and Employment Working Paper Series*.

Lee, H. & Barratt, M. S. (1993). Cognitive development of preterm low birth weight children at 5 to 8 Years Old. *Journal of Developmental and Behavioral Pediatrics*, *14*(4), 242-249.

Lin, M. J., Liu, J. T. & Chou, S. Y. (2007). As low birth weight babies grow, can well educated parents buffer this adverse factor? A research note. *Demography*, *44*(2), 335-343.

Loughran, D. S., Datar, A. & Kilburn, M. B. (2008). The response of household parental investment to child endowments. *Review of Economic Household*, *6*(3), 223-242.

Marsh, L. C. & Cormier, D. R. (2001). *Spline regression models*. Sage Publications.

McCormick, M.C. (1985). The contribution of low birth weight to infant mortality and childhood morbidity. *New England Journal of Medicine*, *312*, 82-90.

McCormick, M.C., Gortmaker, S.L. & Sobol, A.M. (1990). Very low birth weight children: Behavior problems and school difficulty in a national sample. *Journal of Pediatrics*, *117*(5), 687-693.

McGarry, K. (1999). Inter vivos transfers and intended bequests. *Journal of Public Economics*, *73*(3), 321-351.

McGarry, K. & Schoeni, R. F. (1995). Transfer behavior in the health and retirement study: Measurement and the redistribution of resources within the family. *Journal of Human Resources*, *30*(5), S184-S226.

Oreopoulos, P., Stabile, M., Walld, R. & Roos, L. (2006). Short, medium and long term consequences of poor infant health: An analysis using siblings and twins. *NBER Working Paper*, 11998.

Oreopoulos, P., Stabile, M., Walld, R. & Roos, L. (2008). Short, medium and long term consequences of poor infant health: An analysis using siblings and twins. *Journal of Human Resources*, *43*(1), 89-138.

Pitt, M. M., Rosenzweig, M. R. & Hassan, M. N. (1990). Productivity, Health, and Inequality in the Intrahousehold Distribution of Food in Low-Income Countries. *American Economic Review*, *80*(5), 1139-1156.

Richards, M., Hardy, Rebecca, Kuh, D. & Wadsworth, M. E. (2002). Birthweight, postnatal growth and cognitive function in a national UK birth cohort. *International Journal of Epidemiology*, *31*, 342-348.

Rosenzweig, M. R. & Schultz. T. P. (1982). Market opportunities, genetic endowments, and intrafamily resource distribution: Child survival in rural India. *American Economic Review*, *72*(4), 803-815.

Rosenzweig, M. R. & Wolpin, K. I. (1988). Heterogeneity, intrafamily distribution, and child health. *Journal of Human Resources*, *23*(4), 437-461.

Rosenzweig, M. R. & Zhang, J. (2009). Do population control policies induce more human capital investment? Twins, birthweight and China's 'one-child policy'. *Review of Economic Studies*, *76*(3), 1149-1174.

Royer, H. (2009). Separated at girth: US twin estimates of the effects of birth weight. *American Economic Journal: Applied Economics*, *1*(1), 49-85.

Shonkoff, J.P. (2009). Investment in early childhood development lays the foundation for a prosperous and sustainable society. In *Encyclopedia on Early Childhood Development*. Retrieved July 31, 2010, from http://www.child-encyclopedia.com/pages/PDF/ShonkoffANGxp.pdf

World Health Organization. (2004). *Low birthweight country, regional and global estimates*. Retrieved February 1, 2010, from http://whqlibdoc.who.int/publications/2004/9280638327.pdf

Table 2.1: Summary of the View of Prior Studies towards Birth Weight Representation and Omitted Factors

Prior Literature	Birth Weight to be Regarded as	Suggested Omitted Factors in OLS
Behrman and Rosenzweig (2004)	a measure of intrauterine nutrient intake	common genetic endowment, common earnings endowment
Almond et al. (2005)	a measure of the initial endowment of an infant's health human capital	mother's specific unobservable determinants of health (e.g., genetic factors)
Black et al. (2007)	a measure of infant health	unobservable factors that are mother- and birth-specific (e.g., quality of prenatal care, genetic factors)
Oreopoulos et al. (2008)	a measure of infant health	family factors
Royer (2009)	a measure of fetal nutrients intake	family upbring and genetic factors

Table 2 2 Descriptive Statistics of Child Twins and Non-Twins

Variables	Identical Twins (1)	Whole Twins (2)	Non-twins (3)
Birth Weight (kg)	2 42	2 46	3 13
	(0 46)	(0 46)	(0 46)
Age	10 76	10 78	10 99
	(2 81)	(2 80)	(2 81)
Gender	0 47	0 48	0 51
	(0 50)	(0 50)	(0 50)
Father's Age	38 09	38 46	37 31
	(4 94)	(5 26)	(4 34)
Mother's Age	36 10	36 37	35 40
	(4 38)	(4 76)	(4 00)
Mother's Age at Birth	25 34	25 60	24 40
	(3 66)	(4 08)	(3 12)
Father's Years of Schooling	9 39	9 19	9 56
	(3 43)	(3 37)	(3 32)
Mother's Years of Schooling	8 75	8 38	8 90
	(3 44)	(3 33)	(3 17)
Father's Monthly Earnings	722 14	741 02	715 50
	(558 53)	(787 05)	(675 17)
Mother's Monthly Earnings	476 42	480 20	462 03
	(466 67)	(602 27)	(488 11)
Family Monthly Earnings	1198 56	1221 23	1177 52
	(931 57)	(1269 64)	(997 88)
Exempt Region	0 61	0 64	0 67
	(0 49)	(0 48)	(0 47)
Children's Height-for-age Z-score (HAZ)	-1 19	-1 16	-0 88
	(1 44)	(1 47)	(1 54)
Children's Weight-for-age Z-score (WAZ)	-0 85	-0 82	-0 61
	(1 06)	(1 05)	(1 12)
Children's Body Mass Index-for-age Z-score (BAZ)	-0 30	-0 27	-0 23
	(1 25)	(1 24)	(1 31)
Observations	1094	1770	1288

Note Mother's age at birth refers to the mother's age at twin birth in the twin sample and the mother's age at first singleton birth in the singleton sample

Table 2 3 OLS and Within-Twins Results of Birth Weight on Medium-Term Outcomes

	OLS			Within-Twins		
	BW	ln(BW)	LBW	BW	ln(BW)	LBW
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variables						
i School Performance						
Chinese Language Marks	0 606	1 555	-0 729	-0 861	-1 653	0 434
	(0 781)	(1 842)	(0 691)	(1 450)	(3 517)	(0 848)
Z-Score of Chinese Language Marks	0 07	0 179	-0 085	-0 037	-0 058	0 034
	(0 064)	(0 154)	(0 058)	(0 124)	(0 304)	(0 072)
Mathematics Marks	0 976	2 787	-0 816	-0 715	-1 819	0 612
	(0 929)	(2 221)	(0 837)	(1 731)	(4 041)	(0 862)
Z-Score of Mathematics Marks	0 053	0 166	-0 065	-0 054	-0 145	0 057
	(0 067)	(0 159)	(0 060)	(0 122)	(0 283)	(0 061)
Number of "Three-Good Student" Award	0 269**	0 670***	-0 192**	0 2	0 46	-0 037
	(0 109)	(0 255)	(0 096)	(0 148)	(0 330)	(0 078)
ii Physical Growth and Health Conditions						
Height-for-age z-score (HAZ)	0 267***	0 665***	-0 096	0 248***	0 607***	-0 024
	(0 084)	(0 198)	(0 080)	(0 067)	(0 147)	(0 042)
Weight-for-age z-score (WAZ)	0 327***	0 837***	-0 259***	0 424***	1 005***	-0 143***
	(0 063)	(0 150)	(0 062)	(0 068)	(0 156)	(0 041)
BMI-for-age z-score (BAZ)	0 236***	0 599***	-0 263***	0 345***	0 817***	-0 160***
	(0 071)	(0 172)	(0 075)	(0 102)	(0 220)	(0 062)
Underweight	-0 101***	-0 254***	0 084***	-0 049	-0 147	-0 006
	(0 022)	(0 056)	(0 021)	(0 043)	(0 109)	(0 027)
Obese	-0 007	-0 007	-0 003	0 034*	0 068*	-0 017
	(0 012)	(0 027)	(0 014)	(0 019)	(0 037)	(0 012)
Frequency of Hospital Visits	-0 282***	-0 653**	0 214**	-0 146	-0 391	0 055
	(0 104)	(0 261)	(0 103)	(0 129)	(0 315)	(0 072)
iii Character						
Good Character Index (0 to 5)	-0 011	0 018	-0 036	0 073	0 14	0 006
	(0 104)	(0 242)	(0 094)	(0 056)	(0 124)	(0 035)
Bad Character Index (0 to 15)	-0 184*	-0 478*	0 193**	-0 08	-0 223	0 021
	(0 102)	(0 252)	(0 091)	(0 083)	(0 207)	(0 054)
Do Household Chores Index (0 to 8)	0 269**	0 595**	-0 164	0 423**	1 015**	-0 245**
	(0 123)	(0 295)	(0 115)	(0 196)	(0 451)	(0 116)
Twin Pairs	547	547	547	547	547	547
Observations	1094	1094	1094	1094	1094	1094

Notes
Robust standard errors are reported in parentheses
* significant at 10%, ** significant at 5%, *** significant at 1%
OLS regressions include age, gender dummy, birth order dummy, exempt region dummy, mother's age at twin birth, parents' years of schooling, and family earnings
Within-twin-pair regressions include birth order dummy

Table 2 4 Results of Spline Regressions of Birth Weight on Medium-Term Outcomes

Dependent Variables	OLS BW <2500g	OLS BW>2500g	OLS P value of F-test for equal slopes	Within-Twins BW <2500g	Within-Twins BW>2500g	Within-Twins P value of F-test for equal slopes
	(1)	(2)	(3)	(4)	(5)	(6)
Chinese Lang Marks	0 797	0 388	0 87	-1 178	-0 413	0 83
	(1 407)	(1 509)		(2 403)	(2 087)	
Z-Score of Chinese Lang Marks	0 103	0 032	0 73	-0 084	0 03	0 71
	(0 122)	(0 119)		(0 205)	(0 186)	
Maths Mark	1 602	0 263	0 65	-1 704	0 685	0 59
	(1 712)	(1 746)		(2 715)	(2 843)	
Z-Score of Maths Marks	0 112	-0 014	0 57	-0 166	0 106	0 39
	(0 126)	(0 135)		(0 189)	(0 207)	
Number of "Three-Good Student" Award	0 272	0 266	0 98	0 19	0 215	0 95
	(0 171)	(0 199)		(0 195)	(0 300)	
HAZ	0 353**	0 17	0 48	0 282***	0 2	0 65
	(0 146)	(0 161)		(0 082)	(0 141)	
WAZ	0 622***	-0 01	0 00	0 498***	0 319***	0 29
	(0 112)	(0 117)		(0 097)	(0 121)	
BAZ	0 477***	-0 039	0 02	0 432***	0 223	0 35
	(0 137)	-0 124		(0 123)	-0 183	
Underweight	-0 162***	-0 032	0 05	-0 073	-0 014	0 54
	(0 045)	(0 031)		(0 069)	(0 054)	
Obese	0 039*	-0 060**	0 01	0 014	0 062	0 43
	(0 021)	(0 024)		(0 020)	(0 049)	
Frequency of Hospital Visits	-0 302	-0 260*	0 89	-0 370*	0 172	0 11
	(0 214)	(0 145)		(0 201)	(0 227)	
Good Character Index	0 093	-0 129	0 51	0 029	0 134	0 43
	(0 183)	(0 212)		(0 074)	(0 101)	
Bad Character Index	-0 403**	0 066	0 13	-0 179	0 061	0 26
	(0 192)	(0 178)		(0 141)	(0 123)	
Do Household Chores Index	0 173	0 378	0 59	0 604*	0 166	0 42
	(0 220)	(0 234)		(0 311)	(0 359)	

Notes
Robust standard errors are reported in parentheses
* significant at 10%, ** significant at 5%, *** significant at 1%
Control variables in OLS and within-twin-pair regressions are same as those used in Section 2 5 1

Table 2 5 Test Results for Birth Weight's Threshold Effect on Medium-Term Outcomes

Dependent Variables	No of Thresholds	Estimated Threshold of BW (grams)	Test Statistics	Boostrap P-Value
		(1)	(2)	(3)
Chinese Language Marks	Single	1500	1 679	0 980
Z-Score of Chinese Language Marks	Single	2300	2 220	0 920
Mathematics Marks	Single	3100	5 562	0 416
Z-Score of Mathematics Marks	Single	3100	7 215	0 252
Number of "Three-Good Student" Award	Single	2700	5 814	0 420
Height-for-age z-score (HAZ)	Single	1700	5 798	0 384
Weight-for-age z-score (WAZ)	Single	1500	6 330	0 360
BMI-for-age z-score (BAZ)	Single	1500	3 210	0 810
Underweight	Single	1200	15 337	0 124
Obese	Single	3400	2 424	0 864
Frequency of Hospital Visits	Single	2500	2 629	0 878
Good Character Index	Single	2200	6 445	0 432
Bad Character Index	Single	2700	5 471	0 488
Do Household Chores Index	Single	1800	1 846	0 982

Table 2 6 OLS and Within-Twins Results of Birth Weight on Parental Inputs

	OLS			Within-Twins		
	BW	ln(BW)	LBW	BW	ln(BW)	LBW
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variables						
i Parental Coaching						
Parent-Child Contact Index (6 to 30)	-0 359	-0 844	0 264	-0 224	-0 577	-0 176
	(0 223)	(0 533)	(0 203)	(0 365)	(0 847)	(0 238)
Punishment Index (7 to 21)	-0 052	-0 122	0 031	0 284	0 616	-0 299**
	(0 126)	(0 291)	(0 103)	(0 194)	(0 432)	(0 132)
Ignorance index (2 to 6)	0 046	0 106	-0 054	-0 04	-0 088	0 024
	(0 051)	(0 122)	(0 044)	(0 083)	(0 193)	(0 062)
Scolding Index (4 to 20)	-0 175	-0 314	0 191	-0 127	-0 545	0 246
	(0 227)	(0 548)	(0 196)	(0 403)	(0 949)	(0 269)
Concern Index (4 to 20)	-0 198	-0 397	0 084	0 41	0 874	-0 507**
	(0 204)	(0 487)	(0 186)	(0 387)	(0 927)	(0 239)
ii Parental Tutoring on Schoolwork						
Assign Extra Homework (HW) Dummy	-0 002	-0 009	0 003	0 046	0 111	-0 022
	(0 030)	(0 072)	(0 027)	(0 041)	(0 095)	(0 027)
Check HW Dummy	0 025	0 058	-0 009	-0 029	-0 057	0 007
	(0 028)	(0 068)	(0 025)	(0 034)	(0 083)	(0 015)
Tutor Dummy	-0 035	-0 077	0 016	0 048	0 137	-0 03
	(0 031)	(0 074)	(0 028)	(0 049)	(0 113)	(0 028)
iii Parent's Monetary Expenses						
Clothing Expenses	15 16	34 795	0 367	1 089	2 704	-2 656
	(11 591)	(27 770)	(10 602)	(3 511)	(7 195)	(3 372)
School Expenses	-96 462*	-249 125*	111 528**	17 152	61 031	12 292
	(58 104)	(144 625)	(49 340)	(47 822)	(125 421)	(30 175)
Total Expenses	-163 202**	-412 871*	167 190**	67 967	210 168	4 257
	(82 629)	(211 010)	(65 616)	(86 060)	(243 837)	(30 995)
Twin Pairs	547	547	547	547	547	547
Observations	1094	1094	1094	1094	1094	1094

Notes
Robust standard errors are reported in parentheses
* significant at 10% ** significant at 5%, *** significant at 1%
OLS regressions include age, gender dummy, birth order dummy, exempt region dummy, mother's age at twin birth parent' years of schooling, and parent's earnings
Within-twin-pair regressions include birth order dummy

Table 2.7: Comparison of the Prior Findings on Medium-Term Health Conditions

Johnson and Schoeni (2007)						
Control Variables:	dummies for gender, race and birth order of the child, child age, mother's age at birth, whether born to two-parent family dummy, birth year cohort dummies (5-yr intervals), and a spline income above above $10000 per year					
Observations:	2,226 individuals from the U.S.					
Outcome:	General Health Status in Childhood (100 point scale, 100=perfect health)					
	OLS	Sibling FE	Bias			
LBWdummy	-2.3731***	-1.5580***	downward			
	(0.688)	(0.581)				
Relationship between BW and omitted factor:	positive					
Oreopoulos et al. (2008)						
Control Variables:	a dummy for mother's marital status, a dummy for gender of the child, and family sibling size dummies for the birth order of the child within each family size					
Observations:	1,354 twins			40,203 siblings		
Outocme:	Physician Visits Between Ages 12 and 17					
	OLS	Within-Twins	Bias	OLS	Sibling FE	Bias
BW ≤ 1000 grams	2.6851	4.9343	-	-0.8204	2.2148	-
	(4.823)	(10.665)		(3.137)	(3.250)	
1000 < BW ≤ 1500 grams	9.3137***	7.3252**	upward	-0.5904	-1.6869	-
	(2.141)	(2.964)		(1.334)	(1.481)	
1500 < BW ≤ 2500 grams	3.3341**	0.1926	upward	-0.1540	0.5461	-
	(1.522)	(1.886)		(0.366)	(0.443)	
2500 < BW ≤ 3000 grams	3.5727**	0.1849	upward	0.347*	0.2464	upward
	(1.528)	(1.769)		(0.194)	(0.254)	
3000 < BW ≤ 3500 grams	2.9624*	1.9898	upward	0.3026**	0.3215*	-
	(1.608)	(1.656)		(0.138)	(0.170)	
Relationship between BW and omitted factor:	positive					

Note: * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2.8: Comparison of the Prior Findings on Academic Scores

Oreopoulos et al. (2008)						
Control Variables:	a dummy for mother's marital status, a dummy for gender of child, and family sibling size dummies for the birth order of the child within each family size					
Observations:	1,354 twins from Canada			40,203 siblings from Canada		
Outcome:	Language Arts Scores in Grade 12 (Z-Score)					
	OLS	Within-Twins	Bias	OLS	Sibling FE	Bias
BW ≤ 1000 grams	-0.5415	0.01819	-	-0.2576	-0.0491	-
	(0.408)	(0.762)		(0.231)	(0.232)	
1000 < BW ≤ 1500 grams	-0.4608**	-0.185	downward	-0.2302**	-0.0812	downward
	(0.181)	(0.212)		(0.098)	(0.106)	
1500 < BW ≤ 2500 grams	-0.1826	-0.0987	-	-0.2188***	-0.0492	downward
	(0.129)	(0.135)		(0.027)	(0.032)	
2500 < BW ≤ 3000 grams	-0.2063	-0.2139*	-	-0.1303***	-0.0477**	downward
	(0.129)	(0.126)		(0.014)	(0.018)	
3000 < BW ≤ 3500 grams	-0.0969	-0.0672	-	-0.0459***	-0.0154	downward
	(0.136)	(0.118)		(0.010)	(0.012)	
Relationship between BW and omitted factor:	positive					
Currie et al. (2008)						
Control Variables:	mother's age at birth, a dummy for mother's marital status, dummies for gender, birth order, and year of birth indicators of the child					
Observations:	50,404 individuals from Canada					
Other Control Variables:	number of major conditions 0-3, ADHD/conduct 0-3, asthma 0-3, major Injury 0-3, and number of cogenital/perinatal 0-3					
Outcome:	Language Arts Scores in Grade 12 (Z-score)					
Other Control Variables :	No			Yes		
	OLS	Sibling FE	Bias	OLS	Sibling FE	Bias
BW ≤ 1000	*-0.334***	*-0.395***	*upward*	*-0.250**	*-0.348***	*upward*
	(0.148)	*(0.166)*		*(0.149)*	*(0.167)*	
1000< BW ≤ 1500	-0.171**	-0.068	downward	-0.101	-0.035	-
	(0.069)	(0.080)		(0.070)	(0.081)	
1500< BW ≤ 2500	-0.118***	-0.039	downward	-0.092***	-0.025	downward
	(0.020)	(0.025)		(0.020)	(0.025)	
2500< BW ≤ 3500	-0.054***	-0.022**	downward	-0.053***	-0.021**	downward
	(0.008)	(0.010)		(0.008)	(0.010)	
Relationship between BW and omitted factor:	Except for the lowest BW group, the relationship is positive.					

Note: * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2.9 Summary of Within-Twins Estimates of Birth Weight on Medium-Term Outcomes - Controlling After-Birth Sickness

Dependent Variables	Chinese Language Mark				Z-Score - Chin Lang Mark				Mathematics Mark				Z-Score - Math Mark				Number of "Three-Good Student" Awards			
a ln(BW)	-1.653				-0.058				-1.819				-0.145				0.46			
	(3.517)				(0.304)				(4.041)				(0.283)				(0.330)			
LBW Dummy		0.434				0.034				0.612				0.057				-0.037		
		(0.848)				(0.072)				(0.862)				(0.061)				(0.078)		
b ln(BW)	-1.663		-1.623		-0.058		-0.055		-1.826		-1.836		-0.145		-0.146		0.464		0.459	
	(3.523)		(3.524)		(0.304)		(0.304)		(4.035)		(4.040)		(0.283)		(0.283)		(0.330)		(0.331)	
LBW Dummy		0.437		0.397		0.034		0.031		0.614		0.628		0.057		0.058		-0.038		-0.033
		(0.850)		(0.855)		(0.073)		(0.073)		(0.863)		(0.868)		(0.061)		(0.061)		(0.078)		(0.079)
Early Sickness Dummy Aged 0 to 5	-0.23	-0.227	-0.15	-0.147	0	-0.001	0.006	0.005	-0.151	-0.157	-0.172	-0.183	-0.004	-0.005	-0.007	-0.008	0.08	0.073	0.07	0.063
	(1.304)	(1.311)	(1.309)	(1.316)	(0.114)	(0.115)	(0.114)	(0.115)	(2.057)	(2.047)	(2.057)	(2.047)	(0.137)	(0.136)	(0.136)	(0.135)	(0.178)	(0.181)	(0.179)	(0.183)
Later Sickness Dummy Aged 6 or Above			1.644	1.592			0.122	0.117			-0.433	-0.527			-0.055	-0.064			-0.199	-0.2
			(1.631)	(1.657)			(0.132)	(0.134)			(2.417)	(2.433)			(0.148)	(0.149)			(0.292)	(0.292)

Dependent Variables	HAZ				WAZ				BAZ				Underweight				Obese			
a ln(BW)	0.607***				1.005***				0.817***				-0.147				0.068*			
	(0.147)				(0.156)				(0.220)				(0.109)				(0.037)			
LBW Dummy		-0.024				-0.143***				-0.160***				-0.006				-0.017		
		(0.042)				(0.041)				(0.062)				(0.027)				(0.012)		
b ln(BW)	0.613***		0.611***		1.007***		1.003***		0.817***		0.814***		-0.149		-0.148		0.066*		0.065*	
	(0.148)		(0.148)		(0.156)		(0.156)		(0.221)		(0.221)		(0.109)		(0.109)		(0.035)		(0.035)	
LBW Dummy		-0.025		-0.023		-0.144***		-0.140***		-0.160***		-0.158**		-0.005		-0.007		-0.017		-0.017
		(0.042)		(0.042)		(0.041)		(0.041)		(0.062)		(0.062)		(0.027)		(0.028)		(0.012)		(0.012)
Early Sickness Dummy Aged 0 to 5	0.14	0.129	0.137	0.126	0.041	0.03	0.034	0.024	0.013	0.007	0.007	0.002	-0.044	-0.04	-0.041	-0.037	-0.049	-0.049	-0.049	-0.049
	(0.099)	(0.102)	(0.100)	(0.103)	(0.082)	(0.088)	(0.083)	(0.089)	(0.115)	(0.115)	(0.115)	(0.116)	(0.048)	(0.048)	(0.048)	(0.049)	(0.047)	(0.049)	(0.047)	(0.049)
Later Sickness Dummy Aged 6 or Above			-0.073	-0.078			-0.134*	-0.122*			-0.123	-0.105			0.057	0.061			-0.002	0
			(0.080)	(0.076)			(0.074)	(0.072)			(0.085)	(0.091)			(0.066)	(0.068)			(0.005)	(0.007)

Dependent Variables	Frequency of Hospital Visits				Good Character Index				Bad Character Index				Do Household Chores Index			
a ln(BW)	-0.391				0.14				-0.223				1.015**			
	(0.315)				(0.124)				(0.207)				(0.451)			
LBW Dummy		0.055				0.006				0.021				-0.245**		
		(0.072)				(0.035)				(0.054)				(0.116)		
b ln(BW)	-0.38		-0.352		0.14		0.138		-0.227		-0.22		1.003**		1.001**	
	(0.316)		(0.308)		(0.124)		(0.124)		(0.207)		(0.207)		(0.452)		(0.453)	
LBW Dummy		0.052		0.023		0.007		0.008		0.022		0.016		-0.242**		-0.241**
		(0.072)		(0.078)		(0.035)		(0.035)		(0.054)		(0.054)		(0.116)		(0.117)
Early Sickness Dummy Aged 0 to 5	0.268*	0.272*	0.323*	0.329*	-0.008	-0.011	-0.011	-0.015	-0.096	-0.093	-0.084	-0.081	-0.291	-0.294	-0.294	-0.296
	(0.159)	(0.158)	(0.169)	(0.168)	(0.120)	(0.121)	(0.120)	(0.121)	(0.069)	(0.068)	(0.072)	(0.072)	(0.211)	(0.210)	(0.210)	(0.209)
Later Sickness Dummy Aged 6 or Above			1.138	1.139			-0.06	-0.064			0.254	0.254			-0.066	-0.035
			(0.879)	(0.884)			(0.065)	(0.064)			(0.239)	(0.240)			(0.380)	(0.380)

Notes
Robust standard errors are reported in parentheses
* significant at 10%, ** significant at 5%, *** significant at 1%
Other control variables are same as those used in Section 2.5.1

Fig. 2.1: Distribution of Birth Weight in Child Twin Data Set - Singletons and Identical Twins

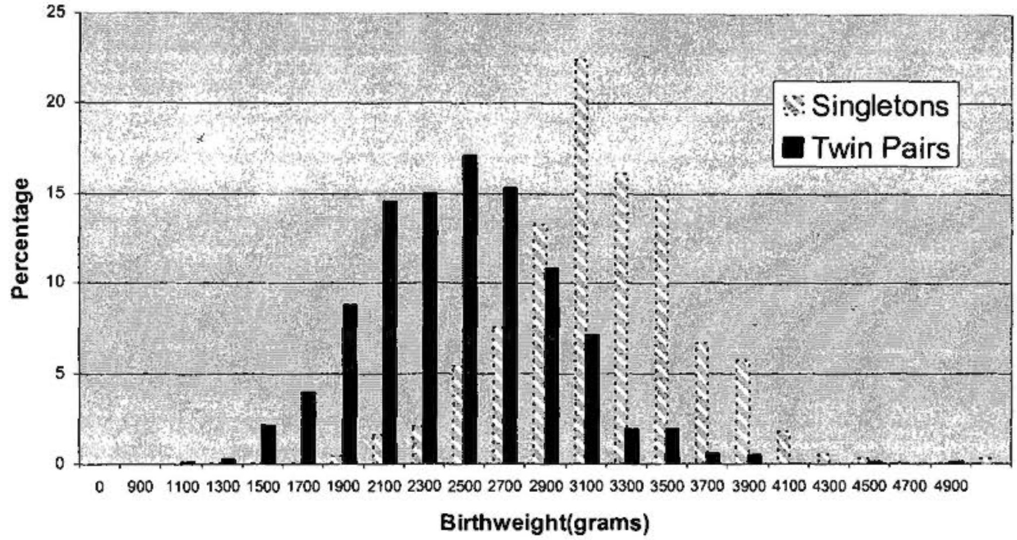
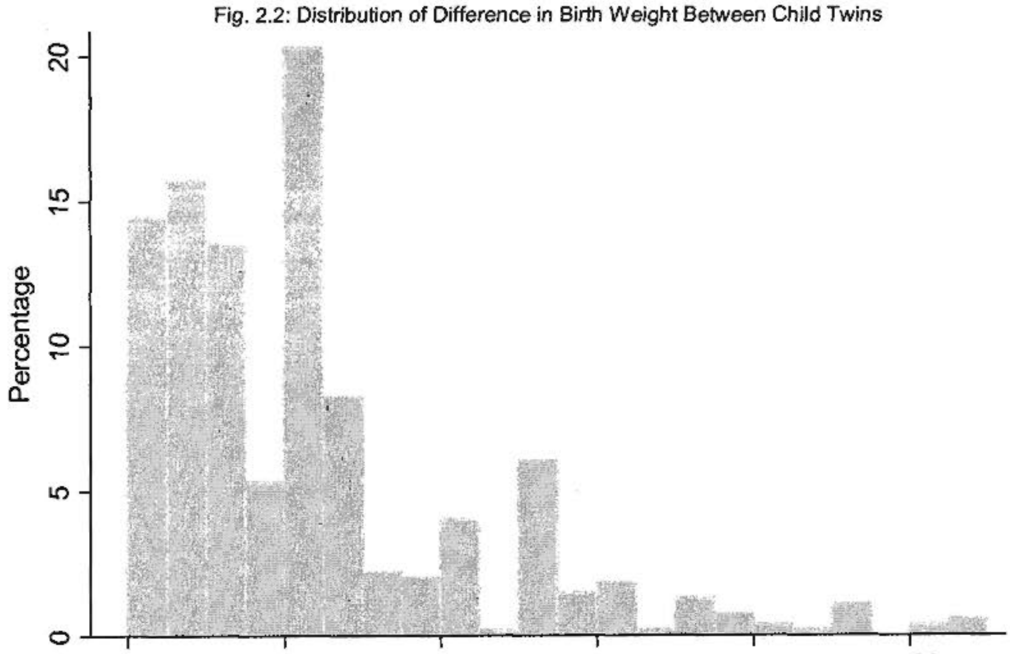
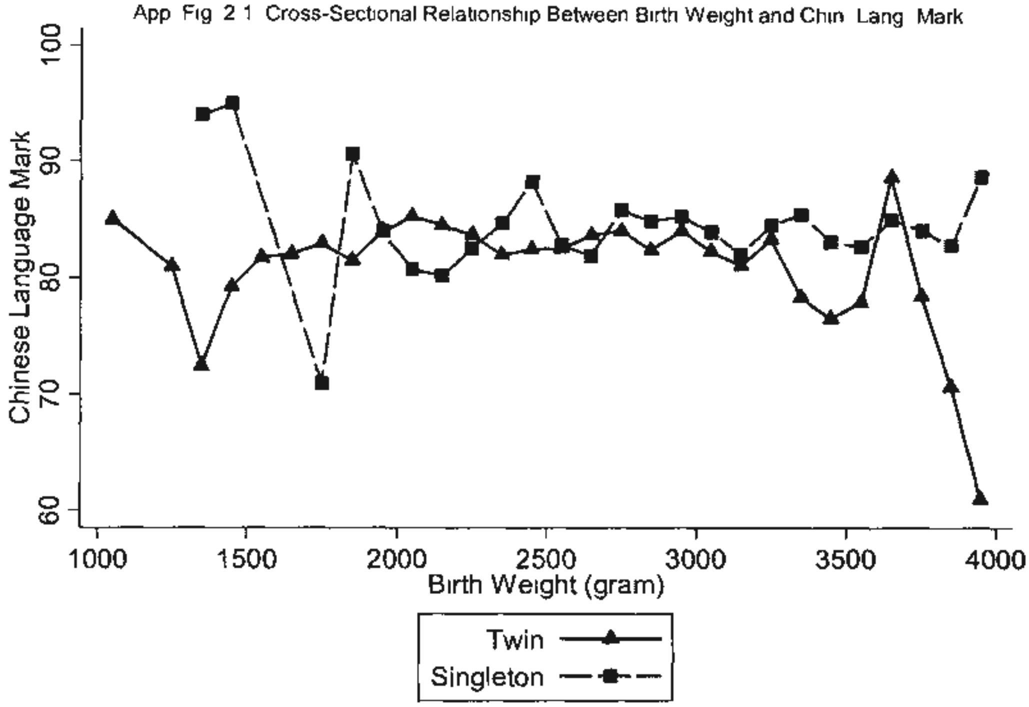


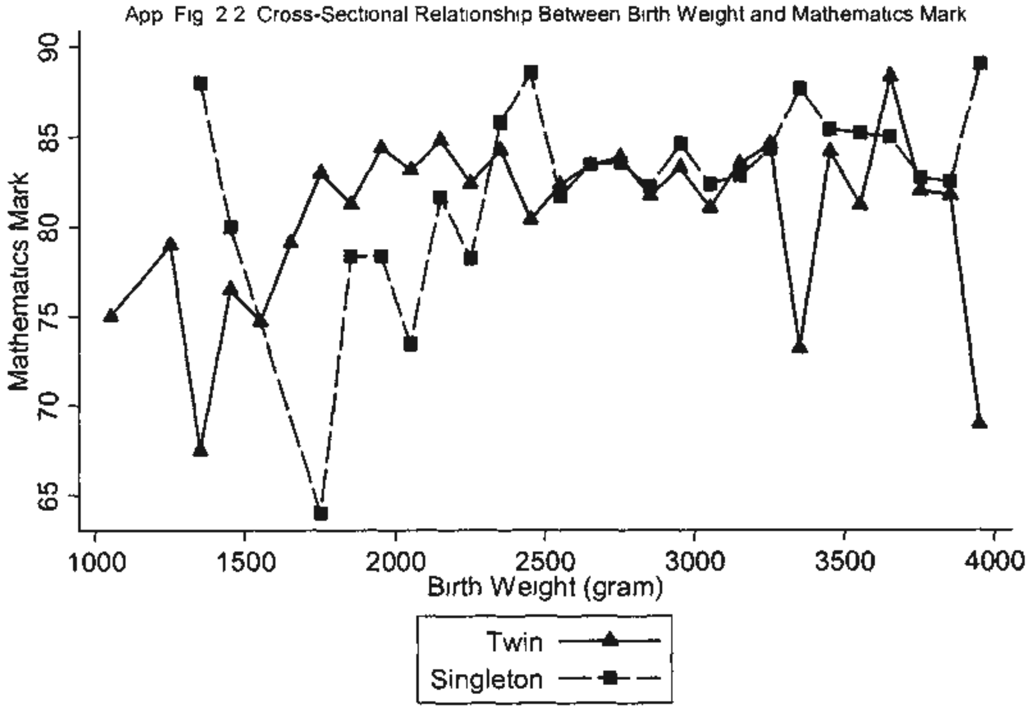
Fig. 2.2: Distribution of Difference in Birth Weight Between Child Twins



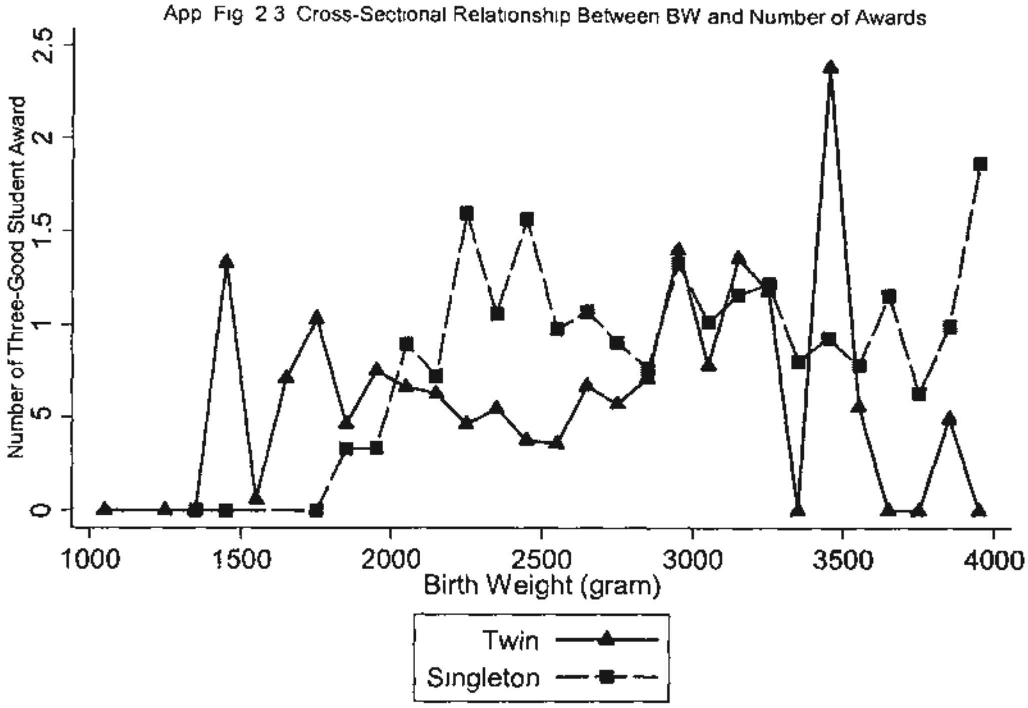
App Fig 2 1 Cross-Sectional Relationship Between Birth Weight and Chin Lang Mark



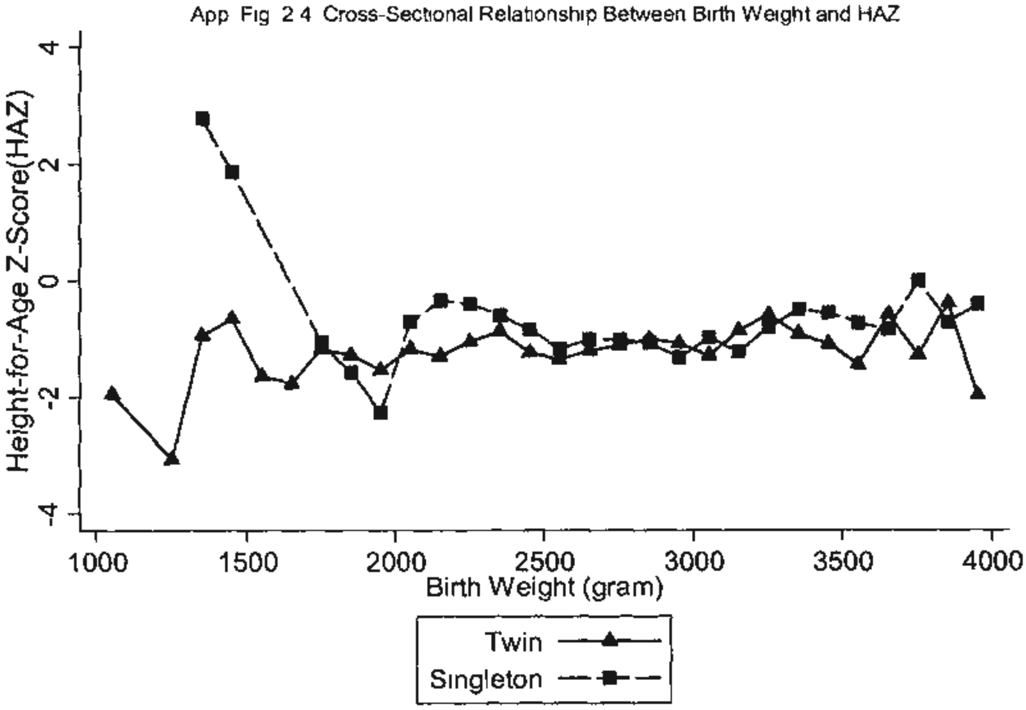
App Fig 2 2 Cross-Sectional Relationship Between Birth Weight and Mathematics Mark



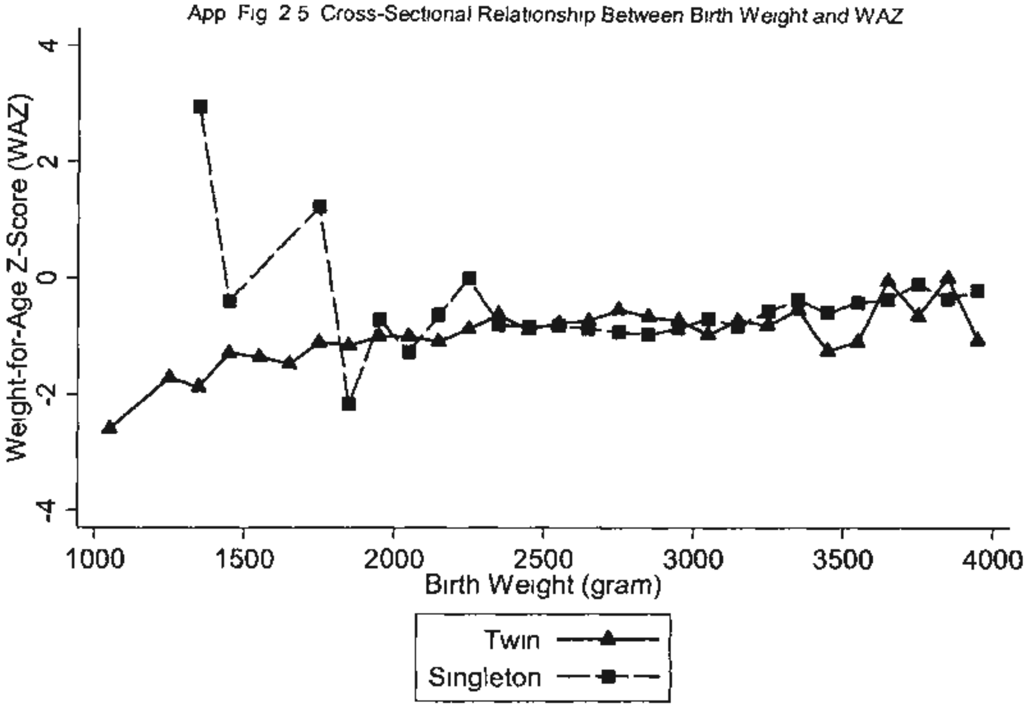
App Fig 2 3 Cross-Sectional Relationship Between BW and Number of Awards



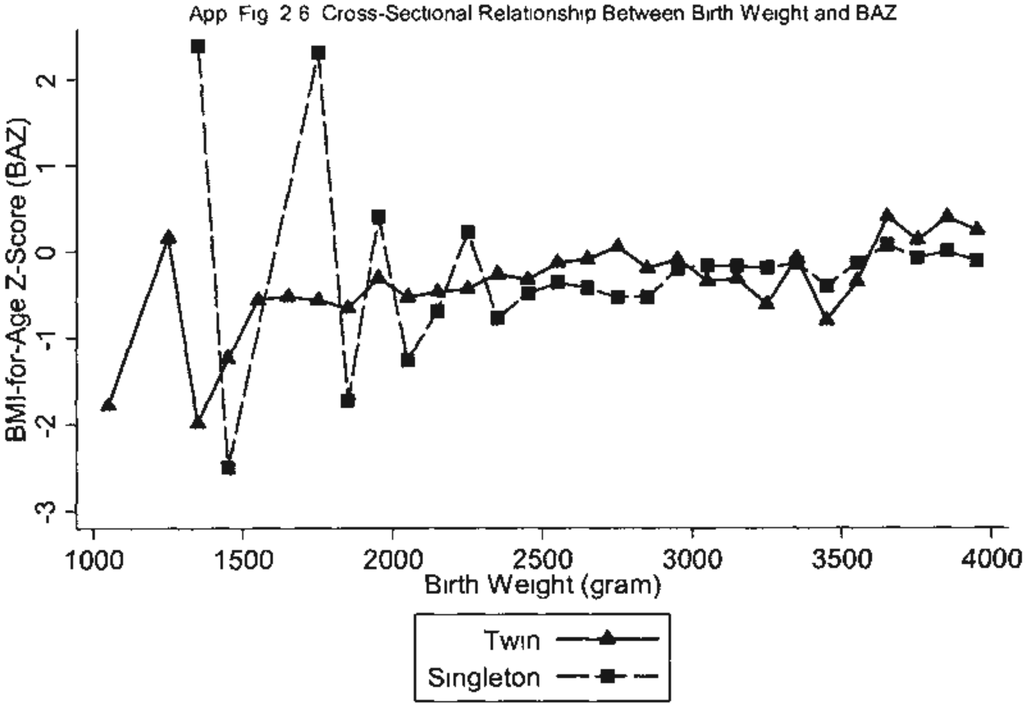
App Fig 2 4 Cross-Sectional Relationship Between Birth Weight and HAZ



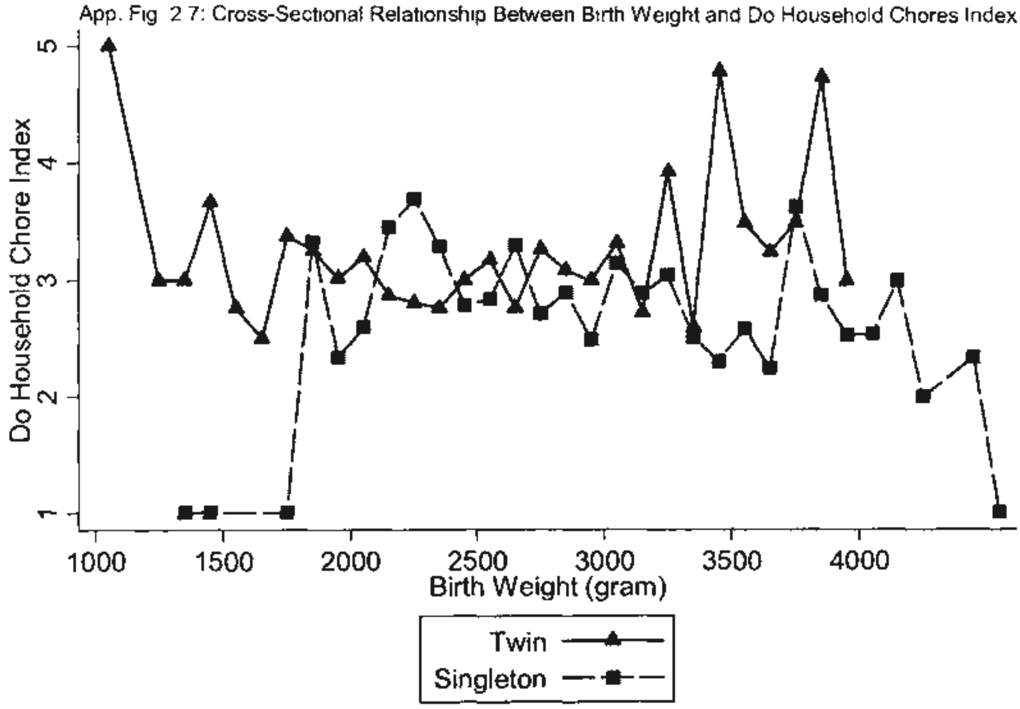
App Fig 2 5 Cross-Sectional Relationship Between Birth Weight and WAZ



App Fig 2 6 Cross-Sectional Relationship Between Birth Weight and BAZ



App. Fig 2 7: Cross-Sectional Relationship Between Birth Weight and Do Household Chores Index



Chapter 3

Impact of Birth Weight on Long-Term Outcomes: Evidence from Chinese Adult Twins

3.1. Introduction

3.1.1. Motivations and Objectives

In Chapter 2, the Chinese child twin data set was used to examine the influence of birth weight on medium-term outcomes. The within-twins results of the preceding chapter indicate that birth weight has a significant favorable effect on individual growth during childhood, but no significant impact on school outcomes and personalities. In particular, the preceding chapter is the first to test directly whether the effect operates through interaction of birth weight with post-birth parental inputs. The said findings indicate that within-twins estimate does not contain the interactive effect. While Chapter 2 examines birth weight effect on medium-term outcomes, this chapter attempts to use a Chinese adult twin data set to examine the effect on long-term outcomes. Our specific objectives of this chapter are presented below.

First, the Chinese adult twin data are used to investigate birth weight effect on long-term performances, including educational attainment, earnings, adult height, body mass, health conditions, and birth weight of the next generation.[37] To our best knowledge, all previous twins-based studies have focused on the impact of birth weight on long-term achievements using data from developed countries such as the US and Canada. The current study uses data from an Asian developing country to examine whether the birth weight impacts on long-term outcomes are more (less) significant in a developing country wherein social welfare and health care systems are less complete as compared to.

Second, similar to the preceding chapter, the present study examines threshold levels as well as the non-linearity impact of birth weight on long-term performances. Black

[37] In the case of intergenerational transmission of birth weight, within-twins results in Black et al. (2007) and Royer (2009) suggest that the mother born heavier gives birth to a child with higher birth weight

et al. (2007) and Royer (2009) use spline regression to test the non-linearity issue; however, the evidence obtained in these studies is mixed. In the case of high school completion, Black et al. (2007) find that within-twins estimate is larger in the range of less than 2,500 grams. In contrast, Royer (2009) finds that within-twins estimate is larger in the range of 2,500 grams or above for years of schooling. Thus, the aim of the present study is to use Chinese adult twin data to test non-linearity with respect to long-term outcomes.

Third, the bias directions of OLS relative to within-twins estimates on specific long-term outcomes across empirical studies are compared and discussed in this study. Similar to past twins-based literature, the adult twin data used in this work do not have information on parental inputs towards twins in childhood. Thus, differentiating the proxy effect and the interactive effect would be impossible. Only the overall bias direction of OLS relative to within-twins estimates can be achieved. Thus, two effects are regarded as a joint effect (i.e., "family effect") in this paper. The upward (downward) bias of OLS relative to within-twins estimates indicates that the family effect is positive (negative). In other words, there is an overall positive (negative) correlation between birth weight and omitted factors (e.g., unobserved genes, neighborhood, parental inputs, and so on). Except for the study of Behrman and Rosenzweig (2004), prior literature seldom interprets the bias direction of OLS relative to within-twins estimates for a given outcome. By comparing their OLS and within-twins results for educational achievement and earnings, Behrman and Rosenzweig (2004) propose two interesting possibilities. One is that a child born with higher birth weight is less intelligent than a child born with lower birth weight. The other is that parents employ compensating actions on children born with lower birth weight. This has aroused our interest to sum up twins-based findings systematically, and then relate possible omitted factors and their correlation with birth weight.

3.1.2. Major Findings and Contributions

The main empirical findings are summarized as follows. First, this study is the first to use Chinese adult twin data to analyze the impact of birth weight on long-term outcomes. The OLS results of this study indicate that the effect of birth weight is significant on earnings, height, and health conditions in the long term. However, within-twin-pair results indicate that birth weight has a significant positive influence on height alone. In contrast to prior studies (e.g., Black et al., 2007), the within-twins results of this present work indicate that birth weight has no significant influence on earnings and birth weight of the next generation. Moreover, as a whole, we find little evidence to support the argument that birth weight effect is non-linear on long-term outcomes, except for educational attainment.

A major limitation of the said results on the impact of birth weight on long-term outcomes using Chinese adult twin data is that both OLS and within-twins estimates suffer from measurement error bias since birth weight records were self-reported by interviewees. As the respondents were approximately 37 years old on the average in the adult twin sample, the measurement error bias tends to be serious. If the error is not related to the true birth weight, then the bias is downward in both the OLS and within-twins (even more exacerbated). Unfortunately, this study lacks appropriate instrumental variable (IV) to tackle such problem. Future study especially using Asian developing countries' data is welcome to further explore the above findings.

In addition, the pattern of bias directions of OLS relative to within-twins estimates from twins-based studies is interpreted systematically across two main types of outcomes (i.e., health-related and ability-related).[38] We find that OLS estimates across empirical studies are consistently biased upward for long-term health measures, relative to within-twins estimates. Overall, this suggests that omitted factors and birth weight are positively related for health outcomes. However, we find that the bias directions of OLS estimates relative to within-twins estimates fluctuate across empirical studies on ability-related outcomes, including educational attainment and earnings. OLS estimates have a downward bias in some studies (e.g., Behrman and Rosenzweig, 2004; Black et al., 2007), while have an upward bias in others (e.g., Oreopoulos et al., 2008).

[38] As prior literature use data from administrative birth records, the measurement error on birth weight is not a big concern Thus, the bias direction of OLS relative to within-twins estimates on a specific outcome is mainly due to the omitted variable bias in the OLS regression.

The rest of this chapter is organized as follows. Section 3.2 reviews some recent and important literature on birth weight impact on long-term performances. Section 3.3 describes the adult twin data set presented by this current work. Section 3.4 introduces the methodology. Section 3.5 reports and analyzes the results. Section 3.6 concludes the main findings and implications.

3.2. Literature Review

To analyze the long-term impact of birth weight, recent studies adopt within-twins regressions to overcome omitted variable bias from unobservable genetic and family factors. Behrman and Rosenzweig (2004) use monozygotic (MZ) female twins drawn from the Minnesota Twins Registry (MTR) to analyze the impact of birth weight on educational attainment, body mass, height, and earnings. To obtain personal information on weight, height, earnings, and family characteristics, the authors mailed survey questionnaires to 5,862 members of MTR and received 3,682 completed questionnaires, of which 804 women were monozygotic (MZ) twins. The within-twin-pair results indicate that birth weight has significant impact on height, educational attainments, and earnings, but no significant impact on body mass and birth weight of the next generation. Interestingly, the effect of birth weight on educational achievement and earnings is underestimated substantially in the pooled OLS regressions relative to within-twins regressions. The authors propose two possible reasons. First, across households, parents compensate more on their weaker child; hence, there is a negative correlation between post-birth parental inputs and birth weight. Next, there is a negative relationship between birth weight and unobserved ability, suggesting that infants born with lower birth weight are more intelligent. These are further discussed in Sections 3.4.3 and 3.5.3.

Subsequently, Royer (2009) uses twin data (both MZ and DZ twins) from California, USA, and finds that birth weight has significant impact on educational attainment (not robust), later pregnancy complications, and birth weight of the next generation. In Royer (2009), spline FE regression results show that the birth weight effect on infant mortality and birth weight of the next generation is more significant in the range of less than 2,500 grams; however, the effect on educational attainment is more significant in the range of 2,500 grams or above. As a whole, the author concludes that birth weight effects are minimal since it is impossible to increase birth weight substantially.

Apart from the US findings, two other studies have used twin data from other countries recently. Black et al. (2007) use Norwegian twin data to study the influence of birth weight on both short-term and long-term outcomes. Their sample size is large. They find that the effects are significant but substantially smaller in within-twins relative to OLS regressions on short-term health outcomes, including one-year mortality and five-minute Apgar score. Moreover, they find significant birth weight impact on several long-term outcomes, including IQ, height, body mass, educational attainment, and earnings. Furthermore, Black et al. (2007) use spline FE regressions to examine the non-linearity of the influence of birth weight. They find that the effects are more significant for birth weight of less than 2,500 grams for short-term health outcomes. Evidence supporting the non-linearity impact on long-term outcomes is weak.

As mentioned in Chapter 2, Oreopoulos et al. (2008) use both siblings and twin data in Canada to analyze birth weight impact on several outcomes in the short, medium, and long term. Their within-twins results show that birth weight has a significant positive effect on the probability of reaching Grade 12 by age 17 and a negative significant effect on the probability to pick up social assistance after reaching 18 years of age.

Despite most prior studies showing significant birth weight effects on long-term outcomes, such studies seldom look into mechanism(s) that underlies the birth weight effect. In particular, studies (except that of Behrman and Rosenzweig, 2004) seldom discuss why OLS estimates are biased upward or downward relative to within-twins estimates for a given outcome. The present study attempts to shed further light on this aspect.

3.3. Data

The Chinese adult twin data set was drawn from the Chinese Twins Survey, which was collected by the Urban Survey Unit (USU) of the National Bureau of Statistics (NBS) in June and July 2002 in five cities of China, including Chengdu, Chongqing, Harbin, Hefei, and Wuhan. This survey was financed by the Research Grants Council of Hong Kong. Using existing twin questionnaires in the US and elsewhere as reference, as well as opinions from Professor Mark Rosenzweig and Chinese experts from the NBS, Professor Junsen Zhang designed the questionnaire to cover a wide range of socio-economic information. Adult twins aged between 18 and 65 were listed by the local Statistical Bureaus through various channels, such as through colleagues, friends, relatives, newspaper advertisements, reports from neighborhoods, neighborhood management committees, household records from the local Public Security Bureau, and so forth. With a wide range of collection channels, the resulting sample can obtain roughly the same probability of contacting all resident twins, thus the sample can be approximately representative.

Household face-to-face personal interviews were conducted; questionnaires were completed during the interviews. Several site checks were made by Professor Junsen Zhang and experts from the NBS to ensure data accuracy. After discussions with Professor Mark Rosenzweig and other experts, the data input process was carried out in July and August 2002 under the close supervision and monitoring of Professor Junsen Zhang. This data set is the first twin data set in China, and consists of rich and representative information on socio-economic aspects. For the adult twin sample, we use three criteria including gender, hair color, and appearance to distinguish whether twins are identical. If both twins responded that they had same gender, hair color, and almost the same appearance, they were regarded as identical twins. As a result, we had 914 pairs of identical twins (1,828 individuals). In addition, to allow for a comparison with the general population dominated by singletons, the survey for non-twin households was conducted at the same period as the twin survey. These non-twin households in the five cities were sought from households at which the USU have carried out regular surveys on a monthly basis. Their initial samples were chosen randomly to ensure data representativeness. To obtain complete information on birth weight, earnings, education, and other relevant variables for both twin siblings, the final sample of the current work includes 808 adult identical twin pairs (1,616 individuals).[39]

Generalizability of Twins-Based Estimation

As mentioned in the preceding chapter, the usefulness of within-twin-pair regression relies on whether the results can be extended to the general population, which is dominated by singletons. Here, the average values of key variables of twins and singletons are first reported and compared (Table 3.1). As shown in Column (1), identical twins were approximately 37 years old on the average in 2002. They weighed approximately 2,400 grams at birth. They were 164.5 centimeters tall at the time of the interview. Furthermore, they had 11 years of education, 17 years of working experience, and earned 873 RMB as monthly (including wage, bonus, and subsidies). All these attributes of identical twins were almost the same as those of all twins from the whole twin sample, as shown in Column (2).

Regarding other characteristics except birth weight, based on Columns (1) and (3), both adult twins and non-twins had similar mean values,[40] and the major difference between adult twins and singletons was mainly on birth weight. Consistent with Chapter 2, the average birth weight of identical adult twins was approximately 2,400 grams. The mean birth weight of non-twins was approximately 3,100 grams. Prior studies (e.g., Behrman and Rosenzweig, 2004; Black et al., 2007) also report such a pattern. As noted in the preceding chapter, because two babies were being carried at the same time, on average, the weight of each twin is less than that of singletons at birth.

Figure 3.1 plots the birth weight distribution of singletons and identical twins from using the adult singleton and twin samples of the present work. The illustration indicates that about 50% of twins were born less than 2,500 grams. However, the shape of the dispersion is similar over twins and singletons. To examine the external

[39] There were four twin pairs with birth weight difference greater than 2,500 grams. Moreover, 15 individuals were deaf before 18 years old. In order to obtain complete information for both twins inside a family, 28 observations were dropped from the data set. In addition, in the final sample (1,616 individual observations), there were 1,048 observations with positive earnings.

[40] As individuals in the non-twin sample were older than in the twin sample, individuals in the non-twin sample had more working experience on the average.

validity of using adult twin data in the present research further, the outcomes of adult twins and singletons were plotted for birth weight distribution (see Appendix Figures 3.1 to 3.6).[41] The patterns of relationship between each outcome and birth weight were similar across adult twins and singletons, suggesting that results from the adult twin data may be generalized to the whole population.

As displayed in Figure 3.2, the variations of birth weight between identical twin siblings were only approximately 25% of identical twin siblings having the same birth weight; 24% had 100 or less than 100 grams of difference in birth weight; approximately 17% had birth weight difference of 100–200 grams; and the remaining 34% had birth weight differences of 300 grams or above. This dispersion allows us to have the variation in the size of birth weight between twins to implement within-twins regression.[42]

3.4. Methodology

3.4.1. OLS, Within-Twin-Pair Regressions and Long-Term Outcomes

The advantage of within-twin-pair regression relative to OLS regression has already been discussed in Chapter 2. As noted earlier, the present study cannot differentiate the proxy and interactive effects. Thus, we simply use μ_{ij} to represent all unobserved factors, such as genetic factors, parental inputs, other family characteristics, and so forth. Below, the regressions are briefly illustrated and variables used in the regression are introduced in detail.

OLS Regression

The following equation uses BW to represent the measure of birth weight:

$$y_{ij} = \beta BW_{ij} + \delta' \mu_{ij} + \alpha' X_i + \varphi' Z_{ij} + \varepsilon_{ij}, \qquad (3.1.1)$$

[41] Outcomes include years of schooling, log earnings, height, body mass index (BMI), sickness index, and birth weight of the next generation (female twins only).

[42] To test the sensitivity of the results to any outliers, the observations in which the absolute difference in birth weight between twins exceeds 3 standard deviations from the mean of the absolute difference are excluded. In whole, 26 observations are dropped, resulting in 1590 observations. The results for the impact of birth weight on long-term outcomes in the reduced adult twin sample (not shown) are almost the same as those from the original sample (1,616 observations). Thus, the empirical results are not sensitive to any outliers

where i refers to a family; j refers to a specific twin sibling in a family; y_{ij} is the outcome of sibling j in family i; BW_{ij} is the birth weight measure; μ_{ij} is a set of unobservable factors, including genetic factors, parental inputs, and so forth; X_i refers to a set of other observed family factors; Z_{ij} is a set of observed individual variables that affect the outcome, such as age, gender, birth order, marital status, and so forth; and ε_{ij} is the error term, which is assumed to be independent of all other variables in the equation.

The coefficient of interest is β, which measures the own impact of birth weight, holding all other observable and unobservable factors constant. Unfortunately, the OLS estimate (β_{OLS}) is biased in general because μ_{ij} , which is correlated with birth weight, cannot be controlled in the regression.

$$\beta_{OLS} = \beta + \underbrace{\delta' \frac{\operatorname{cov}(BW_{ij}, \mu_{ij})}{\operatorname{var}(BW_{ij})}}_{family\ effect}. \tag{3.1.2}$$

Within-Twins Regression

Ideally, as identical twins have identical genes and common family background, μ_{ij} is expected to be invariant between twins ($\mu_{i1} = \mu_{i2}$).

The within-twin-pair fixed effects estimation is specified as follows:

$$y_{i1} = \beta BW_{i1} + \delta' \mu_{i1} + \alpha' X_i + \varphi' Z_{i1} + \varepsilon_{i1}, \tag{3.1.3}$$

$$y_{i2} = \beta BW_{i2} + \delta' \mu_{i2} + \alpha' X_i + \varphi' Z_{i2} + \varepsilon_{i2}. \tag{3.1.4}$$

The result of first difference of Equations (3.1.3) and (3.1.4) is

$$y_{i1} - y_{i2} = \beta\left(BW_{i1} - BW_{i2}\right) + \varphi' (Z_{i1} - Z_{i2}) + \varepsilon_{i1} - \varepsilon_{i2}. \tag{3.1.5}$$

The within-twin-pair estimate (β_{FE}) is unbiased and measures the own effect of birth weight.

The following introduces the present study's measures for long-term performances.

Educational Attainment

Four measures of educational attainment are utilized. The first measure is self-reported years of schooling, which is the sum of years spent on each educational level, as reported by interviewees. The second measure is standardized years of schooling by educational level: 3 years for education below primary school; 6 years for primary school; 9 years for junior high school; 12 years for high school; 14 years for technical school; 15 years for college; 16 years for a bachelor; 18 years for a master; and 19 years for a doctorate. The other two measures are "high school or above" dummy and "college or above" dummy.[43]

Earnings

Earnings of employees are used as measure of performance in the labor market.[44] Respondents might be self-employed, unemployed, or retired, which can result in records on zero or missing earnings. To tackle the sample selection bias in the pooled OLS estimation, Heckman two-step selection method is used. In the first step, an extra variable is added (i.e., non-labor income) into the probit estimation.[45] To tackle the selection problem in within-twin-pair estimation, Tunali's approach (1986) of double selection is utilized.[46] In the first step, a bivariate probit model is estimated for working decision of a twin pair as having four possible outcomes: both twins work, only one sibling works (either Twin 1 or Twin 2), or neither twins works. Non-labor income of each twin sibling is added in the first step of bivariate probit regression. Next, a double-selection term for each twin sibling, an analogy of the inverse mill ratio in the case of single-selection, is computed. In the second step, these two selection terms are added in the earnings regression.[47]

[43] "High school or above" dummy is a dummy variable that is equal to 1 if the individual has high school, technical school or above educational level; otherwise, it is 0. "College or above" dummy is a dummy variable that is equal to 1 if the individual has a college degree or above educational level, otherwise, it is 0

[44] Earnings include employee wage with bonus and subsidies only

[45] Non-labor income includes net operating income, rental income, interest income, parents' transfer payments, and other sources of income

[46] Bonjour et al (2004) also apply Tunali's method to tackle the selection problem in within-twin-pair regression

[47] Since the original estimated standard error is inappropriate, bootstrapped standard error is used

The yields of educational attainment with and without birth weight measure are compared in order to check whether return to schooling is affected significantly. Previous studies estimating the return to education, such as that by Ashenfelter and Krueger (1994), presume that identical twins have the same ability and common background, and thus, differencing could remove omitted variable bias. However, twins often have different birth weight. In other words, the infant health condition and nutrient intake before being born (represented by birth weight) of twins may not be the same. If in fact birth weight matters and affects both educational attainment and earnings, the results of previous twins-based studies on the return to education may still suffer from omitted variable bias because birth weight is uncontrolled for in previous studies. Miller et al. (2005) use Australian twin data to estimate return of schooling with or without adding birth weight as control variables. They conclude that the omitted variable bias in within-twins regressions when estimating the return to education is negligible as the estimated coefficient of years of schooling diminishes very slightly (i.e., less than 1 percentage point) when birth weight measure is added. Using the present Chinese adult twin sample, we follow the approach of Miller et al. to examine whether similar qualitative results can be replicated.

Health-Related Outcomes

The first measure of health-related outcome is height, as measured in centimeters. Height can serve as a long-term health indicator.[48] As mentioned in Chapter 2, body mass index (BMI) is a measure of body fat.[49] An increase in BMI does not necessary imply an improvement or a deterioration in health conditions. In general, the normal range of BMI for an adult is from 18.5 to 24.9. If BMI is less than 18.5, then the person is considered underweight; if greater than or equal to 25, then the person is said to be overweight.[50] Thus, two dummy variables to represent being underweight and overweight are used to examine the influence of birth weight on the probability of having extreme body mass.

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[48] For example, Chen and Zhou (2007) use height as a health indicator in studying the influence of Great Famine (1959–1961) occurred in China on affected cohorts. Behrman and Rosenzweig (2004) and Black et al (2007) also use height as the measure of long-term outcomes.

[49] $BMI = \left(\frac{Weight\ in\ Ki\log rams}{(Height\ in\ centimers)^2} \right) \times 10{,}000.$

[50] If BMI is greater than or equal to 30, then the person is classified as obese. However, the observations for being obese are very few in our sample. Hence, overweight and obese categories are combined as one group in the present study.

In addition, the questionnaire for the present study consists of information on whether interviewees have had the following: migraine, hay fever, skin allergy, hypertension, neurasthenia, heart problem, and functional disability on neck, back, arms, and legs. Such complaints are listed to form a sickness index ranging from 0 to 10, and are used as a measure of present health conditions; the lower the value of the sick index, the better the present health conditions.

Finally, the impact of the mother's birth weight vis-à-vis the birth weight of her first biological child is examined using the female identical twin data. If the first child is not the respondent's biological child, then the second child is used, or the third, and so forth.

3.4.2. Threshold Estimation and Test of Non-Linearity Effect of Birth Weight on Long-Term Outcomes

As noted in Chapter 2, a potential limitation on the usefulness of twin data in studying birth weight impact is non-linearity. If the influence of birth weight appears at the bottom range of the birth weight distribution alone, then the results from twin data may overstate the influence of birth weight. As in the preceding chapter, apart from spline regression,[51] threshold estimation is used to test the non-linearity influence in terms of long-term outcomes.

3.4.3. Investigation on the Bias Direction of OLS relative to Within-Twins Estimates

The preceding chapter examined whether the interactive effect is contained in OLS estimates, in within-twins estimates, or in both in terms of medium-term performances. However, similar to prior twins-based studies, the adult twin data set used in the present study does not have any information on parental inputs on twins in childhood. Thus, it is not possible to differentiate the proxy effect and interactive effect based using the said adult twin sample. In the present work, these two effects are combined as a joint effect, referred to as "family effect." The aim is to analyze

[51] Again, a knot point at 2,500 grams is used for spline regression.

whether the biases of OLS relative to within-twins estimates across empirical studies display a regular direction in terms of various long-term outcomes.[52] The type of omitted factors and their relationship with birth weight, which are likely to result in the bias direction, are discussed as well. For instance, if a child born heavier is really less intelligent, a downward bias direction of OLS estimates in twins-based studies on educational attainment is expected.

To simplify analysis on the bias direction of OLS relative to within-twins estimates and the link to omitted factors in response to different types of outcomes, the following assumptions are added. First, long-term outcomes are divided into two categories: health-related and ability-related outcomes. Second, no measurement error problem exists.[53] Third, omitted factors are divided into two main groups: unobserved endowments (health-related and ability-related) and unobserved parental inputs. In the succeeding segments, results of bias direction of OLS relative to within-twins estimates for health-related and ability-related outcomes are presented.

Health-Related Outcomes, such as height

Result (1): In the case of health-related outcomes, if omitted factors and birth weight are positively related, the OLS estimate is biased upward relative to within-twin-pair estimate.

Remark: $\beta_{OLS} = \beta + \underbrace{\delta_h' \frac{\text{cov}(BW_{ij}, \mu_{ij})}{\text{var}(BW_{ij})}}_{+ve\ family\ effect}$.

Unobserved family factors and birth weight are likely to be related positively in terms of health performances. For instance, individuals are born heavier because their parents are endowed with better health-related genes. These individuals inherit better health-related genes, and thus have better health conditions in the long run. Due to the positive family effect, the OLS estimate is biased upward.

[52] Some studies conduct robustness checks with different sample sizes, for simplicity and brevity, in general, the present work compares the results with the largest sample size.

[53] The birth weight records in prior literature come from birth certificates and thus the measurement error bias is not a big concern in their empirical results.

Ability-Related Outcomes, such as educational attainment and earnings

Result (2): In the case of ability-related outcomes, if omitted factors and birth weight are positively related, the OLS estimate is biased upward relative to within-twins estimate.

Remark: $\beta_{OLS} = \beta + \underbrace{\delta_a^{'} \frac{\text{cov}(BW_{ij}, \mu_{ij})}{\text{var}(BW_{ij})}}_{+ve\ family\ effect}.$

A possible reason is the positive correlation between unobserved ability and birth weight. For instance, smarter parents tend to have more endowed children born with higher birth weight. Children who inherit better ability can perform better in school and labor market. The OLS estimate, which contains the positive family effect, is biased upward.

Result (3): In the case of ability-related outcomes, if omitted factors and birth weight are negatively related, the OLS estimate is biased downward relative to within-twins estimate.

Remark: $\beta_{OLS} = \beta + \underbrace{\delta_a^{'} \frac{\text{cov}(BW_{ij}, \mu_{ij})}{\text{var}(BW_{ij})}}_{-ve\ family\ effect}.$

There are two possible reasons for the negative family effect. One is on the negative correlation between unobserved ability and birth weight (i.e., a heavier baby is less intelligent). The other reason is the negative correlation between parental inputs and birth weight (i.e., parents compensate on children born with lower birth weight in order for them to catch up with other children).

3.5. Results

3.5.1. Results of Birth Weight Impact on Long-Term Outcomes

In this section, the OLS and within-twins results for birth weight effect on long-term outcomes are reported.

Table 3.2 lists the regression results of four measures of educational attainment. For self-reported years of schooling, all OLS estimates of birth weight measures are insignificant; in contrast, within-twins estimates of birth weight measures are significant at the 5% level. These suggest that the OLS estimates have a downward bias. Such findings are similar to those by Behrman and Rosenzweig (2004) and Black et al. (2007) on educational attainment. The significance in within-twins estimates disappears in the case of years of schooling by educational level, "high school or above" dummy, and "college or above" dummy, even though OLS estimates remain smaller than within-twins estimates.[54] Overall, the findings of the present study for the birth weight effect on educational achievement are mixed.

Table 3.3 displays the regression results (tackling sample selection) of birth weight impact on log earnings.[55] In Columns (1) to (6), the OLS estimates of birth weight and log birth weight are significant and positive.[56] For instance, a 10% increase in birth weight increases earnings by approximately 1.7%. However, birth weight measures become insignificant in within-twin-pair estimation. Moreover, unlike the bias direction for educational attainment, OLS estimates have an upward bias on earnings,[57] suggesting positive correlation for unobserved earnings ability and birth weight. Having opposite bias directions of OLS estimates on educational attainment (biased downward) and log earnings (biased upward) are interesting. This may indicate that ability has multiple dimensions in which learning ability and earnings

[54] All logit and FElogit coefficients of birth weight measures are insignificant for "high school or above" dummy and "college or above" dummy

[55] The estimates of birth weight measures are very close with or without handling the selection problem. In particular, the estimated selection terms are insignificant in OLS and within-twin-pair estimations. This indicates that the selection problem is not serious The regression results without handling the selection problem are shown in Appendix Table 3 1.

[56] In Table 3.3 and Appendix Table 3.1, educational attainment is measured by self-reported years of schooling.

[57] The OLS estimate of the return to education is biased upward relative to the within-twin-pair estimate (0.075 relative to 0.023).

ability are different. Possibly, birth weight is related positively to earnings ability, and negatively related to learning ability. Future work is needed to clarify this point further.

Apart from analyzing birth weight effect on earnings, we are also interested in investigating whether return to education would be affected by adding birth weight in the regressions. Table 3.4 lists the returns to education estimated by OLS, within-twins, and instrumental variable (IV) within-twins regressions[58] with and without controlling for birth weight measures.[59] For the OLS estimation, once controlled for birth weight, the estimated coefficient of years of schooling diminishes. Among within-twins and IV within-twins results in the present study, no significant difference on the coefficients of years of schooling with and without controlling for birth weight is evident. Miller et al. (2005) also find similar results. The findings in the present study further confirm that the within-twins estimate of return to education is less biased compared with the OLS estimate.

Table 3.5 summarizes the regression results on health-related outcomes. Within-twins results suggest that birth weight has a significant positive influence on adult height; however, the magnitude is smaller than in OLS results. An increase in birth weight by 1000 grams leads to a 0.8-centimeter increase in height. Both OLS and within-twins results further suggest that birth weight has no effect on the probability of being underweight or overweight. This is different from within-twins results of Black et al. (2007), in which birth weight has a significant negative effect on the probability of being underweight and significant positive effect on the probability of being overweight. In addition, OLS results suggest that individuals born heavier have lower probability of suffering from several common sicknesses. However, all the estimates of birth weight measures are insignificant in within-twins regressions. Similar to the

[58] If there are measurement errors in schooling, within-twins regression intensifies the downward bias problem. To deal with this problem, an instrument suggested by Ashenfelter and Krueger (1994) is used by the present study: Let Z_j^k denote twin k's report of twin j's schooling level, $\Delta Z^* = Z_1^1 - Z_2^1$ and $\Delta Z^{**} = Z_1^2 - Z_2^2$ Years of schooling for each of the siblings reported by one twin is used Years of schooling for each of the siblings reported by the other twin is used as an instrument. The within-twins regression is as follows:

$$y_{1i} - y_{2i} = \beta(BW_{1i} - BW_{2i}) + \Delta Z_i^* \varphi + (\varepsilon_{1i} - \varepsilon_{2i}),$$

where ΔZ^{**} is used as an instrumental variable for ΔZ^*.

[59] Educational attainment is measured by self-reported years of schooling.

findings on medium-term health conditions in Chapter 2, we find that the OLS regression overestimates the impact of birth weight on the present health conditions of adults. Furthermore, for birth weight of the next generation, both OLS and within-twins estimates are insignificant.[60]

In short, OLS results suggest that there are positively significant relationships between birth weight and earnings, as well as height and health conditions, in the long term. However, within-twins results indicate that birth weight has a significantly positive effect on height alone.[61] The within-twins results on educational achievement of this present study are mixed. Interestingly, the OLS estimates tend to be biased upwards relative to within-twins estimates on earnings, height, and health conditions, but biased downward on educational attainment.

Potential Biases of Within-Twin-Pair Estimates

Fraga et al. (2005) find that the epigenetic modifications which affect the gene expressions and phenotypes were more obvious when MZ twins become older as they have different lifestyles and have spent less of their lives together. For instance, smoking habits, physical activity and diet are external factors that have long-term influence on epigenetic modifications. Thus, it is possible that some unobserved variables remain in ($\varepsilon_{i1} - \varepsilon_{i2}$) which are correlated with birth weight difference ($BW_{i1} - BW_{i2}$) and affect later outcomes. Bound & Solon (1999) have shown that within-twins estimation may still be subject to the same sort of bias that affects the OLS estimation. Thus, the major concern to carry out within-twins estimation depends on whether it is less biased than the OLS estimate.

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[60] As the sample size is small (233 observations), it is likely that the estimated coefficients are imprecise and statistically insignificant

[61] Some studies use only male or female same-sex twins for analysis (e g , Behrman and Rosenzweig, 2004). Black et al (2007) compared the estimates using all twins (consisting of both male and female same-sex twins) with estimates from using male same-sex twins and female same-sex twins separately According to their findings, most of the results from all twins are similar to those using male and female same-sex twins One may argue that the influence of birth weight may differ by gender In order to clarify the possibility, the present study replicated the analysis on male and female identical twin sub-samples The results (not shown) from the whole sample, male sub-sample, and female sub-sample are somewhat similar Thus, for estimates that are more precise, the whole sample for long-term outcomes is used, except for birth weight of the next generation In addition, several prior studies, such as those by Black et al (2005), find that birth order is important and can affect later outcomes Overall, within-twins results in the present study indicate that birth order has no significant influence on long-term outcomes This suggests that birth order is not important between twins.

Following Ashenfelter & Rouse (1998), we conduct a correlation analysis. We use the correlation of average family birth weight over each twin pair with the average family characteristics that may be correlated with ability (for example, membership of the Chinese Communist Party, job tenure, working in a foreign firm, marital status, and spousal education) to indicate the expected ability bias in a cross-sectional OLS regression. We then estimate the correlations of the within-twins differences in birth weight with the within-twins differences in these characteristics to indicate the expected remaining bias in a within-twin-pair regression. The results (shown in Appendix Table 3.2) strongly supports that within-twins estimate is likely to be less affected by omitted variables than the OLS estimation overall. The correlation between average family siblings' birth weight and average family attributes are highly significant in marital status and job tenure. But none of the within-twin-pair correlations is significant in first-difference form of these attributes. Of course, these characteristics are only an incomplete set of ability measures, but the evidence is suggestive.

Measurement Error

In the adult twin sample, as birth weight records were self-reported by interviewees who were about 37 years old on the average in the adult twin sample, the measurement error bias tends to be serious. If interviewees did not intentionally over-report or under-report the birth weight record based on their true birth weight, then the classical errors-in-variables assumption holds (that is, the recall error is not related to the true birth weight). As mentioned in the preceding chapter, the measurement error problem results in a downward bias in both OLS and within-twins regressions. In particular, within-twins regression exacerbates the measurement error bias.

To deal with this problem, a possible solution is to find an instrument that correlates strongly with birth weight and has no direct effect on the outcome of interest. The questionnaire used in the adult twin survey consists of three variables on the infancy period: birth date, birth weight, and birth order. The correlation between birth weight and birth order is too weak for birth order to be an instrumental variable of birth weight. Understandably, the above results are subject to measurement error bias; however, unfortunately, this study cannot overcome this problem. Future study using

Asian developing country's data is welcome to explore the said findings of birth weight impact in this study.

3.5.2. Results of Spline and Threshold Regressions on Long-Term Outcomes

In this section, results of spline and threshold regressions on long-term outcomes are reported.[62] Table 3.6 shows the results of spline regressions in which there is one knot point at 2,500 grams. According to the p-value of F-test in the OLS results, the null hypothesis that birth weight estimates are equal across two segments is not rejected for long-term outcomes, except for "high school or above" dummy and height. Results from within-twins regressions do not provide any evidence on non-linearity. Table 3.7 reports the likelihood ratio test results for the existence of threshold effect. Under a single threshold framework, except for three measures on educational attainment, the p-values are greater than 0.10 for other long-term outcomes, supporting the birth weight effect as being linear. The following table reports the threshold level and the estimated coefficients of birth weight across two segments on these three measures: self-reported years of schooling, years of schooling by educational level, and "high school or above" dummy.

Threshold Level and Estimates of Birth Weight on Three Measures of Educational Attainment

Dependent Variables		Coefficient	White SE	t-statistics
Years of Schooling (Self-Reported)	BW ≤ 2750 g	1.019	0.279	3.659
	BW > 2750 g	0.772	0.222	3.471
Years of Schooling by Educational Level	BW ≤ 3500 g	-0.182	0.243	-0.746
	BW > 3500 g	0.172	0.239	0.719
High School or Above Dummy	BW ≤ 3500 g	-0.037	0.042	-0.864
	BW > 3500 g	0.028	0.044	0.633

The estimated single threshold of birth weight is at 2,750 grams in the case of self-reported years of schooling. The favorable effect is slightly higher in the lower range (less than or equal to 2,750 grams) of birth weight (1.019 vs. 0.772), and both coefficients are significant. However, the results for other two measures of educational outcomes are different. First, the threshold of birth weight is at 3,500

[62] In Section 3.5.1, in the case of log earnings, the regression results are close with and without addressing the sample selection problem. For simplicity, when testing the non-linearity effect of birth weight on earnings, we use the reduced sample in which both twin siblings were employees and had positive earnings.

grams. Second, the estimates in the range of less than or equal to 3,500 grams are negative, while the estimates in the range of greater than 3,500 grams are positive. Third, all estimates across two segments are insignificant. As a whole, the threshold regression results are mixed across measures of educational attainment.

In summary, in the present study, there is little evidence to indicate that the effect of birth weight is non-linear for long-term outcomes, except for educational attainment.

3.5.3. Analysis of Bias Direction of OLS Relative to Within-Twins Estimates: Comparison with the Literature

In the next segments, the OLS and within-twins results across empirical studies are compared to examine any consistent bias direction of OLS relative to within-twins estimates for health-related and ability-related outcomes. We attempt to relate the pattern with unobservable omitted factors and Results (1 to 3) in Section 3.4.3.

Health-Related Outcomes

The study compares empirical findings with health-related outcomes. Table 3.8 shows the OLS and within-twin-pair results of prior literature and the present study on adult height. Generally, OLS estimates are larger than within-twins estimates in Behrman and Rosenzweig (2004) and Black et al. (2007). This holds true in the present study. Similarly, according to the results on birth weight of the next generation (Table 3.9), the OLS estimates are much larger than within-twins estimates reported previously in Behrman and Rosenzweig (2004), Royer (2006), and Black et al. (2007).[63] In Table 3.10, using measures for present health conditions, Oreopoulos et al. (2008) use the frequency of visiting physicians between 12 and 17 years of age, while the present study uses the sickness index. Again, both studies find that the OLS estimates are upwardly biased relative to within-twins estimates in general.

In the case of health measures, in general, OLS estimates tend to overstate the influence of birth weight. As a whole, the above-mentioned findings are consistent

[63] The present study uses a small sample of female twins for analysis. OLS estimates of birth weight and log birth weight are positive and larger than within-twins estimates, even if all estimates are insignificant.

with Result (1). Most of the spurious relationships found in OLS results are likely a result of omitted unobservable factors (i.e., the positive family effect).

Ability-Related Outcomes

OLS and within-twins findings are compared across empirical studies in terms of ability-related achievements. As listed in Table 3.11, Black et al. (2007) find that birth weight has a significant influence on IQ in OLS and within-twins regressions. The results support that birth weight has a significant favorable effect on the cognitive ability of individuals. Interestingly, by Black et al. (2007), the OLS estimate is slightly smaller than within-twins estimate on IQ (0.48 vs. 0.62). This pattern seems to match Result (3), wherein family effect is negative. This suggests that unobserved ability and birth weight are negatively related, or that parents compensate on children born with lower birth weight. In contrast, according to Oreopoulos et al. (2008), OLS estimates are much larger than within-twins estimates in terms of language art scores in Grade 12. This is consistent with Result (2), which showed a positive correlation between omitted factors and birth weight.

Empirical findings on educational achievement in literature are summarized in Table 3.12. As mentioned earlier, Behrman and Rosenzweig (2004) find that the within-twins estimate is much greater than the OLS estimate on years of schooling. In Black et al. (2007), the within-twins estimate is larger than the OLS estimate. In the present study, a downward bias of OLS is observed relative to within-twins estimates for the four measures of educational attainment shown in Table 3.2. The downward bias seems to match Result (3). In contrast, Oreopoulos et al. (2008) find that OLS estimates are greater than within-twins estimates in terms of reaching Grade 12 by age 17, which is consistent with Result (2). The findings from Royer (2006) are not robust. Interestingly, as a whole, no consistent bias direction of OLS relative to within-twins estimates is evident across the empirical studies for educational attainment.

The summary of empirical findings on earnings is shown in Table 3.13. OLS estimates are smaller than within-twins estimates in Behrman and Rosenzweig (2004) and Black et al. (2007), consistent with Result (3). On the contrary, in the present study, OLS estimates are much larger than within-twins estimates, consistent with

Result (2). Hence, once again, no regular pattern on the bias direction can be found across studies in terms of earnings.

In brief, as for health measures, the OLS estimates are biased upward relative to within-twins estimates; this direction is consistent across empirical studies. The pattern strongly supports the argument that omitted factors and birth weight are related positively in terms of health conditions. Moreover, the inconsistent bias direction across empirical studies appears on ability-related outcomes, such as educational attainment and earnings. The upward bias direction of OLS estimates in the case of ability-related outcomes suggests that unobservable factors and birth weight are positively related. However, the downward bias direction of OLS estimates supports the opposite story on a given ability-related outcome. If unobserved ability and birth weight are positively (negatively) related, a consistent upward (downward) bias in the OLS estimates for specific outcomes across empirical studies is expected. Similarly, if parents often compensate on children born with lower birth weight, obtaining inconsistent bias directions (i.e., sometimes biased upward, sometimes biased downward) on specific outcomes across empirical studies would be impossible. Thus, the inconsistent pattern suggests that there are two main types of omitted variables (i.e., endowments and post-birth parental inputs), each type having different correlation with birth weight. The resulting bias direction of OLS relative to within-twins estimates depends on which type of omitted variable bias dominates on specific ability-related outcomes in empirical studies. Unfortunately, without further information, these two kinds of omitted variable bias cannot be differentiated. Further study on this aspect should be conducted.

3.6. Concluding Remarks

This study is the first to use Chinese adult twin data, perhaps the first to use Asian twin data, to analyze the influence of birth weight on long-term outcomes. The present OLS results suggest that birth weight has positive and significant relationship with earnings, height, and health conditions in the long term. However, within-twins results indicate that birth weight has a significant positive influence on height alone. Overall, the current within-twins results are quite different from those of previous twins-based studies because extant studies often indicate that birth weight has significant impact on earnings and birth weight of the next generation.

In whole, little evidence from spline and threshold regressions support the argument that the birth weight effect is non-linear for long-term outcomes, except for educational achievement.

This study sums up and interprets the bias direction of OLS relative to within-twins estimates of empirical studies across two main types of outcomes. For health-related outcomes, overall, OLS estimates are consistently larger than within-twins estimates across empirical studies. However, for ability-related outcomes such as educational attainment and earnings, there is an inconsistent pattern across empirical studies. This suggests that two main types of omitted variable bias exist in terms of ability-related outcomes. Depending on which type of omitted variable bias dominates, OLS estimates are biased downward in some studies, while biased upward in other studies for specific outcomes. Conducting further study in order to clarify these issues, and further assisting in the understanding of underlying mechanisms of birth weight effect, would therefore be greatly desirable.

The preceding and the present chapters have contributed several ways to the literature. However, these findings are subject to two limitations. First, as noted earlier, birth weight data are subject to measurement error. This problem is particularly serious in the adult twin sample. The downward bias from measurement error may lead to insignificant birth weight estimates in the within-twins regressions. Thus, future studies using Chinese data is welcome to explore these findings further. Next, the results of birth weight impact on medium-term outcomes in the preceding chapter and long-term outcomes in this chapter come from two different Chinese twin data sets. The Chinese adult twin data in this study were collected from five cities in China in 2002, with interviewees aged 37 years old on the average, whereas the Chinese child twin data were collected from Kunming District in Yunnan Province in 2002 and 2003 with interviewees aged 7-18 years old. Thus, a generation gap between child twins and adult twins exists. Furthermore, in the past three decades, China has undergone dramatic economic development. Due to the unbalanced economic development occurring mainly in urban areas, especially along coastal regions, there are significantly large regional differences in cultural and economic conditions across provinces. Hence, the results obtained in Chapter 2 using Chinese child twin data, and the findings in this chapter using Chinese adult twin data, might not be linked together as a complete analysis of the birth weight effect on outcomes from medium to long term.

References for Chapter 3

Almond, D., Chay, K. Y. & Lee, D. S. (2005). The costs of low birth weight. *Quarterly Journal of Economics, 120*(3), 1031-1083.

Ashenfelter, O. & Krueger, A. (1994). Estimates of the economic return to schooling from a new sample of twins. *American Economic Review*, *84*(5), 1157-1174.

Ashenfelter, O. & Rouse, C. (1998). Income, schooling and ability: Evidence from a new sample of identical twins. *Quarterly Journal of Economics, 113*(1), 253-284.

Ayalew, T. (2005). Parental preference, heterogeneity and human capital inequality. *Economic Development and Cultural Change, 53*(2), 381-407.

Becker, G. S. & Tomes, N. (1976). Child endowments and the quantity and quality of children. *Journal of Political Economy, 84*(4), S143-S162.

Behrman, J. R., Pollak, R. A. & Taubman, P. (1982). Parental preferences and provision for progeny. *Journal of Political Economy, 90*(1), 52-73.

Behrman, J. R. & Rosenzweig, M. R. (1999). "Ability" biases in schooling returns and twins: A test and new estimates. *Economics of Education Review, 18*(2), 159-167.

Behrman, J. R. & Rosenzweig, M. R. (2001). The returns to increasing body weight. *Penn Institute for Economic Research Working Paper*, 01-052.

Behrman, J. R. & Rosenzweig, M. R. (2004). Returns to birthweight. *Review of Economics and Statistics, 86*(2), 586-601.

Behrman, J. R., Rosenzweig, M. R., & Taubman, P. (1994). Endowments and the allocation of schooling in the family and in the marriage market: The twin experiment. *Journal of Political Economy, 102*(6), 1131-1174.

Black, S. E., Devereux, P. J. & Salvanes, K. G. (2005). From the cradle to the labor market? The effect of birth weight on adult outcomes. *NBER Working Paper*, 11796.

Black, S. E., Devereux, P. J. & Salvanes, K. G. (2007). From the cradle to the labor market? The effect of birth weight on adult outcomes. *Quarterly Journal of Economics, 122*(1), 409-439.

Bonjour, D., Cherkas, L. F., Haskel, J. E., Hawkes, D. D. & Spector, T. D. (2003). Returns to education: Evidence from U.K. twins. *American Economic Review, 93*(5), 1799-1812.

Bound, J & Solon, G. (1999). Double trouble: On the value of twins-based estimation of the return to schooling. *Economics of Education Review, 18*(2), 162-182.

Case, A., Fertig, A. & Paxson, C. (2005). The lasting impact of childhood health and circumstance. *Journal of Health Economics, 24*(2), 365-389.

Case, A., Lubotsky, D. & Christina, P. (2002). Socioeconomic status and health in childhood: The origins of the gradient. *American Economic Review, 92*(5), 1308-1334.

Chen, Y. & Zhou, L. (2007). The long-term health and economic consequences of the 1959–1961 famine in China. *Journal of Health Economics, 26*(4), 659-681.

Conley, D. & Bennett, N. G. (2000). Is biology destiny? Birth weight and life chances. *American Sociological Review, 65*(3), 458-467.

Conley, D. & Bennett, N. G. (2001). Birth weight and income: Interactions across generations. *Journal of Health and Social Behavior, 42*(4), 450-465.

Conley, D., Strully, K. & Bennett, N. G. (2003). A pound of flesh or just proxy? Using twin differences to estimate the effect of birth weight on life chances. *NBER Working Paper*, 9901.

Corman, H. & Chiakind, S. (1998). The effect of low birthweight on the school performance and behavior of school-aged children. *Economics of Education Review, 17*(3), 307-316.

Cunha, F. & Heckman, J. (2007). The technology of skill formation. *American Economic Review, 97*(2), 31-47.

Currie, J. (2009). Healthy, wealthy, and wise: Socioeconomic status, poor health in childhood, and human capital development. *Journal of Economic Literature, 47*(1), 87-122.

Currie, J. & Hyson, R. (1999). Is the impact of health shocks cushioned by socioeconomic status? The case of low birth weight. *American Economic Review, 89*(2), 245-250.

Currie, J., Stablie, M., Manivong, P. & Roos, L. (2008). Child health and young adult outcomes. *NBER Working Paper,* 14482.

Datar, A., Kilburn, M. B. & Loughran, D. S. (2006). Health endowments and parental investments in infancy and early childhood. *RAND Labor and Population Working Paper*, WR-367.

Fraga, M.F., Ballestar, E., Paz, M.F., Ropero S., Setien, F., Ballestar, M.L., Heine-Suñer, D., Cigudosa, J.C., Urioste, M., Benitez, J., Boix-Chornet, M., Sanchez-Aguilera, A., Ling, C., Carlsson, E., Poulsen, P., Vaag, A., Stephan, Z., Spector, T.D., Wu, Y., Plass, C. & Esteller, M. (2005). Epigenetic differences arise during the lifetime of monozygotic twins. *Proceedings of the National Academy of Sciences of the United States of America, 102*(30), 10604–10609.

Green, W. (2005). *Econometric Analysis*. Upper Saddle River, N.J.: Prentice Hall.

Griliches, Z. (1979). Sibling models and data in economics: Beginnings of a survey. *Journal of Political Economy, 87*(5), S37-S64.

Gringras, P. & Chen, W. (2001). Mechanisms for differences in monozygous twins. *Early Human Development, 64*(2), 520-525.

Hansen, B. E. (1996). When a nuisance parameter is not identified under the null hypothesis. *Econometrica*, 64(2), 413-430.

Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing and inference. *Journal of Econometrics, 93*(2), 345-368.

Johnson, R. C. & Schoeni, R. F. (2007). The influence of early-life events on human capital, health status, and labor market outcomes over the life course. *Institute for Research on Labor and Employment Working Paper Series*.

Lee, H. & Barratt, M. S. (1993). Cognitive development of preterm low birth weight children at 5 to 8 Years Old. *Journal of Developmental and Behavioral Pediatrics, 14*(4), 242-249.

Li, H., Liu, P., Ma, N. & Zhang, J. (2005). Does education pay in urban China? Estimating returns to education using twins. *Chinese University of Hong Kong Working Paper.*

Lin, M. J., Liu, J. T. & Chou S. Y. (2007). As low birth weight babies grow, can well educated parents buffer this adverse factor? A research note. *Demography, 44*(2), 335-343.

Loughran, D. S., Datar, A. & Kilburn, M. B. (2004). The interactive effect of birth weight and parental investment on child test scores. *RAND Labor and Population Working Paper,* 168.

Loughran, D. S., Datar, A. & Kilburn, M. B. (2008). The response of household parental investment to child endowments. *Review of Economic Household, 6*(3), 223-242.

Marsh, L. C. & Cormier, D. R. (2001). *Spline regression models*. Sage Publications.

Miller, P., Mulvey C. & Martin N. (2005). Birth weight and schooling and earnings: Estimates from a sample of twins. *Economics Letters, 86*(3), 387-392.

Neumark, D. (1999). Biases in twin estimates of the return to schooling. *Economics of Education Review, 18*(2), 143-148.

Oreopoulos, P., Stabile, M., Walld, R. & Roos, L. (2008). Short, medium and long term consequences of poor infant health: An analysis using siblings and twins. *Journal of Human Resources, 43*(1), 89-138.

Richards, M., Hardy, Rebecca, Kuh, D. & Wadsworth, M. E. (2002). Birthweight, postnatal growth and cognitive function in a national UK birth cohort. *International Journal of Epidemiology, 31*, 342-348.

Rosenzweig, M. R. & Schultz, T. P. (1982). Market opportunities, genetic endowments and intrafamily resource distribution: Child survival in rural India. *American Economic Review, 72*(4), 803-815.

Rosenzweig, M. R., & Wolpin, K. I. (1988). Heterogeneity, intrafamily distribution and child health. *Journal of Human Resources, 23*(4), 437-461.

Rosenzweig, M. R. & Zhang, J. (2009). Do population control policies induce more human capital investment? Twins, birthweight and China's 'one-child policy'. *Review of Economic Studies, 76*(3), 1149-1174.

Royer, H. (2006). Separated at girth: Estimating the long-run and intergenerational effects of birthweight using twins. *University of Michigan Working Paper.*

Royer, H. (2009). Separated at girth: US twin estimates of the effects of birth weight. *American Economic Journal: Applied Economics, 1*(1), 49-85.

Shonkoff, J.P. (2009). Investment in early childhood development lays the foundation for a prosperous and sustainable society. In *Encyclopedia on Early Childhood Development.* Retrieved July 31, 2010, from http://www.child-encyclopedia.com/pages/PDF/ShonkoffANGxp.pdf

Tunali, I. (1986). A general structure for models of double-selection and an application to a joint migration/earnings process with remigration. *Research in Labor Economics*, *8*(Part B), 235-283.

Wooldridge, J. M. (2002). *Econometric analysis of cross section and panel data.* Cambridge, Mass.: MIT Press.

Table 3.1: Descriptive Statistics of the Adult Twin and Non-Twin Samples

Variable	Identical Twins (1)	Whole Twins (2)	Non-twins (3)
Birth Weight (kg)	2.43	2.43	3.12
	(0.60)	(0.59)	(0.54)
Height (cm)	164.46	164.83	164.15
	(7.84)	(7.94)	(7.57)
Weight (kg)	59.78	59.66	61.33
	(10.96)	(10.57)	(10.36)
BMI (kg/cm^2)	22.03	21.90	22.71
	(3.28)	(3.23)	(3.18)
Years of Schooling	11.33	11.36	11.40
	(2.88)	(2.89)	(2.90)
Earnings (monthly)	872.91	860.55	847.55
	(498.28)	(534.94)	(550.93)
Tenure	16.58	15.59	21.72
	(10.03)	(9.95)	(9.13)
Age	37.45	36.43	43.09
	(10.13)	(10.19)	(8.64)
Gender (Male)	0.55	0.57	0.44
	(0.50)	(0.50)	(0.50)
Marital Status	0.73	0.69	0.90
	(0.45)	(0.46)	(0.30)
Sample size (observations)	1616	2656	1602

Note: There are 1,048 identical twins with positive earnings, 1,738 whole twins with positive earnings, and 1,234 non-twins with positive earnings.

Table 3 2 OLS and Within-Twins Estimates of Birth Weight on Educational Attainment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Model		OLS			Within-Twins			Logit			FElogit	
Dependent Variable						Years of Schooling (Self-Reported)						
BW	-0 009			0 529***			-			-		
	(0 108)			(0 194)								
ln(BW)		-0 049			1 231**			-			-	
		(0 255)			(0 480)							
LBW Dummy			0 111			-0 375**			-			-
			(0 127)			(0 163)						
Dependent Variable						Years of Schooling (by Educational Level)						
BW	-0 021			0 086			-			-		
	(0 113)			(0 239)								
ln(BW)		-0 121			0 085			-			-	
		(0 269)			(0 545)							
LBW Dummy			0 147			-0 078			-			-
			(0 131)			(0 182)						
Dependent Variable						High School or Above Dummy						
BW	-0 023			0 012			-0 115			0 129		
	(0 020)			(0 043)			(0 097)			(0 440)		
ln(BW)		-0 068			0 007			-0 342			0 099	
		(0 048)			(0 095)			(0 237)			(1 250)	
LBW Dummy			0 036			-0 006			0 187*			-0 068
			(0 023)			(0 032)			(0 113)			(0 425)
Dependent Variable						College or Above Dummy						
BW	0 014			0 044			0 119			0 863		
	(0 016)			(0 031)			(0 118)			(0 688)		
ln(BW)		0 035			0 092			0 31			1 956	
		(0 038)			(0 071)			(0 284)			(1 678)	
LBW Dummy			0 006			-0 017			0 017			-0 369
			(0 019)			(0 026)			(0 135)			(0 530)

Notes

Robust standard errors are reported in parentheses

* significant at 10%, ** significant at 5%, *** significant at 1%

OLS and logit regressions include age, birth order dummy, gender dummy, dummies for parent's educational attainment, and city dummies

Within-twins and FElogit regressions include birth order dummy

For OLS and within-twins regressions, there are 1,616 observations

The observations are 1,616 for logit regression, but are 226 and 204 for FElogit in the case of "high school or above" dummy and "college or above" dummy respectively

Table 3.3: OLS and Within-Twins Estimates of Birth Weight on Log Earnings

Dependent Variable: Log Earnings

Model	OLS						Within-Twins					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
BW	0.063**			0.065**			-0.05			-0.061		
	(0.030)			(0.026)			(0.055)			(0.065)		
ln(BW)		0.152**			0.161**			-0.095			-0.121	
		(0.074)			(0.070)			(0.143)			(0.147)	
LBW Dummy			-0.009			-0.02			0.068			0.067
			(0.032)			(0.033)			(0.050)			(0.050)
Years of Schooling				0.075***	0.075***	0.075***				0.02	0.02	0.019
				(0.010)	(0.010)	(0.009)				(0.021)	(0.022)	(0.021)
Age	0.006	0.006	0.006	0.003	0.003	0.003						
	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)	(0.005)						
Gender	0.164***	0.165***	0.167***	0.173***	0.174***	0.177***						
	(0.041)	(0.044)	(0.038)	(0.038)	(0.037)	(0.038)						
Birth Order	0.041	0.041	0.042	0.029	0.028	0.03	0.034	0.034	0.034	0.035	0.035	0.035
	(0.032)	(0.032)	(0.033)	(0.031)	(0.030)	(0.029)	(0.027)	(0.025)	(0.023)	(0.027)	(0.026)	(0.025)
Marital Status	0.008	0.007	0.006	-0.004	-0.005	-0.006	-0.082	-0.081	-0.078	-0.077	-0.076	-0.073
	(0.051)	(0.047)	(0.044)	(0.044)	(0.043)	(0.042)	(0.064)	(0.068)	(0.067)	(0.057)	(0.056)	(0.057)
Tenure	0	0	0	0.010*	0.010*	0.010*	0.011	0.011	0.012	0.014	0.014	0.014
	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.012)	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)
Uncensored Twin pairs							429	429	429	429	429	429
Uncensored Observations	1048	1048	1048	1048	1048	1048						

Notes:
Robust standard errors are reported in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.
OLS regressions include city dummies.

Table 3 4 OLS and Within-Twins Estimates of the Return to Education - Controlling Birth Weight Measures

Dependent Variable Log Earnings

Model	OLS				Within-Twins				IV Within-Twins			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Years of Schooling (Self-Reported)	0 082***	0 075***	0 075***	0 075***	0 019	0 02	0 02	0 019	0 023	0 024	0 024	0 023
	(0 005)	(0 010)	(0 010)	(0 009)	(0 021)	(0 021)	(0 022)	(0 021)	(0 017)	(0 017)	(0 017)	(0 017)
BW		0 065**				-0 061				-0 06		
		(0 026)				(0 065)				(0 057)		
ln(BW)			0 161**				-0 121				-0 117	
			(0 070)				(0 147)				(0 143)	
LBW Dummy				-0 02				0 067				0 068
				(0 033)				(0 050)				(0 049)
Twin pairs					429	429	429	429	429	429	429	429
Observations	1048	1048	1048	1048								

Notes

Robust standard errors are reported in parentheses

* significant at 10%, ** significant at 5%, *** significant at 1%

Control variables used in OLS regressions consist of age, gender dummy, birth order dummy, marital status dummy, tenure, and city dummies

Control variables used in within-twins regressions include birth order dummy, marital status dummy, and tenure

Table 3.5: Summary of the OLS and Within-Twins Results on Long-Term Health-Related Outcomes

Model	OLS			Within-Twins			
	BW	ln(BW)	LBW	BW	ln(BW)	LBW	Twin Pairs
Dependent Variables	(1)	(2)	(3)	(4)	(5)	(6)	
Height	1.444***	3.716***	-1.701***	0.831**	2.137***	-0.515**	808
	(0.268)	(0.658)	(0.316)	(0.325)	(0.809)	(0.204)	
Underweight Dummy	0.004	0.009	-0.008	-0.024	-0.061	-0.061	808
	(0.013)	(0.031)	(0.015)	(0.025)	(0.068)	(0.068)	
Overweight Dummy	0.022	0.048	-0.024	0.032	0.079	-0.05	808
	(0.015)	(0.037)	(0.018)	(0.039)	(0.097)	(0.032)	
Sickness Index	-0.102**	-0.241**	0.05	-0.019	-0.08	0.024	808
	(0.042)	(0.106)	(0.052)	(0.102)	(0.273)	(0.086)	
Birth Weight (Next Generation)	0.069	0.157	-0.071	-0.147	-0.316	0.014	233
	(0.049)	(0.114)	(0.056)	(0.115)	(0.260)	(0.083)	

Notes:
Robust standard errors are reported in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.

For height, underweight dummy, and overweight dummy, control variables for OLS regressions include birth order dummy, age, gender dummy, dummies for parent's educational attainment, and city dummies. For within-twins regressions, birth order dummy is used as a control variable.

For sickness index, control variables for OLS regressions include birth order dummy, age, gender dummy, self-reported years of schooling, and city dummies. Control variables for within-twins regressions include birth order dummy and self-reported years of schooling.

For birth weight of the next generation, age at birth and self-reported years of schooling are added in both OLS and within-twins regressions.

Table 3.6: Results of Spline Regressions on Long-Term Outcomes

	OLS			Within-Twins		
Dependent Variables	BW <2500g	BW>2500g	P value of F-test for equal slopes	BW <2500g	BW>2500g	P value of F-test for equal slopes
	(1)	(2)	(3)	(4)	(5)	(6)
Years of Schooling (Self-Reported)	-0.107	0.074	0.58	0.700*	0.363	0.52
	(0.197)	(0.193)		(0.357)	(0.290)	
Years of Schooling by Educational Level	-0.311	0.227	0.11	-0.006	0.176	0.74
	(0.207)	(0.200)		(0.332)	(0.390)	
High School or Above Dummy	-0.086**	0.031	0.05	-0.016	0.04	0.56
	(0.037)	(0.034)		(0.054)	(0.073)	
College or Above Dummy	0.006	0.02	0.78	0.024	0.064	0.62
	(0.028)	(0.031)		(0.045)	(0.057)	
Log Earnings	0.056	0.061	0.95	-0.032	-0.071	0.79
	(0.051)	(0.049)		(0.097)	(0.087)	
Height	2.614***	0.445	0.002	1.052**	0.617	0.57
	(0.390)	(0.316)		(0.532)	(0.468)	
Underweight Dummy	0.003	0.005	0.95	-0.027	-0.021	0.93
	(0.025)	(0.023)		(0.053)	(0.030)	
Overweight Dummy	0.005	0.037	0.47	0.048	0.017	0.73
	(0.028)	(0.025)		(0.069)	(0.050)	
Sickness Index	-0.075	-0.133**	0.65	-0.066	0.049	0.69
	(0.090)	(0.063)		(0.215)	(0.139)	
Birth Weight (Next Generation)	0.057	-0.104	0.86	0.086	-0.248	0.65
	-0.087	-0.169		-0.107	-0.219	

Notes:
Robust standard errors in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.
Control variables in OLS and within-twins regressions are same as in Section 3.5.1.

Table 3.7: Test Results for Birth Weight's Threshold Effect on Long-Term Outcomes

Dependent Variables	No. of Threshold	Test Statistics	Bootstrap P-Value
Years of Schooling (Self-Reported)	**Single**	9.634	**0.050**
	Double	5.745	0.254
Years of Schooling by Educational Level	**Single**	9.716	**0.086**
	Double	4.613	0.406
High School or Above Dummy	**Single**	9.593	**0.064**
	Double	4.087	0.452
College or Above Dummy	Single	4.300	0.610
Log Earnings	Single	3.949	0.688
Height	Single	6.720	0.278
BMI	Single	2.805	0.838
Underweight	Single	2.101	0.958
Overweight	Single	3.743	0.686
Sickness Index	Single	1.758	0.972
Birth Weight (Next Generation)	Single	1.500	0.876

Table 3.8: Comparison of the Findings on Adult Height

Behrman and Rosenzweig (2004)			
Control Variables:	age, twins' father's and mother's years of schooling, and twins' father's occupational earnings		
Observations:	1,418 female twins from the US - Minnesota Twin Survey Data		
	OLS	Within-Twins	Bias
Fetal Growth	1.50***	1.48***	-
	(0.186)	(0.170)	
Relationship between fetal growth and omitted factor:	positive if exist		
Black et al. (2007)			
Control Variables:	dummies for year and month-of-birth, birth order, and gender and dummies for twins' mother's educational level		
Observations:	5,382 male twins from Norway		
	OLS	Within-Twins	Bias
Log Birth Weight	7.48**	5.68***	upward
	(0.550)	(0.560)	
Relationship between BW and omitted factor:	positive		
This Study			
Control Variables:	age, dummies for birth order, gender, city, and and twins' parental educational level		
Observations	1,616 twins		
	OLS	Within-Twins	Bias
Birth Weight (kg)	1.444***	0.831**	upward
	(0.268)	(0.325)	
Relationship between BW and omitted factor:	positive		

Table 3.9: Comparison of the Findings on Birth Weight of the Next Generation

Behrman and Rosenzweig (2004)			
Control Variables:	age, twins' father's and mother's years of schooling, and twins' father's occupational earnings		
Observations:	1,207 female twins from the US - Minnesota Twin Survey Data		
Outcome:	Birth Weight of the Next Generation (ounce)		
	OLS	Within-Twins	Bias
Fetal growth	7.48***	1.87	upward
	(1.496)	(3.667)	
Relationship between fetal growth and omitted factor:	positive		
Royer (2006)			
Control Variables:	dummies for birth order, year of birth and race		
Observations:	6,792 female twins from California, US		
Outcome:	Birth Weight of the Next Generation (grams)		
	OLS	Within-Twins	Bias
Birth Weight (kg)	177.8679***	70.4188***	upward
	(14.720)	(30.668)	
Relationship between BW and omitted factor:	positive		
Black et al. (2007)			
Control Variables:	dummies for year and month-of-birth, birth order, and gender and dummies for twins' mother's educational level		
Observations:	1,862 female twins from Norway		
Outcome:	Log Birth Weight of the Next Generation		
	OLS	Within-Twins	Bias
Log Birth Weight	0.18**	0.15**	upward
	(0.040)	(0.060)	
Relationship between BW and omitted factor:	positive		
This Study			
Control Variables:	age at birth, years of schooling, birth order dummy, and city dummies		
Observations	466 female twins		
Outcome:	Birth Weight of the Next Generation (kg)		
	OLS	Within-Twins	Bias
Birth Weight (kg)	0.069	-0.147	-
	(0.049)	(0.115)	
Relationship between BW and omitted factor:	-		

Table 3.10: Comparison of the Findings on Health Conditions

Oreopoulos et al. (2008)			
Control Variables:	dummy for twins' mother's marital status, dummy for gender, and family sibling size dummies for the birth order of the twin within each family size		
Observations:	1,354 twins from Canada		
Outcome:	Physician Visits Ages between 12 and 17		
	OLS	Within-Twins	Bias
BW ≤ 1000 grams	2.6851	4.9343	-
	(4.823)	(10.665)	
1000 < BW ≤ 1500 grams	9.3137***	7.3252**	upward
	(2.141)	(2.964)	
1500 < BW ≤ 2500 grams	3.3341**	0.1926	upward
	(1.522)	(1.886)	
2500 < BW ≤ 3000 grams	3.5727**	0.1849	upward
	(1.528)	(1.769)	
3000 < BW ≤ 3500 grams	2.9624*	1.9898	upward
	(1.608)	(1.656)	
Relationship between BW and omitted factor:	positive		
This study			
Control Variables:	age, years of schooling, birth order dummy, gender dummy, and city dummies		
Observations:	1,616 twins		
Outcome:	Sickness Index		
	OLS	Within-Twins	Bias
Birth Weight (kg)	-0.102**	-0.019	downward
	(0.042)	(0.102)	
Relationship between BW and omitted factor:	positive		

Table 3.11: Comparison of the Findings on IQ and Academic Scores

Black et al. (2007)			
Control Variables:	dummies for year and month-of-birth, birth order, and gender and dummies for twins' mother's educational level		
Observations:	4,920 male twins from Norway		
Outcome:	IQ		
	OLS	Within-Twins	Bias
Log Birth Weight	0.48**	0.62**	?
	(0.140)	(0.180)	
Relationship between BW and omitted factor:	negative if exist		

Oreopoulos et al. (2008)			
Control Variables:	dummy for twins' mother's marital status, dummy for gender, and family sibling size dummies for the birth order of the twin within each family size		
Observations:	1,354 twins from Canada		
Outcome:	Language Arts Scores in Grade 12		
	OLS	Within-Twins	Bias
BW ≤ 1000 grams	-0.5415	0.01819	-
	(0.408)	(0.762)	
1000 < BW ≤ 1500 grams	-0.4608**	-0.185	downward
	(0.181)	(0.212)	
1500 < BW ≤ 2500 grams	-0.1826	-0.0987	-
	(0.129)	(0.135)	
2500 < BW ≤ 3000 grams	-0.2063	-0.2139*	-
	(0.129)	(0.126)	
3000 < BW ≤ 3500 grams	-0.0969	-0.0672	-
	(0.136)	(0.118)	
Relationship between BW and omitted factor:	positive		

Table 3.12: Comparison of the Findings on Educational Attainment

Behrman and Rosenzweig (2004)			
Control Variables:	age, twins' father's and mother's years of schooling, and twins' father's occupational earnings		
Observations:	1,418 female twins from the US - Minnesota Twin Survey Data		
Outcome:	Years of Schooling		
	OLS	Within-Twins	Bias
Fetal Growth	0.385***	0.657***	downward
	(0.139)	(0.211)	
Relationship between fetal growth and omitted factor:	negative		
Royer (2006)			
Control Variables:	dummies for birth order, year of birth and race		
Observations:	6,792 twins from California, US (with congenital anomalies)		
Outcome:	Years of Schooling (maximum)		
	OLS	Within-Twins	Bias
Birth Weight (kg)	0.1862***	0.1281*	upward
	(0.054)	(0.076)	
Relationship between BW and omitted factor:	positive		
Observations:	3,060 twins from California, US (no congenital anomalies)		
Outcome:	Years of Schooling (maximum)		
	OLS	Within-Twins	Bias
Birth Weight (kg)	0.1295	0.1537	downward if exist
	(0.085)	(0.113)	
Relationship between BW and omitted factor:	negative		
Outcome.	High School Completion		
Observations:	5,604 twins from California, US (with congenital anomalies)		
	OLS	Within-Twins	Bias
Birth Weight (kg)	0.0156	0.0179	-
	(0.012)	(0.019)	
Relationship between BW and omitted factor:	?		
Black et al. (2007)			
Control Variables:	dummies for year and month-of-birth, birth order, and gender and dummies for twins' mother's educational level		
Observations:	13,106 twins from Norway		
Outcome:	High School Completion (dummy for 1 with at least twelve years of education)		
	OLS	Within-Twins	Bias
Log Birth Weight	0.07**	0.09**	downward
	(0.020)	(0.040)	
Relationship between BW and omitted factor:	negative if exist		
Oreopoulos et al. (2008)			
Control Variables:	dummy for twins' mother's marital status, dummy for gender, and family sibling size dummies for the birth order of the twin within each family size		
Observations:	1,354 twins from Canada		
Outcome:	Reaching Grade 12 by Age 17		
	OLS	Within-Twins	Bias
BW ≤ 1000 grams	-0.3346*	-0.0837	downward
	(0.197)	(0.343)	
1000 < BW ≤ 1500 grams	-0.2708***	-0.2315**	downward
	(0.087)	(0.095)	
1500 < BW ≤ 2500 grams	-0.1284**	-0.0685	downward
	(0.062)	(0.061)	
2500 < BW ≤ 3000 grams	-0.1094*	-0.0921	-
	(0.062)	(0.057)	
3000 < BW ≤ 3500 grams	-0.0639	-0.0488	-
	(0.066)	(0.053)	
Relationship between BW and omitted factor:	positive		

Table 3 13: Comparison of the Findings on Log Earnings

Behrman and Rosenzweig (2004)			
Control Variables:	age, twins' father's and mother's years of schooling, and twins' father's occupational earnings		
Observations:	1,418 twins from the US - Minnesota Twin Survey Data		
	OLS	Within-Twins	Bias
Fetal Growth	0.0329 (0 003)	0.19*** (0.008)	downward
Relationship between fetal growth and omitted factor:	negative		
Black et al. (2007)			
Control Variables:	dummies for year and month-of-birth, birth order, and gender and dummies for twins' mother's educational level		
Observations:	5,952 twins from Norway		
	OLS	Within-Twins	Bias
Log Birth Weight	0.09** (0.030)	0.12** (0.060)	downward
Relationship between BW and omitted factor:	negative		
This Study			
Control Variables:	age, years of schooling, birth order dummy, gender dummy, and city dummies		
Observations	1,048 uncensored obs for OLS and 429 twin pairs for within-twins		
	OLS	Within-Twins	Bias
Birth Weight (kg)	0.065** (0.026)	-0.061 (0.065)	upward
Relationship between BW and omitted factor:	positive		

Fig. 3.1: Distribution of Birth Weight in Adult Twin Data Set - Singletons and Twins

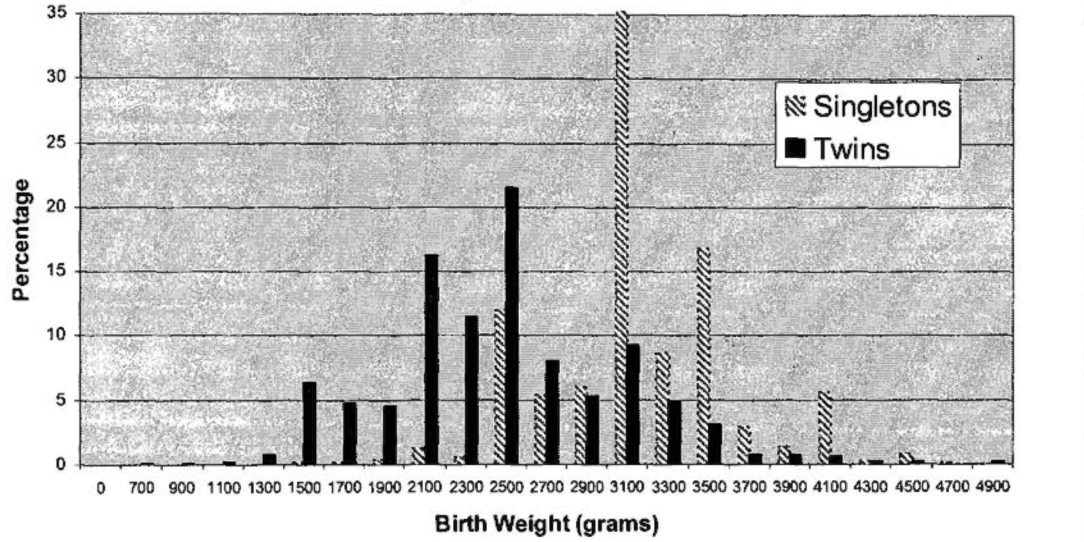
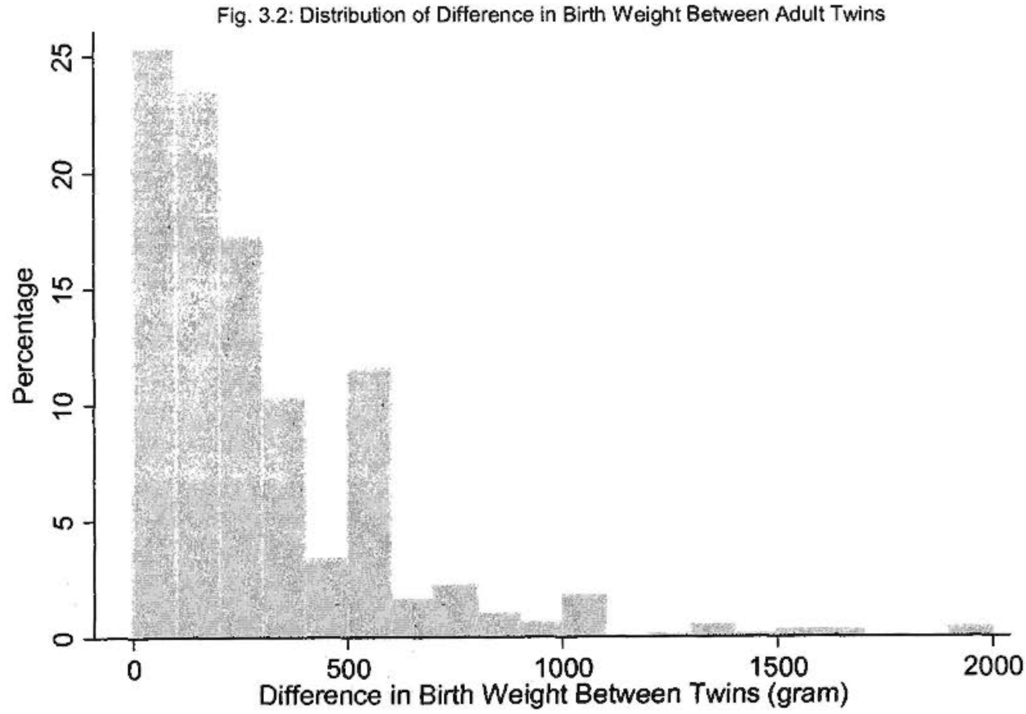


Fig. 3.2: Distribution of Difference in Birth Weight Between Adult Twins



Appendix Table 3.1: OLS and Within-Twins Estimates of Birth Weight on Earnings - Samples with Positive Earnings

Dependent Variable: Log Earnings

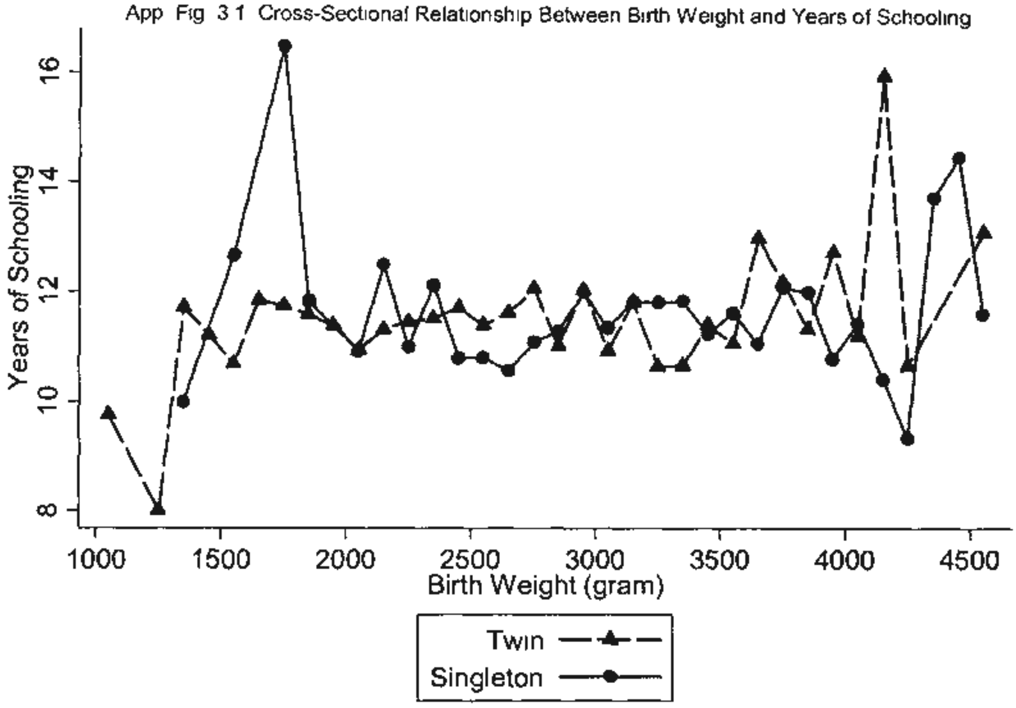
Sample	Sample Include Individuals with Positive Earnings			Sample Include Twin Pairs in which Both Siblings Have Positive Earnings					
Model	OLS			OLS			Within-Twins		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
BW	0.071***			0.059**			-0.053		
	(0.027)			(0.029)			(0.057)		
ln(BW)		0.177***			0.150**			-0.103	
		(0.065)			(0.069)			(0.141)	
LBW Dummy			-0.026			-0.019			0.069
			(0.030)			(0.033)			(0.050)
Education	0.082***	0.082***	0.082***	0.083***	0.083***	0.083***	0.016	0.016	0.015
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.015)	(0.015)	(0.015)
Age	0.001	0.001	0.001	0.006	0.006	0.006			
	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)			
Gender	0.190***	0.191***	0.195***	0.195***	0.196***	0.200***			
	(0.031)	(0.031)	(0.031)	(0.034)	(0.034)	(0.034)			
Birth Order	0.027	0.026	0.028	0.025	0.025	0.026	0.03	0.03	0.03
	(0.029)	(0.029)	(0.029)	(0.032)	(0.032)	(0.032)	(0.025)	(0.025)	(0.025)
Marital Status	0.005	0.004	0.003	0.005	0.005	0.004	-0.081	-0.08	-0.077
	(0.041)	(0.041)	(0.041)	(0.045)	(0.045)	(0.045)	(0.051)	(0.051)	(0.051)
Tenure	0.010**	0.010**	0.010*	0.006	0.006	0.006	0.013	0.013	0.013
	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.011)	(0.011)	(0.011)
Twin pairs							429	429	429
Observations	1048	1048	1048	858	858	858			
R-square	0.224	0.225	0.219	0.238	0.239	0.234	0.016	0.015	0.018

Appendix Table 3.2: Between-Families and Within-Twin-Pair Correlations of Birth Weight with Other Variables

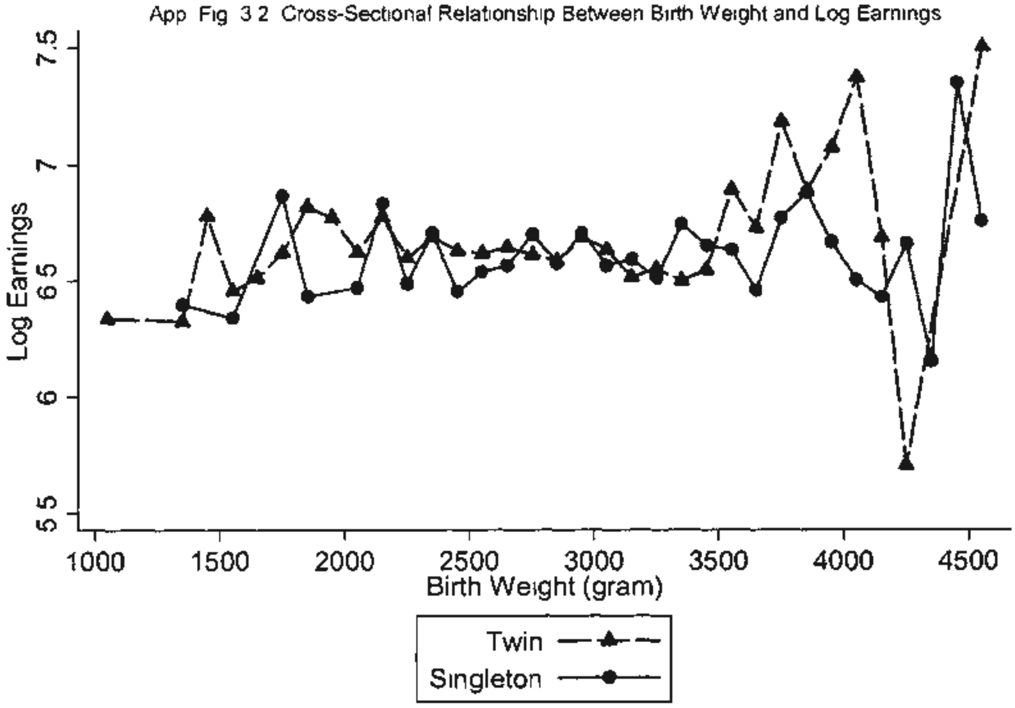
Between-Family Correlation		Within-Twin-Pair Correlation		
	Birth Weight		ΔBirth Weight	Twin Pairs
Party Membership	-0.035	ΔParty Membership	0.0452	791
Job Tenure	-0.123 ***	ΔJob Tenure	0.008	791
Working in a Foreign Firm	0.002	ΔWorking in a Foreign Firm	0.0052	791
Married	-0.085 **	ΔMarried	-0.0469	791
Spousal Education	-0.024	ΔSpousal Education	0.0319	504

Notes:
* significant at 10%; ** significant at 5%; *** significant at 10%
Between-family correlations are correlations of average family birth weight (average of the twins) with average family characteristics, and within-twin-pair correlations are correlations of within-twin-pair differences in birth weight with within-twin-pair differences in these characteristics.

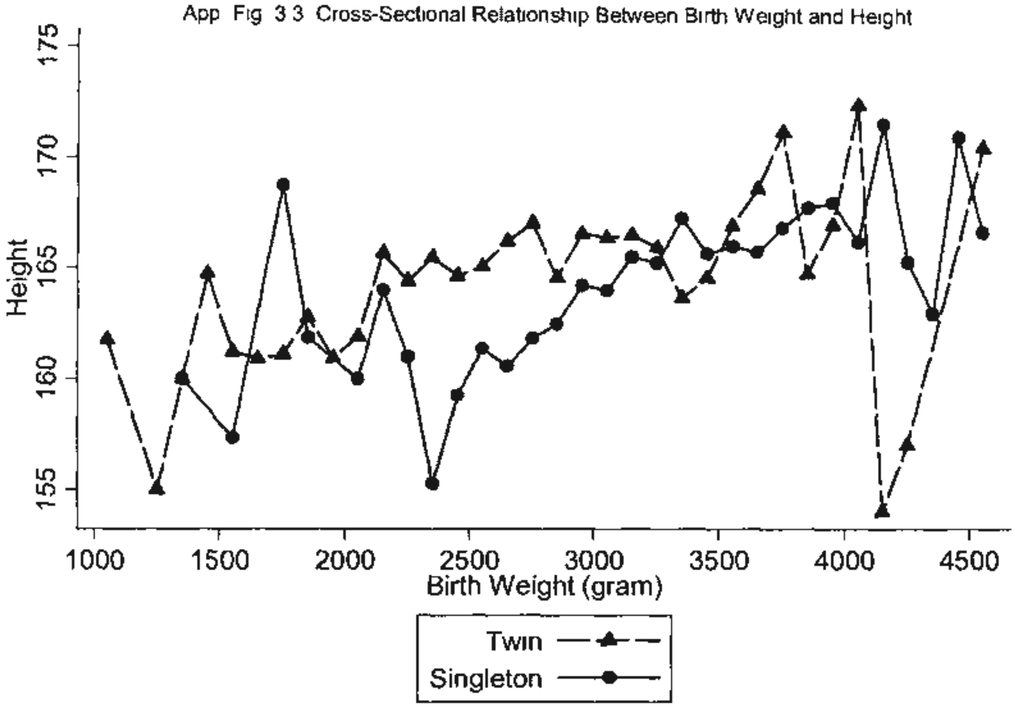
App Fig 3 1 Cross-Sectional Relationship Between Birth Weight and Years of Schooling



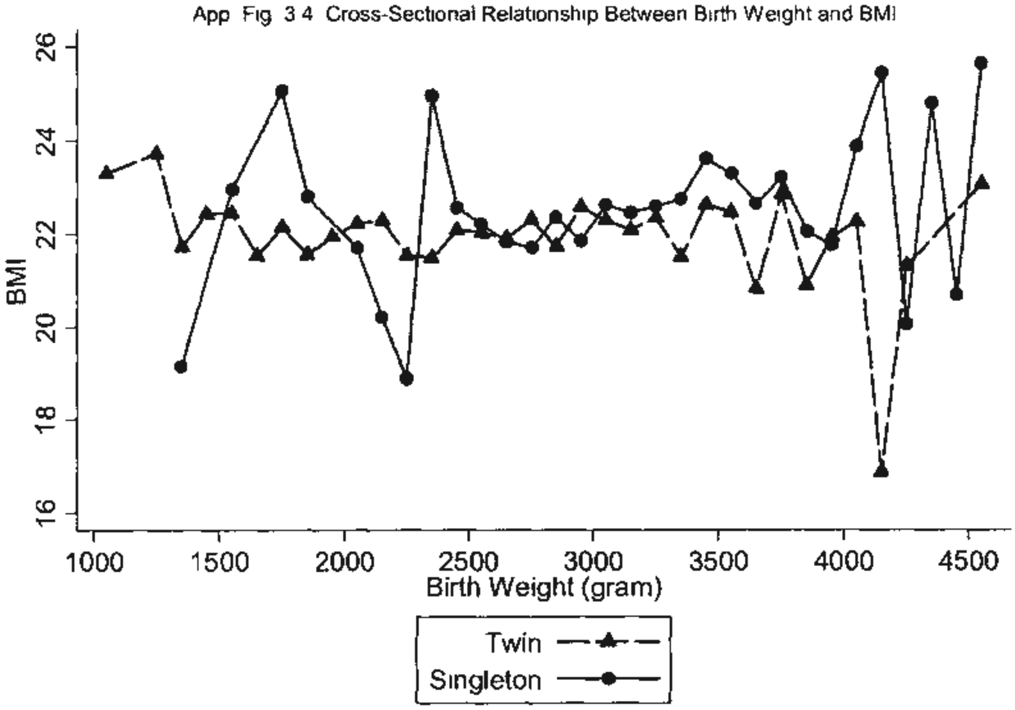
App Fig 3 2 Cross-Sectional Relationship Between Birth Weight and Log Earnings

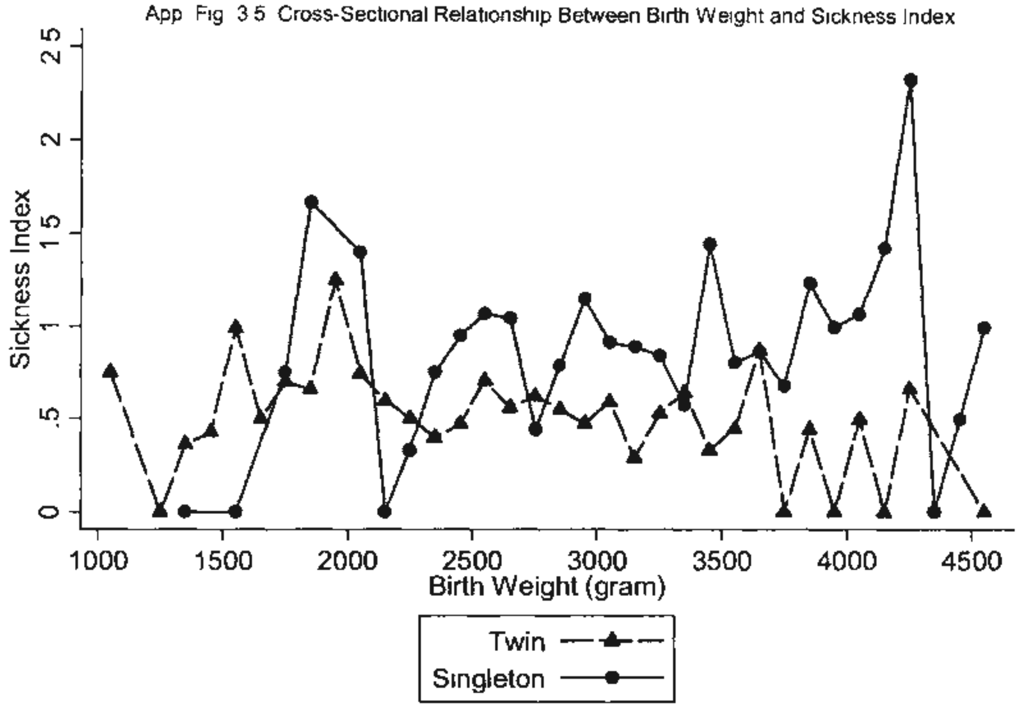


App Fig 3 3 Cross-Sectional Relationship Between Birth Weight and Height

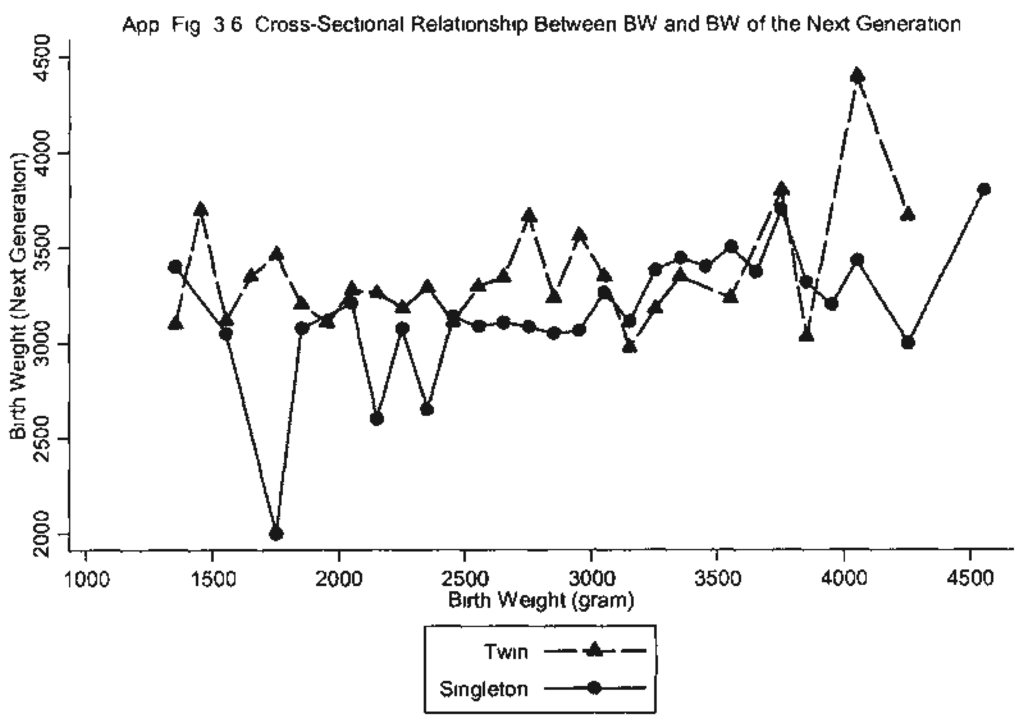


App Fig 3 4 Cross-Sectional Relationship Between Birth Weight and BMI





App Fig 3 5 Cross-Sectional Relationship Between Birth Weight and Sickness Index
Sickness Index
0
.5
1
1.5
2
2.5
1000
1500
2000
2500
3000
3500
4000
4500
Birth Weight (gram)
Twin
Singleton



App Fig 3 6 Cross-Sectional Relationship Between BW and BW of the Next Generation
Birth Weight (Next Generation)
2000
2500
3000
3500
4000
4500
1000
1500
2000
2500
3000
3500
4000
4500
Birth Weight (gram)
Twin
Singleton

Chapter 4

Trends on Marriage Age, Marriage Rate, and Assortative Mating on Age in China from 1970 to 2004, Impact of the One-Child Policy

4.1. Introduction

4.1.1. Background

Why do people prefer to marry? Why is positive assortative mating on age widely observed worldwide, with husbands being older than their wives, in general? Why and how does economic development affect the marital behavior of people? Several theoretical and empirical studies in economics and sociology offer answers to the above-mentioned questions.

To answer the first question from a theoretical perspective, as elaborated in a framework by Becker (1973, 1974), an individual chooses either to marry or to remain single in an attempt to maximize his/her utility. The advantages of forming a partnership can stem from various reasons, including gender division of labor in home production and in the workplace. The advantage from division of labor comes from specialization in production by gender, in which men are presumed as more productive at work, while women are more productive at home.

In response to the second question, Becker (1973) builds up a model to show that when traits are complementary, "mating of likes" becomes optimal. In other words, the marriages formed by parties having similar complementary traits yield higher utility. As age is one kind of complementary trait, people tend to marry others of similar age. Bergstrom and Bagnoli (1993) further argue that the quality of women is revealed during their youth, while, relatively, the quality of men manifest as they grow older. Thus, men who predict that they will be more successful in their later years will not marry until their achievements are revealed. As a result, in general, the age of the wives is lesser compared with that of their husbands. In addition, Giolito (2003) utilizes fecundity to explain why women marry earlier than do men. The age gap between spouses is positive on the average, as women have shorter fertility periods than men, and women have better likelihood of bearing children at a younger age. Based on empirical evidences on Western countries, age homogamy (i.e., spouses of the same age) and marriages wherein wives are older than their husbands had become more popular in the 20th century.

As for the third question, several theoretical considerations are offered on marriage age by gender with respect to economic growth. For instance, Keeley (1977) extends Becker's model and proposes that high-earning men are more likely to marry earlier, while high-earning women delay marriage. In contrast, some researchers argue that people with higher wages tend to marry later since a higher income is usually associated with greater uncertainty at the young stage of career, and young people are willing to delay marriage in order to settle their success and to find a better match in later years. Within a developing economy, women often have more opportunities in the labor market and earn more. Hence, the willingness of women to marry decreases accordingly with potential gains from the marriage. Evidence from other countries (such as the US, Argentina, Japan) indicates that the marriage rate of women falls as the economy develops, and that the marriage age of men and women increases with economic growth and increased complexity in their respective career (Qian, 1998; Ellas, 2003; Iwasawa and Mita, 2008).

4.1.2. Motivations and Objectives

Relative to numerous studies on the developed countries in the West, only a few studies investigate marriage age and marriage rate in China. The following paragraphs illustrate the government policies on marriage and population, as well as the economic development in 1970–2004. Findings from relevant literature on Chinese marriage are also summarized.

China saw great changes in terms of policies on population and economic transitions from 1970 to 2004. In the 1970s, the Chinese government encouraged people to marry at a later age, have fewer children, and widen the interval between childbirths. To control proactively the population expansion, the government implemented a birth control policy – the one-child policy in 1979 in order to restrict couples from having more than one child, barring exemptions. In contrast, the restriction on late marriages was relaxed in lieu of the direct control on fertility. A new marriage law implemented in 1980 sets the new minimum marriage age at 20 and 22 for women and men, respectively; this law is being enforced up to the present.[64] At the same time, under the leadership of Chairman Deng Xiaoping of the Communist Party of China in the early 1980s, a more pragmatic political philosophy was adopted, emphasizing the need to pursue national economic development. Since then, the government has begun to transform from a central planned economy to a market economy. Such transition has been very successful.

As far as we know, two studies on Chinese people's likelihood to marry and marriage age exist. Xu et al. (2003) use a data set collected in 1991 on Shanghai, Guangdong, Sichuan, Jilin, Shandong, Shaanxi, and Ninxia, consisting of 4,509 couples based in city, and 4,524 couples based in the countryside. They find that in the urban areas, Chinese people who have higher wages are less likely to marry. The overall economic growth has also delayed the timing of marriage. Moreover, Yang and Chen (2004) examine China's transition in demographic pattern from 1970 to 1989, including women's average age on marriage, average age when bearing their first child, fertility, and the sex ratio among children. For their analysis, they use data from the 1992 Household Economy and Fertility Survey, incorporating 14,000 households from 10 provinces in China. They find that the marriage age of women has been affected by the government's encouragement on "later marriage" in the 1970s and the relaxation on the marriage age in the early 1980s, leading to an inverted V shape on women's average age at first marriage from 1970 to 1989. For instance, marriage age rose in rural areas from 21.5 in 1970 to 23.1 in 1979, after which it decreased in the 1980s (e.g., 22 in 1986).

To the best of our knowledge, prior literature on China mainly focuses on trends in the 1970s and 1980s. This study attempts to study such trends further by extending the time interval to 2004, as well as by investigating the impact of the one-child

[64] The statutory minimum marriage ages for men and women had been raised relative to the law in the 1950s (20 for men and 18 for women). The new minimum ages are lower than the so-called "late marriage age" carried out in the 1970s. For details, see Section 4.2.1.

policy on marriage age, marriage rate, and assortative mating on age. The following paragraphs illustrate the two objectives for Chapter 4.

The first objective is to investigate the trends in marital behavior of Chinese people from 1970 to 2004, a period of policy changes and rapid economic growth, in relation to three related aspects: marriage age, marriage rate, and assortative mating on age. China has developed quickly, and the economic structure of the country has moved closer to that of developed countries. The lifestyle of the Chinese has also been more Westernized, including their consumption preference. However, China remains strongly influenced by Confucianism, which promotes good morality on rituals, filial piety, and so forth. Such traditional culture is deeply rooted in each household. Examining whether Chinese people follow the Western experience would be of great interest. Are they more likely remain single, marry late, and diversify their choices on age mating, instead of following traditional practices?

The second objective is to examine the impact of the one-child policy, which has aroused the interest of many researchers due to its impact on various fields, such as sex selection at birth, welfare of women in the family, quantity and quality tradeoff of children, and so forth (Short et al., 2001; Li, 2003; Yang, 2007; Rosenzweig and Zhang, 2009). Unlike past literature, this study focuses on marriage rate, marriage age, and assortative mating on age by applying a difference-in-differences (DiD) estimation for analysis.

4.1.3. Major Findings and Contributions

This chapter contributes to literature in two ways. First, it is the first to use large-scale Chinese national data (2000 and 2005 censuses) covering a longer timeframe, allowing for the examination of trends in China from 1970 to 2004. We find that the timing of marriage fluctuated over these inclusive 35 years. Consistent with the findings by Yang and Chen (2004), the present results show that most Chinese people delayed marriage up to their mid-twenties in the 1970s, compared to marrying at in their early twenties in the 1980s. From 1990 onwards, more people married during their mid-twenties or later. Interestingly, the prevailing marriage rates of men and women over 35 years old were maintained at their very high levels up to the early 2000s, despite China becoming more prosperous. In addition, the present findings indicate that the positive assortative mating on age was preserved in 1970–2004.

Second, this chapter is the first to compare the marriages of Zhuang people with other non-Han minority groups (excluding Man people) around 1989 in order to implement difference-in-differences (DiD) estimation to examine the effect of the one-child policy. This approach is more definitive than the comparison of the Han versus non-Han in previous literature.[65] The present findings indicate that the policy encourages men and women to delay marriage. Surprisingly, the policy effect on marriage age is found to be more significant on the side of the men than on women. On the average, men delayed marriage by 1.3 years while women delayed marriage by 6 months. Interestingly, the findings of the present work indicate that more men from their late teens to mid-twenties marry older women. Furthermore, as more men marry from age 30 years and onwards, most still choose younger women, such as those in their twenties. Overall, the policy tends to increase the positive mean age difference between spouses in terms of first marriages.

The rest of this study is organized as follows. Section 4.2 discusses the expected trends from 1970 to 2004, and the expected impacts of the one-child policy based on theories from economics and sociology, as well as evidence from other countries. Section 4.3 introduces the CS function [the function developed by Choo and Siow, (2006a, b)] and illustrates how the empirical framework corresponds to the two issues. Section 4.4 presents and analyzes the results. Section 4.5 summarizes the findings.

[65] Apart from the one-child policy, the Han and non-Han Chinese people differ in socio-economic factors, and the changes in these factors are likely to differ over time. We will elaborate this point and the reasons for excluding the Man people in Section 4.3.2.2.

4.2. Two Issues for Analysis

4.2.1. Expected Trends during 1970–2004

The first aim of this study is to investigate the trends for 1970–2004 in terms of three related aspects: marriage age of men and women, marriage rate, and assortative mating on age. Various theories from economics and sociology explain the traits relating to marriage rate, marriage age, and age gap between spouses. Below, we illustrate some important changes in China, then present two expected outcomes that might have resulted from policy changes and rapid economic development in the country during this period. Related theories and experience from other countries are also discussed.

Government's Policies and Economic Growth between 1970 and 2004

In the 1970s, the Chinese government promoted the "Later, Longer, and Fewer" slogan. Chinese people were urged to marry later. Officials involved in family planning imposed the "late marriage age" at 23 years old for rural women and 25 years old for urban women, albeit the exact restrictions varied across provinces. Moreover, at that time, the marriage registration system dictated that people who wanted to marry needed to obtain the approval of their working or residence units (Yang and Chen, 2004). In 1979, the government implemented the one-child policy, restricting the number of children allowed to each couple; the restriction on late marriage, however, was relaxed.

Since the late 1970s, China has undergone rapid transition and development. The planned economy shifted to market economy. China has achieved great success in economic transition with a rocketing economic growth. Meanwhile, in general, the Chinese people have become more affluent. For instance, the GDP per capita rose from 419 RMB in 1978 to approximately 12,336 RMB in 2004. Based on the aforementioned major changes in China over the past decades, we predict the following expected patterns.

Expected Result (1.1): More Chinese men and women are expected to delay marriage by a few years in the 1990s and early 2000s.[66]

As noted earlier, theoretically speaking, the impact of economic prosperity is ambiguous for the marriage age of men. Keeley (1977) proposes that males with higher wages gain more from specialization at work after marriage, and that such higher benefit induces them to marry earlier relative to males with lower wages.[67] Bergstrom and Bagnoli (1993) believe that men tend to delay marriage in order to display their success to potential spouses. Some researchers link marriage age to career cycles. High-wage jobs may be associated with greater uncertainty at the young stage, as men would opt postpone marriage until their careers have reached a settled stage. According to evidence on other countries, as a whole, when a country becomes more prosperous, men tend to marry later. In addition, women are also likely to delay marriage because they receive more education than before on the average. Furthermore, the introduction of the one-child policy restricts each couple to have only one child. As the number of children is a key output from marriage, the policy may have reduced the perceived benefit from early marriage.[68]

Expected Result (1.2): The age gap between spouses is expected to be smaller during the 1970s.

It is common for husbands to be of the same age or one to three years older than their wives. Marriages in which spouses have a large age gap are much less likely to appear. According to Becker (1973), "mating of likes" occurs when traits such as age and educational attainment are complementary. This explains why positive assortative mating on age occurs. In general, women marry earlier than do men. Keeley (1977) proposes that the ability of women in home production is not fully utilized until she is married; opportunity cost of delaying marriage for women is higher than for men.

[66] Prior literature (Xu et al., 2003; Yang and Chen, 2004) has shown that the marriage age for men and women increased throughout the 1970s under the government's late marriage policy, and then fell in the early 1980s As far as we know, this study is the first to analyze the timing of marriage in China using 1990s and early 2000s data

[67] According to the model, females with higher wages gain less from forming a partnership Thus, the marriage age of females increases because they have higher cost of searching for a spouse and have lower probability of entering into the marriage market

[68] The expected impacts of this policy are thoroughly discussed in Section 4 2 2.

Oppenheimer (1988) proposes that the achievement of men in the labor market is an important concern for women when finding a suitable husband. Thus, a young woman in her twenties would commonly marry a man three or four years older. Meanwhile, a woman aged 25 is likely to find a man of similar age because, during this time, men have already established their careers. Siow (1998) proposes that men wait to have more resources to afford young fertile women, and hence husbands are older than their wives in general.

In the 1970s, Chinese men and women were discouraged from marrying early. Chinese women who married in their mid-twenties would likely choose to marry men with similar age; however, Chinese men in their mid-twenties were not able to choose young women aged early twenties. In this case, it is expected that marriage in which spouses have similar ages became more popular as more men and women married in their mid-twenties, and that the resulting positive mean age gap between spouses would be smaller during the 1970s.[69]

4.2.2. Expected Impacts of the One-Child Policy

The Chinese government launched the one-child policy in 1979, restricting each household to having only one child; however, there were some exemptions, such as in rural areas in some provinces, most ethnic minorities, and so forth. As households are allowed to have only one child and females are usually pregnant only once, the policy may have changed the marital behavior of the Chinese. The following four conjectures are the expected influences of the policy.

Expected Result (2.1): Both men and women may be more willing to delay marriage.

The incentive to marry earlier may decrease as the couple is allowed to have one child only. This is different from the past wherein marrying earlier was ascribed to having

[69] When the Chinese economy developed quickly, more Chinese men and women were expected to delay marriage (e.g., in the 1990s and early 2000s). Meanwhile, the expected impact on age gap between spouses was uncertain because the effect from increasing marriage age for men may counteract the effect of increasing marriage age for women. The impact of the one-child policy on this aspect is also indeterminate

more children. Women do not rush in early pregnancy, and would rather spend more time to search for better spouses.

Expected Result (2.2): The one-child policy may lead to husbands being younger than their wives.

Giolito (2003) proposes that the fecundity time horizon of women is much shorter than men. Such shorter fecundity horizon lowers women's reservation value and encourages them to accept a lower match quality. Thus, traditionally speaking, women usually marry older men. As observed, the one-child policy weakens the importance of women's fecundity horizon and fertility. On the one hand, women may be more willing to marry later so as to spend more time finding a suitable mate; on the other hand, men, especially during their early twenties, may be more willing to marry slightly older women, as their wives are expected to have one child only.

Expected Result (2.3): Both men and women who marry late are more likely to look for a spouse of similar age.

As illustrated earlier, women who marry late tend to find men of similar age.[70] Moreover, men and women with similar ages are more likely to have common socio-economic status, such as educational achievement, occupational prestige, and common interests. Thus, men who marry late may be more willing to marry women of similar age or slightly younger, as their wives are expected to bear a child only once. In this sense, the attractiveness of a common background becomes more important.

Expected Result (2.4): Men who marry late continue to prefer to marry young women.

Two possible reasons may be ascribed to this phenomenon. One is physical and sexual attractiveness. Men are willing to marry young women regardless of their fertility. Moreover, as older men who marry late are more likely to have better economic conditions than younger men, this favorable attribute can attract younger women. The other is on the quality of the next generation. As each couple is allowed

[70] For details, see expected result (1.2).

to have one child only, the quality of the child is important. Men want to marry young women, as the health of the offspring is likely to be better if the mother is young. In addition, young women also want to marry older men with better economic status and stable careers in order to obtain more resources to rear their child.

4.3. Methodology

In this section, we first introduce the function developed by Choo and Siow (2006a, b) (hereafter referred to as the "CS function") and then present the empirical framework in order to examine the above-mentioned issues.

4.3.1. Introduction of the CS Function

Gary Becker is one of the earliest economists to extend economic analysis on the marital behavior of individuals. As noted earlier, Becker (1973, 1974) has built up an economic model to explain why and whom individuals would like to marry. In his theoretical framework, Becker (1973, 1974) proposes that the benefits from marriage involve the utility derived from a wide range of activities inside the household. Becker assumes that these goods and services can be combined into a single aggregate, Z, which represents the gains from the marriage. Z can be expressed as an output of a household production functions consisting of inputs of the husband and wife, such as time, energy, caring devoted to each other, and so forth. His model is useful in explaining the positive correlation among couple's attributes, such as education, age, and others. In particular, this model can derive many refutable implications for empirical testing.[71] However, Becker (1973, 1974) has not quantified empirically the unobservable martial outputs into numerical variables. Becker (1991) mentions this point explicitly: the output maximized by households cannot be identified because it comprises of variables, including the quality of children, happiness from sexual behavior, and other household products that are hard to measure.

[71] For instance, the model predicts that there is positive assortative mating of non-market traits with property income. Intuitively speaking, rich men commonly marry beautiful women. Another insightful implication is on negative assorative mating of couples in terms of wage; that is, high-earning men should marry low-earning women since low wages denote spending more time at home for household production and vice versa.

In Becker (1973, 1974)'s model, the gains from marriage depends on various attributes of spouses. Choo and Siow (2006a, b) propose that marital gains are derived by matching a specific attribute of spouses (e.g., age). They further assume that the corresponding utility function follows a Type 1 extreme value distribution. Under this framework, Choo and Siow (2006a, b) offer a function that can be computed using observable information to measure the expected gain from individual marriages with respect to a specific trait relative to both parties if they remain single. This function is in a reduced form under the equilibrium condition, and is deduced from a structural framework that models the demand for and supply of available candidates in the marriage market. Choo and Siow (2006b) state, *"The CS model provides a behavioral interpretation of π_{ij}. It is an empirical implementation of Becker's transferable utility model of the marriage market"* (2006b, p. 467). In other words, the CS function transforms the vague concept of marital output into a numerical value. In turn, this allows for the empirical comparison of the gains from the mating in terms of a specific attribute among different groups of people and across time.

The following segment briefly introduces the basic framework of the CS model and focuses on the intuitive meaning of the CS function and its empirical implementation.[72]

The model assumes that a society consists of I types of men and J types of women. Two individuals want to marry because the marriage makes them better off; thus, the gains for each party must be greater than their gains from remaining single.

Let $\tilde{\pi}_{ij}$ denote the output generated by a mating of type i men with type j women on the average. When a type i man wants to marry a type j woman, he needs to transfer τ_{ij} (a measure of resource) to her and enjoy the remaining output ($\tilde{\pi}_{ij} - \tau_{ij}$). On the average, a type j woman who chooses to marry type i man is willing to receive τ_{ij}. In an equilibrium, the demand of type i men for type j women is the same as the supply of type j women for type i men for all types of (i, j) matches simultaneously.

[72] For details, see Choo and Siow (2006a, b).

Type j women are supposed to marry various types of men, suggesting that each type j woman should have unique gain different from the rest of other type j women when choosing a type i man. If each type j woman receives the same gain when choosing a type i man, then all type j women will choose a specific type of men only because this specific match (i, j) maximizes each of type j women's gain. Thus, Choo and Siow (2006a, b) assume marriage of each partner consists of two types of gain: systematic and idiosyncratic. For instance, the payoff of a woman, k, who belongs to type j and marries a male of type i is

$$V_{kij} = \tau_{ij} + \varepsilon_{kij}, \tag{4.1}$$

where τ_{ij} denotes the systematic gain of a type j woman obtained when marrying a type i man, which is non-stochastic and is the same for all type j women who marry type i men. In contrast, ε_{kij} is idiosyncratic and the payoff is specific to this individual k when she chooses a type i man.[73]

According to the above-mentioned setting, all type i men are perfect substitutes to type j women, even if the idiosyncratic payoff is specific to each type j woman. Hence, type j women will marry different types of men, as their own idiosyncratic payoffs are different. In turn, their gain ($\tau_{ij} + \varepsilon_{kij}$) from marrying any specific type of men becomes different, consequently leading to diverse decisions.

If a type j woman decides to remain single, her payoff is

$$V_{k0j} = \tilde{\pi}_{0j} + \varepsilon_{k0j}, \tag{4.2}$$

where $\tilde{\pi}_{0j}$ denotes the systematic payoff for not marrying. This is the same for all type j females.

Assuming that she chooses to maximize her payoff (i.e., whether or not to marry, the type of men she chooses for marriage), then,

$$V_{kj} = \max_{i} \left\{ V_{k0j}, \cdots, V_{kij}, \cdots, V_{kIj} \right\}. \tag{4.3}$$

---

[73] ε_{kij} is an i.i.d random variable, which follows a Type 1 extreme value distribution Type 1 extreme value cumulative distribution and density functions are $F(\varepsilon_{ijg}) = \exp\left(e^{-\varepsilon}\right)$ and $f(\varepsilon) = \exp\left[-\varepsilon - \exp(-\varepsilon)\right]$, respectively.

The said maximizing payoff function can be transformed into a quasi-supply function of type j women who would like to marry type i men:

$$\ln\left[\frac{\mu_{ij}^{s}}{\mu_{0j}}\right]=\tau_{ij}-\tilde{\pi}_{0j}, \tag{4.4}$$

where μ_{ij}^{s} denotes the number of type j women who are willing to marry type i men, and μ_{0j} is the number of women who want to remain single.

Symmetrically, the payoff of a man, g, who belongs to type i and marries a female of type j is

$$V_{gij}=\tilde{\pi}_{ij}-\tau_{ij}+\varepsilon_{gij}. \tag{4.5}$$

Once again, this payoff consists of two parts. One is $\tilde{\pi}_{ij}-\tau_{ij}$, which measures the systematic payoff common to all type i men. The other is an idiosyncratic payoff ε_{gij}, which is specific to him when marrying a type j woman. If a type i man remains single, his payoff is

$$V_{gi0}=\tilde{\pi}_{i0}+\varepsilon_{gi0}. \tag{4.6}$$

Similarly, each type i man decides whether to marry, and which type of woman is chosen (if he marries) in order to maximize his gain. The quasi-demand function for type j women of type i men is

$$\ln\left[\frac{\mu_{ij}^{d}}{\mu_{i0}}\right]=\tilde{\pi}_{ij}-\tau_{ij}-\tilde{\pi}_{i0}, \tag{4.7}$$

where μ_{ij}^{d} denotes the number of type i men who want to marry type j women, and μ_{i0} is the number of type i men chosen to be single.

In equilibrium, for each (i, j) sub-marriage market, under optimal τ_{ij}, the supply of type j women for type i men equals the demand by type i men for type j women for all (i, j). The equilibrium is $\mu_{ij}^{s}=\mu_{ij}^{d}=\mu_{ij}$ for all (i, j) pairs. Then, Equations (4.4) and (4.7) give the following condition:

$$\ln\left[\frac{\mu_{ij}}{\sqrt{\mu_{i0}\mu_{0j}}}\right]=\frac{\tilde{\pi}_{ij}-\tilde{\pi}_{i0}-\tilde{\pi}_{0j}}{2}=\pi_{ij}. \tag{4.8}$$

This is called the CS marriage matching function. Here, π_{ij} represents the expected total gain per partner from any (*i*, *j*) marriages relative to both partners remaining single. π_{ij} is measured by the ratio of the number of (*i*, *j*) marriages to the geometric average of type *i* men and type *j* women who remain single. As the required information is observable, π_{ij} can be computed.[74] An increase in the ratio of observed (*i*, *j*) marriage to the number of unmarried type *i* men and type *j* women suggests that the total gain from the (*i*, *j*) mating relative to both spouses remaining single is higher on average. Moreover, the CS function allows for a spillover effect, which means that the number of marriages (*i*, *j*) is affected by the change in number of other types of men ($i' \neq i$) and women ($j' \neq j$).[75]

Before the CS function, researchers such as Qian (1998) usually used a matching function with zero spillover effect, the Schoen's marriage matching function, to study mating of a specific trait[76]:

$$\mu_{ij}\left(m_i, f_j; \hat{\pi}_{ij}\right) = \frac{m_i f_j}{m_i + f_j} e^{\hat{\pi}_{ij}}.$$

Taking log on both sides, this becomes

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[74] The CS function is subject to two major limitations The CS function does not account for dynamic matter wherein individuals could postpone marriage for the next period The remaining single men and women may not remain single forever, instead, they defer the decision after several periods to match the decision of a better partner Another limitation is that τ_{ij} in the CS model cannot be recovered

[75] For instance, given that π_{ij} is constant for all *i* and *j*, the marginal effect of an increase in the total number of type *r* $(r \neq i)$ men (m_r) on the number of marriages formed by type *i* men and type *j* women (μ_{ij}) is

$$\frac{\partial \mu_{ij}}{\partial m_r} = \frac{1}{2}\pi_{ij}\left[\left(\frac{\mu_{0j}}{\mu_{i0}}\right)^{0.5}\frac{\partial \mu_{i0}}{\partial m_r} + \left(\frac{\mu_{i0}}{\mu_{0j}}\right)^{0.5}\frac{\partial \mu_{0j}}{\partial m_r}\right],$$

where m_i is the total number of type *i* men, f_j is the total number of type *j* women, $\mu_{i0} = m_i - \sum_k \mu_{ik}$, $\mu_{0j} = f_j - \sum_l \mu_{lj}$, $\frac{\partial \mu_{i0}}{\partial m_r} \neq 0$, and $\frac{\partial \mu_{0j}}{\partial m_r} \neq 0$ As $\frac{\partial \mu_{ij}}{\partial m_r} \neq 0$, this means that when more type *r* men appear in the marriage market, some of them are willing to marry type *j* women, thereby competing with type *i* men for type *j* women, leading to a spillover effect on μ_{ij} For details, see p 183 and Appendix B of Choo and Siow (2006a), and p. 471-473 of Choo and Siow (2006b)

[76] For details, see Choo and Siow (2006b)

$$\ln \mu_{ij} = \ln\left(\frac{m_i f_j}{m_i + f_j}\right) + \hat{\pi}_{ij},$$

where $\sum_j \exp \hat{\pi}_{ij} \leq 1$, and $\sum_i \exp \hat{\pi}_{ij} \leq 1$.

Herein, $\hat{\pi}_{ij}$ is interpreted as force of attraction. The lack of a spillover effect highly restricts its intuitive meaning and predictive power.[77] For instance, using age as the trait, the number of younger people does not affect the marriage rate or the net gain of older people because younger people and older people cannot substitute each other. Such an assumption highly restricts its usefulness in empirical analysis.

The key advantage of the CS model is to derive a static non-parametric function embedding a substitution effect to fit any cross-sectional marriage distribution. As mentioned earlier, the amount of other types of men ($i' \neq i$) and women ($j' \neq j$) also affects the number of marriages formed by type i men and type j women. This is because other types of men and women are potential candidates to compete for type j women and type i men, respectively.

As the CS function can estimate the gain from marriage empirically from observable information, the study can now compare the total gains from different types of mating with respect to a trait directly across cohorts in order to examine whether the marital surpluses from different types of mating based on this trait change on the average over time. The results provide insights on the trend on the mating with respect to this trait. Moreover, the impact of a policy from the comparison of total gains of treatment and control groups can be analyzed. For instance, Choo and Siow (2006a) use the CS function to measure the total gains from the new marriage distribution in US, as well as the corresponding changes from 1971/72 to 1981/82 periods. Furthermore, they use a DiD estimation to examine the influence of legal abortion on the total gains to marriages in the US.

[77] For details, see Choo and Siow (2006b) and Brandt et al. (2008).

4.3.2. Empirical Framework to Analyze the Two Issues

For the analysis of the one-child policy, this present work uses information before 2000. The required data was obtained via the 2000 population census of China. For the analysis for trends from 1970 to 2004, we use both 2000 census and a sub-sample of 2005 census; these two data sets were collected by the National Bureau of Statistics in Mainland China in November 2000 and 2005, respectively. The 2000 census is a 1% sample consisting of approximately 11 million individual records. The sub-sample from 2005 census has 2,585,481 observations, drawn from the original data contained randomly in the 2005 census, accounting for approximately 20% of the original 2005 census data (1% of national population). More importantly, unlike the 1982 and 1990 censuses, the 2000 and 2005 censuses contain the date of initial marriage; thus, we can trace the number of men and women who were single or married, as well as the number of newly married men and women (first marriage), over a particular period. The pattern of both newlyweds and prevailing marriages across time are then studied. However, using this method, people who had left mainland China or did not survive by 2000 (i.e., using 2000 census) or by 2005 (i.e., using 2005 sub-census) are not taken into account.[78] Another limitation is that we need to drop from the list individuals who have divorced, re-married, or lost spouses; the data sets record the date of initial marriage only, but lack information on the date of divorce and loss of spouse.[79]

As, generally, Chinese couples have age gaps (husband's age minus wife's age) from zero to three years, and most of them marry in their twenties, it is less likely for marriages in which the husband is older than his wife by a significant number of years or vice versa, or both spouses are very old or very young to occur during a year. Due

[78] According to China Population Statistical Yearbook 1997-2006, the morality rate for people aged 15-29, 30-39, 40-44, 44-49, 50-54, and 55-59 were approximately 0.1%, 0.15%, 0 2%, 0 4%, 0 5% and 1% respectively Most of Chinese people have married over their twenties For those married in 1970, most of them were still alive in 2000 It is likely that the mating pattern of people died earlier is similar to that of people still alive in 2000 and 2005 Thus, the sample generated by the tracing method is believed to be representative and would not be affected by the mortality substantially Moreover, as far we know, there is no regular official statistics for Chinese people's emigration Meanwhile, according to 2000 and 2005 censuses, the number of people living outside mainland China 5 years ago took about 0 01% only If the number of migrants and immigrants are similar in China, the percentage of Chinese people's emigration is very tiny relative to the whole population Thus, the impact of selective attribution due to international migration is negligible

[79] As a result, 8 63% of the raw sample (780,353 observations) and 8 57% (176,409 observations) was dropped in 2000 census and 2005 sub-census, respectively

to this thin cell problem, the present work combines two years of new marriages as one period of new marriages when computing and plotting the total gains in diagrams.[80] According to census data, the youngest age for first marriage in males or females is at 15 years old. The number of newlyweds with spouses being older than 40 years old is very limited, and takes a small percentage (less than 1%). Most of Chinese people obtain their permanent marital status after 30 years old. Thus, in this study, the age range of marriages covers the spouse age of 13–41, with "41" denoting that the age of a spouse is 41 years old or above.

4.3.2.1 Methods to Analyze the Trends from 1970 to 2004

To provide the basic ideas on the characteristics of trends in marriage age, marriage rate, and assortative mating on age, this study first plots the distribution of newlyweds by spouse age, average marriage ages of men and women in first marriage, age gaps between spouses, prevailing marriage rates of men and women from 1970 to 2004. The distribution of newlyweds in 1971/72, 1981/82, 1991/92, and 1998/99 is obtained from 2000 census, while those in 2003/04 comes from 2005 sub-census. For the rest of the aforementioned measures on 1970–2004, the information is obtained from 2005 sub-census.[81] These figures are helpful in understanding the trends in China for over 35 years.[82]

Second, the OLS regression is used for age at first marriage and age gap between spouses. Age at first marriage of males and females is estimated as

$$Y_{irpt} = \sum_{r=1}^{2} \eta_r D_r + \sum_{p=1}^{30} \lambda_p D_p + \sum_{t=71}^{04} \theta_t D_t + \alpha' X_i + \varepsilon_{irpt}, \qquad (4.11)$$

where i refers to an individual; Y_{irpt} refers to the age at first marriage at location r in province p in year t; D_r is a set of two dummies for city and town (village as the

[80] Choo and Siow (2006a) have the same treatment However, in order to examine the impact of the one-child policy, the current work uses DiD regression on total gains, which are computed from the annual newlywed distribution

[81] The present study also uses 2000 census to plot the figures from 1970 to 1999, and the patterns are almost the same as using data from 2005 sub-census over this period

[82] For regression analysis on the trends, the sample includes individual observations and provincial dummies are controlled for in the regressions Moreover, Choo and Siow (2006a, b) only use the whole national data of the US and Canada to estimate the total gains for analysis These two studies also do not separate the data by the states or provinces for further investigation It would be interesting to examine the trends on marriage of Chinese people at city or provincial levels in the future

base); D_p is a set of dummies for province,[83] zhiziqu or zhixiashi; D_t is a set of year dummies; and X_i denotes other control variables, such as educational attainment.[84]

As an outcome of interest, for the age gap between spouses at their first marriage, the setting is similar: X_i includes the educational attainment of husband and wife (dummies) or educational gap between spouses (the difference between years of schooling).[85]

Third, to examine the assortative mating on age, this study computes and plots total gains (π_{ij})[86] using the information on newlyweds according to Equation (4.8) at two time spots: 1971/72 (from 2000 census) and 2003/04 (from 2005 sub-census).[87] When computing total gains, according to the date of initial marriage, the numbers of single men and women by the end of a specific year (e.g., the end of 2002) are traced. For the next period (e.g., 2003/04), the number of these original single (not yet married by the end of 2002) men and women who marry or opt to remain single over this period (e.g., by the end of 2004) are traced. The plots of total gains are interpreted to identify the kinds of assortative mating on age and the marriage age that bring higher total gains. To further examine whether the attractiveness to marry and the assortative

[83] The time horizon is from 1970 to 2004. Chongqing became a municipality in 1997. For simplicity, only a dummy is used for Chongqing and Sichuan Province.

[84] The OLS regression is used for the sample of married couples The results from Tobit regressions are similar Moreover, the results are nearly the same when using samples from 2000 census during 1970–1999 For the sake of brevity, the results are not shown

[85] Years of schooling is computed as follows 3 years for primary school below, 6 years for primary school, 9 years for junior high school, 12 years for high school/technical school, 15 years for college, 16 years for university, and 19 years for postgraduate or above

[86] As there are no marriages for some potential matches in which the husband is older than his wife by a significant number of years or vice versa, or both spouses are very old or very young during a period, the method by Choo and Siow (2006a) is followed Kernel smoothing is used for computing total gains when plotting a bivariate distribution of total gains by spouse age.

$$\bar{\pi}^t(k,l) = \sum_{j=1}^{J}\sum_{i=1}^{I} \omega_{ij}(k,l)\cdot \pi_{ij}^t, \tag{4.12}$$

where $\omega_{ij}(k,l) = \dfrac{(IJb^2)^{-1} K\left(\frac{i-k}{b}\right)\cdot K\left(\frac{j-l}{b}\right)}{(IJb^2)^{-1}\sum_{i=1}^{I}\sum_{j=1}^{J} K\left(\frac{i-k}{b}\right)\cdot K\left(\frac{j-l}{b}\right)}$.

Gaussian kernel weighting function is used, and the bandwidth is selected by examining various values in order to ensure appropriate smoothness However, to compute the difference in total gains across period and the DiD estimates on total gains, the present work does not apply smoothing because smoothing by itself may add nuisance to the estimate

[87] The shapes of the distribution of total gains are similar to other periods, thus, they are not shown

mating on age change over time, the changes in total gains from newlyweds are plotted across the following periods: 1971/72–1976/77, 1976/77–1981/82, 1981/82–1986/87, 1986/87–1991/92, 1991/92–1998/99, and 1998/99–2003/04.[88]

4.3.2.2. DiD Estimation to Identify the Impact of the One-Child Policy

In this section, we first explain why marital behavior of Zhuang and other non-Han people (excluding Man people) around 1989 is compared for analysis, and provide for the advantage of this comparison relative to the Han versus non-Han comparison.[89] Then, the framework of the DiD estimation is presented to identify the impact of the one-child policy on marriage rate, marriage age, and assortative mating on age.

The Reason for Comparing Zhuang people vs. Other Non-Han people (Excluding Man people)

In the early 1980s, Han households were strictly restricted to the one-child policy, whereas ethnic minorities were exempted from the policy. In 1984, the Chinese government declared that minorities should also follow the birth control policy; however, restriction remained loosely carried out toward them. In the late 1980s, the government announced that minority groups with populations of more than 10 million should be rigorously constrained to the one-child policy. At that time, the Zhuang ethnic group had a population of more than 10 million; thus, the local government of Guangxi started to impose the policy on the Zhuang people beginning September 1988. Other provinces followed suit and imposed the policy on the Zhuang people in their respective areas gradually. On a similar note, the Man people's population reached 10 million based on the 1990 census. Hence, the Man people have also been subjected to the birth control policy since the early 1990s (Li and Zhang, 2009).

[88] The differences in total gains over 1971/72–1976/77, 1976/77–1981/82, 1981/82–1986/87, 1986/87–1991/92, and 1991/92–1998/99 use information from 2000 census. The differences in total gains between 1998/99 and 2003/04 use information from 2005 sub-census.

[89] At present, the Han people are the largest ethnic group in China, accounting for 91 59% (approximately 1 2 billion) of the population Apart from the Han group, there are other 55 ethnic groups in Mainland China with a population of approximately 105 million people The 55 ethnic minorities mainly concentrate in the Northwest, North, Northeast, South, and Southwest China, although some live in central interior areas The largest minority group is Zhuang (16 1 million), followed by the Man (10 6 million)

This provides opportunity to apply DiD estimations on the marriage of Zhuang group and that of other non-Han groups. The following illustrates the reasons why Man people are excluded, as well as the advantage of this comparison. Appendix Tables 4.1 to 4.3 list the summary statistics of the socio-economic attributes of Han, Man, Zhuang, and other non-Han ethnics in 1982, 1990, and 2000, respectively.[90]

Evidently, from Appendix Table 4.1, the socio-economic attributes of the Zhuang and other non-Han people in 1982 were different from those of Han and Man people on the average. For instance, approximately 44% of Han Chinese and 51% of Man people had junior high educational level or above, whereas approximately 40% of Zhuang people and 30% of the other non-Han people had junior high school educational level or above. Moreover, according to the distribution of industrial structure and occupational status, over 80% of Zhuang and other non-Han groups worked in primary sectors, as compared to the 70% of Han people and 60% of Man people. Interestingly, on the average, the socio-economic attributes of Man people were close to or superior to those of Han people.

In Appendix Tables 4.2 and 4.3, the percentage of having urban *hukou* and the percentage of living in urban areas by gender and by ethnicity in 1990 and 2000 is reported, respectively.[91] In 1990, there were approximately 25% of Han and Man people with urban *hukou*, compared with less than 17% of Zhuang and other non-Han ethnics. Moreover, approximately 30% of Han and Man people lived in urban areas, as opposed to less than 25% of Zhuang and other non-Han people. As a whole, urbanization significantly lagged for the Zhuang and other minority groups compared with the Han and Man people. In addition, overall, non-Han Chinese (except the Man people) suffered from lower educational level, and over 80% worked in the primary sector in 1990. There were also significant differences between Han/Man groups and Zhuang/other non-Han groups in terms of these socio-economic conditions in 2000.

As a whole, in the case of socio-economic factors, Zhuang and other non-Han ethnics were close to each other and were systematically different from Han and Man ethnics.

[90] Throughout this chapter, other non-Han people refer to people in minority groups except for the Zhuang and Man people.

[91] The 1982 census data do not contain the information on *hukou* and residential areas.

The Man people founded the Qing Dynasty and ruled China for over 250 years, from 1644 to 1912. Most likely, the Man people had already been assimilated closely with Han people, and their historical privilege aided them to outperform other non-Han minorities on the average. Hence, Man people are excluded from the DiD estimation. Furthermore, with China's economic reform since 1979, the resulting changes in the socio-economic conditions of Zhuang and non-Han Chinese have been similar according to the summary of statistics for 1982, 1990, and 2000.

In the investigation on the impact of the one-child policy on marriage, we believe that comparing the behavior of Zhuang and other non-Han people around 1989 is better than that of the Han versus non-Han around 1980. First, as noted earlier, in terms of socio-economic factors, the Han people are systematically different from minority groups, except for the Man people. Moreover, the changes in socio-economic factors are also likely to be different for Han and non-Han people over time. In addition to the one-child policy, in the early 1980s, the impacts of the "open door" policy and the loosening of restrictions on early marriage were likely imposed differently towards Han and non-Han people. Hence, it is difficult to identify the effect of the one-child policy by comparing the behavior of Han and non-Han Chinese around the early 1980s.[92]

Zhuang People and the One-Child Policy since the Late 1980s

The aforementioned discussion shows that the DiD estimation is more suitably applied on the Zhuang and other non-Han people around 1989. Before getting into the details of the empirical framework, it is important to clarify whether the Zhuang people have been subjected to the one-child policy since the late 1980s. The mean numbers of children by the Han, Zhuang and other non-Han women by age in 1982 (using 1982 census), 1990 (using 1990 census), and 2000 (using 2000 census) are plotted in Appendix Figures 4.2.1a, b to 4.2.3a, b accordingly.[93] Based on Appendix

[92] Urban and rural households are constrained by this policy in different magnitude; these two types of households are also different in many other aspects

[93] To exclude the effects from geographical location and *hukou*, the OLS regression is first employed prior computing the residual The mean of residual number of children over women's age is then plotted The OLS regression is

Figure 4.2.1a, the number of children for Zhuang and other non-Han women were very close and higher than that of Han women for the ages of married women in 1982. Excluding the effect of geographical location, according to Appendix Figure 4.2.1b, the gap between Han and minority groups nearly disappears for women in their early twenties. However, Han women over 30 years old had a lesser number of children.

According to Appendix Figures 4.2.2a and b, the mean number of children for Zhuang and other non-Han women were almost the same for the ages of married women in 1990 with or without controlling the effects of *hukou* and geographical location. The average number of children for Han women was significantly lower at 30 years old and onwards, which is rather expected as they had been subjected to the one-child policy for almost 10 years.

More importantly, according to Appendix Figures 4.2.3a and b, the average number of children for Zhuang women was close to that of Han women for women aged 20-30; however, the values for Zhuang women converged with other non-Han women for ages 35 and older. Such pattern strongly supports that Zhuang couples had been subjected to the one-child policy since the late 1980s. Hence, a DiD estimation is applicable through comparing the behavior of Zhuang people relative to the rest of minority groups (excluding Man people) around 1989.

Empirical Framework of a DiD Estimation

Choo and Siow (2006a) use two periods before and after subjecting to legal abortion to compute DiD estimates on total gains between treatment and control groups for investigation. In the present work, the approach is applied by computing DiD

$$N_{jpu} = c + \sum_{p} \gamma_{1p} D_p + \gamma_2 D_u + \varepsilon_{jpu},$$

where j refers to a woman; N refers to the number of children to have; D_p is a set of dummies for province; and D_u is a dummy for having urban *hukou*.

Residual number of children $\hat{\varepsilon}_{jpu} = N_{jpu} - \hat{c} - \sum_{p} \hat{\gamma}_{1p} D_p - \hat{\gamma}_2 D_u$.

estimates on total gains from newlyweds on Zhuang people relative to other non-Han people between the periods of 1987/88 and 1994/95.[94]

A type of an individual is classified by age, Zhuang (z for male and Z for female) or other minority groups (n for male and N for female), and time (t). Herein, s and S are used to denote the race of a man and a woman, respectively, where $s \in \{z,n\}$ and $S \in \{Z,N\}$. For newlyweds, *t=87/88* refers to 1987/88 period, and *t=94/95* refers to 1994/95 period. Let μ_{ijt}^{sS} represent the number of (i, j) marriages of type (i) ethnic (s) men and type (j) ethnic (S) women at time t. Let the total gain from the marriage of a type (i) ethnic (s) man with a type (j) ethnic (S) woman at time t be π_{ijt}^{sS}. The impact of the policy can be estimated by the following DiD estimator:

$$\Delta^2 \pi_{ij}^{zZ} = \left(\hat{\pi}_{ij94/95}^{zZ} - \hat{\pi}_{ij87/88}^{zZ}\right) - \left(\hat{\pi}_{ij94/95}^{nN} - \hat{\pi}_{ij87/88}^{nN}\right), \qquad (4.13)$$

where $\hat{\pi}_{ijt}^{sS} = \ln\left(\frac{\mu_{ijt}^{sS}}{\sqrt{\mu_{i0t}^{sS}\mu_{0jt}^{sS}}}\right)$.

In the said equation, $\Delta^2 \pi_{ij}^{zZ}$ measures the impact of the one-child policy on the total gains of a particular match (i, j). For instance, if the policy leads to more men and women delaying their marriage [i.e., expected result (2.1)], then $\Delta^2 \pi_{ij}^{zZ}$ should be negative for couples married at their early twenties but positive for couples married from mid-twenties onwards.

Similarly, DiD estimates on newlywed rates of males and females can be computed. For instance,

$$\Delta^2 \rho_j^f = \left(\hat{\rho}_{j94/95}^{Z} - \hat{\rho}_{j87/88}^{Z}\right) - \left(\hat{\rho}_{j94/95}^{N} - \hat{\rho}_{j87/88}^{N}\right), \qquad (4.14)$$

where f refers to female; j denotes the age of the female; $\hat{\rho}$ represents the new marriage rate; Z denotes Zhang females; and N denotes females belonging to other non-Han ethnic minorities.

[94] As noted earlier, the Guangxi Government restricted Zhuang people to follow the one-child policy from September 1988 onwards, and people in other provinces were subject to the policy eventually in the 1990s Thus, 1987/88 is selected as the period before being subjected to the policy, and 1994/95 as the period after being subjected to the policy

Herein, $\Delta^2 \rho_j^f$ measures the impact of the policy on new marriage rate of female aged j. If the one-child policy discourages more women from marrying early, then $\Delta^2 \rho_j^f$ is negative for the new marriage rate of women aged early twenties but positive for of women aged mid-twenties or older. Such can be extended to prevailing marriage rates across two periods (1988 and 1999). The diagrams of the resulting DiD estimates on the marriage rates and total gains are plotted and analyzed in Section 4.4.2.

Empirical Framework of DiD Regression on Marriage Age and Marriage Rate

In fact, we have yearly information far before and after year 1989. Thus, apart from the above-mentioned approach proposed in Choo and Siow (2006a), for more precise estimations and implications, we also apply DiD estimation in a regression having multiple periods.

The following equation introduces the DiD regression framework to identify the effect of the policy on marriage age and marriage rate.[95]

$$Y_{it} = c + \tau_1 D_{89} + \lambda D^z + \beta D_{89}^z + X_t \alpha + v_{it}, \tag{4.15}$$

where i refers to an individual or a couple; t refers to a period; Y is the outcome of interest, including marriage age and age gap between spouses in year t; D_{89} is a dummy variable equal to 1 if an individual is married on or after 1989; D^z is a dummy variable equal to 1 if the individual/couple is of Zhuang descent; D_{89}^z is the interaction term of D^z and D_{89}; and X_t denotes other control variables, such as dummies for educational attainment, living in city and town (village as the base), and so forth.

The time dummy (D_{89}) captures the time factors that would affect the outcome of interest (Y) over time in the same way for both groups from 1989 onwards, even if the Zhuang people were not constrained by the policy. D^z captures the possible differences between Zhuang and other non-Han groups that do not change over time.

[95] The sample consists of observations for Zhuang and other non-Han Chinese only.

The coefficient (β) of D^z_{89} is expected to estimate the impact of the policy on the outcome (Y) of Zhuang people.

To examine further the effect on the people's marriage age and age gap between spouses over time, the current study adds interaction terms with a set of dummies for each year after enactment of the one-child policy (i.e., from 1989 onwards). The regression form changes as follows:

$$Y_{it} = c + \sum_{t=1989}^{1995} \tau_t D_t + \lambda\, D^z + \sum_{t=1989}^{1995} \beta_t\, D^z_t + X_i \alpha + v_{it}, \qquad (4.16)$$

where D_t is a set of year dummy for time beginning 1989, and D^z_t is a set of interaction terms of D_t and D^z. The aforementioned setting allows $\beta_t \neq \beta_{t'}$ $(t \neq t')$. Hence, the policy effect over time can be estimated.

In addition, the regression form for the newlywed rate is

$$\rho_{at} = c + \sum_{a=20}^{34} \alpha_a D_a + \tau_1 D_{89} + \lambda\, D^z + \sum_{a=20}^{34} \beta_a D^z_{a89} + v_{at}, \qquad (4.17)$$

where ρ_{at} is the newlywed rate (or prevailing marriage rate) of Zhuang or other non-Han people aged a at period t; D_a is a set of age dummies from 20–34 years old or above during their wedding; D_{89} is a dummy variable equal to 1 if an individual is married on or after 1989; D^z is a dummy variable equal to 1 if the individual is of Zhuang descent; and D^z_{a89} is a set of interaction terms across D_a, D^z, and D_{89}. Herein, α_a measures the average proportion of people aged a who marry; τ_1 captures the time effect on marriage rate from 1989 onwards; λ measures the extra effect on the rate if people are of Zhuang descent, relative to other non-Han people; β_a, the interest, measures the extra effect on marriage rate for Zhuang people aged a who married on or after 1989, which is expectedly influenced by the one-child policy.

For marriage age, age gap in newlyweds, and newlywed marriage rate, the sample covers the period of 1985 to 1995.[96] In the case of prevailing marriage rate, the regression form is similar to Equation (4.17). It takes time to reflect the influence on prevailing marriage rate at particular time spots; therefore, the period is extended from 1985 to 1999 for prevailing marriage rate.

Empirical Framework of DiD Regression on Total Gains

In order to estimate the impact of the one-child policy on assortative mating on age, DiD regression is applied on total gains. Herein, π_{ijt} denotes the total gains from a particular mating in which husbands are aged i and wives are aged j at period t. For simplicity, the possible age matches are separated into broader categories. Let m denote a specific category of age match. Table 4.1 displays the first set, in which ages of husbands and wives are classified under six categories: 16 years old or below, 17–19 years old, 20–22 years old, 23–26 years old, 27–29 years old, and 30 years old or above. There are 26 possible outcomes of mating (m) in terms of the age of spouses. The base group shows the matches in which either spouse or both spouses are 16 years old or below. Category 2 represents mating in which both husbands and wives are 17–19 years old. Category 3 represents mating in which husbands are 17–19 years old, while wives are 20–22 years old.

[96] The DiD approach may confound the impact of the one-child policy with the impact of other changes that may have occurred from 1989 onwards but may have affected Zhuang and other non-Han minority groups differently. To avoid this problem, 11 years (1985–1995) is selected as the length of the period for the outcomes on newlyweds. The regression results are similar when the duration of period is lengthened.

Table 4 1 The First Set of Possible Matches by Spouse Age

Male \ Female	15 16	17 18 19	20 21 22	23 24 25 26	27 28 29	>=30
15 16				1		
17 18 19		2	3	4	5	6
20 21 22	1	7	8	9	10	11
23 24 25 26		12	13	14	15	16
27 28 29		17	18	19	20	21
>=30		22	23	24	25	26

Table 4 2 The Second Set of Possible Matches by Spouse Age

Male \ Female	15 16	17	18	19	20	21	22	23	24	25	26	27	28	29	>=30
15															
16									1						
17															
18		2	3	4	5	6	7				8				
19		9	10	11	12	13	14	15				16			
20		17	18	19	20	21	22	23	24				25		
21		26	27	28	29	30	31	32	33	34			35		
22		36	37	38	39	40	41	42	43	44	45			46	
23		47	48	49	50	51	52	53	54	55	56	57		58	
24	1	59	60	61	62	63	64	65	66	67	68	69	70	71	
25		72	73	74	75	76	77	78	79	80	81	82	83	84	85
26		86	87	88	89	90	91	92	93	94	95	96	97	98	99
27		100		101	102	103	104	105	106	107	108	109	110	111	112
28			113		114	115	116	117	118	119	120	121	122	123	124
29				125		126	127	128	129	130	131	132	133	134	135
30				136			137	138	139	140	141	142	143	144	145
31					146			147	148	149	150	151	152	153	154
32					155						156				157
>=33						158					159				160

Table 4.2 displays the second set of possible matches, with 160 possible outcomes based on spouse age.

The DiD regression form on total gain is

$$\pi_{yt} = c + \sum_{m} \alpha_m D_m + \sum_{t=1989}^{1995} \tau_t D_t + \lambda D^z + \sum_{m} \beta_m D^z_{m89} + v_{yt}, \quad (4.18)$$

where D_m is a set of dummies equal to 1 for a specific type of match, and D^z_{m89} equals 1 if the couple is of Zhuang ethnic with a specific mating type (m) married on 1989 or after.

The above-mentioned DiD regression is employed for total gains to examine the impact of the policy on assortative age mating. A change in total gains on a specify type of age mating represents the change in marital attractiveness of this type of age mating. For instance, the policy may lead to more marriages wherein husbands are younger than their wives. If so, the coefficients (β_m) of interaction terms in Equation (4.19) are expected to be positively significant corresponding to the matches with husbands being younger than wives, such as m = 9, 10, 11, and so forth, in the first set of possible age mating (Table 4.1).

Herein, the sample covers Zhuang and other non-Han people aged 15-41 or above from 1985 to 1995. Total gain (π_{yt}) is computed from the newlywed information from the 2000 census.[97]

4.4. Results

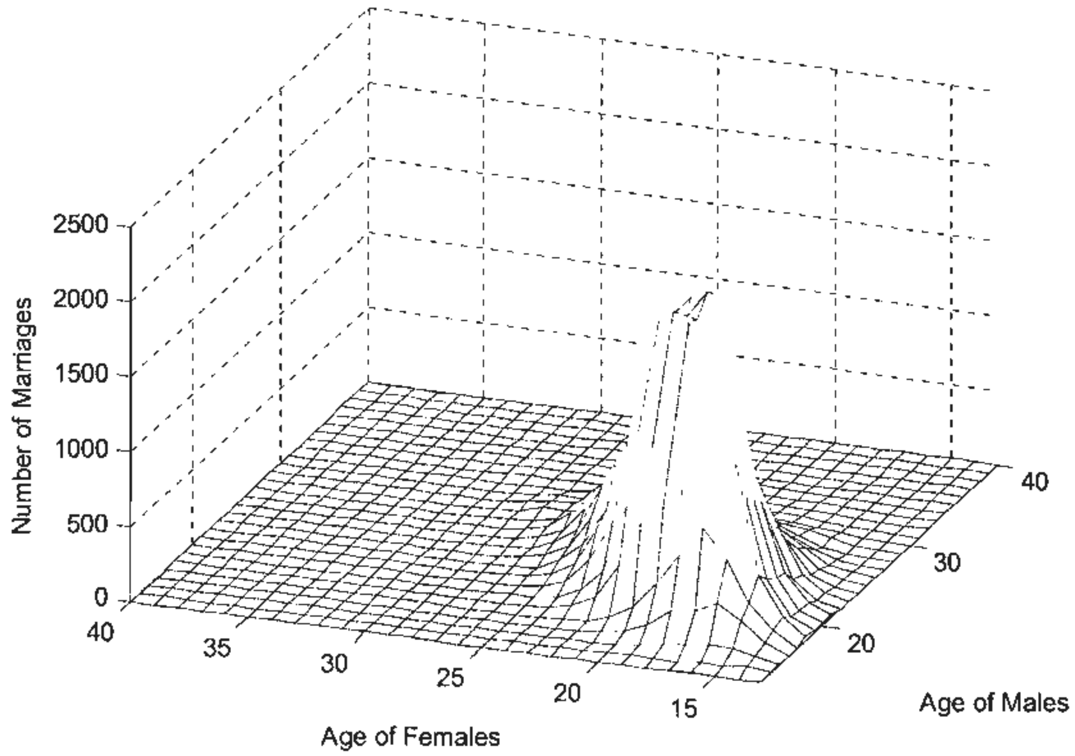
4.4.1. Trends for 1970–2004

In this section, the trends on marriage age, marriage rate, and assortative mating on age from 1970 to 2004 are examined.

[97] As noted earlier, the total gains are computed from new marriage distribution for each year rather than from combined biennial new marriage distribution for regression analysis.

First, the bivariate distribution of newlyweds over spouse age across time is plotted.[98] According to Figure 4.1.1a, the shape of the distribution is quite steep and the peak mainly clusters around late nineteen and early twenties of men and women. This suggests that in 1971/72, a number of men and women married at by the time they were 20 years old or earlier. However, in 1981/82, as shown in Figure 4.1.1.b, the peak of the distribution shifted to couples in their mid-twenties, also manifesting a steeper distribution. This indicates that most people married in their mid-twenties due to the official promotion of late marriage throughout the 1970s. Then, as shown by Figure 4.1.1c, in 1991/92, many people married in their "new" statutory minimum ages, as mandated by law in 1980 (i.e., 20 for women and 22 for men). Based on Figure 4.1.1d, in 1998/99, more people married in their mid-twenties. In Figure 4.1.1e, for 2003/04, the shape was less sharp relative to 1991/92 and 1998/99, indicating that more people diversified their timing of marriage and more people resorting to delayed marriage.

Fig. 4.1.1a: Distribution of New Marriages by Spouse Age in 1971/72



[98] The newlywed information in 1971/72, 1981/82, 1991/92, and 1998/99 comes from the 2000 census, and the newlywed information in 2003/04 comes from the 2005 sub-census. In the diagrams of newlywed distribution and total gains over the age of the spouses, the age of newly married individuals refers to the age from the previous period. For example, for 1998/99, 21 refers to 21 years old in 1997, and the individual is approximately 22 to 23 years old at the time of marriage. For the analysis on prevailing marriage distribution, the age refers to the age in that period. For instance, in year 1980, age refers to the age by the end of 1980.

Fig. 4.1.1b: Distribution of New Marriages by Spouse Age in 1981/82

Fig. 4.1.1c: Distribution of New Marriages by Spouse Age in 1991/92

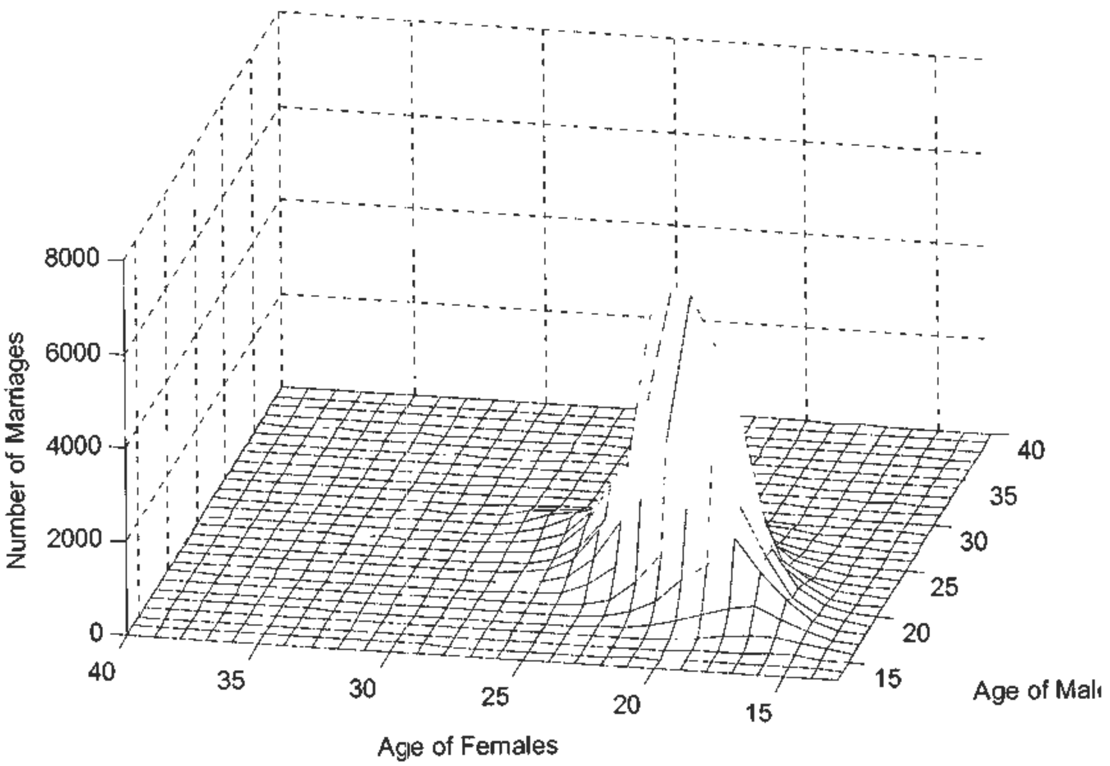


Fig. 4.1.1d: Distribution of New Marriages by Spouse Age in 1998/99

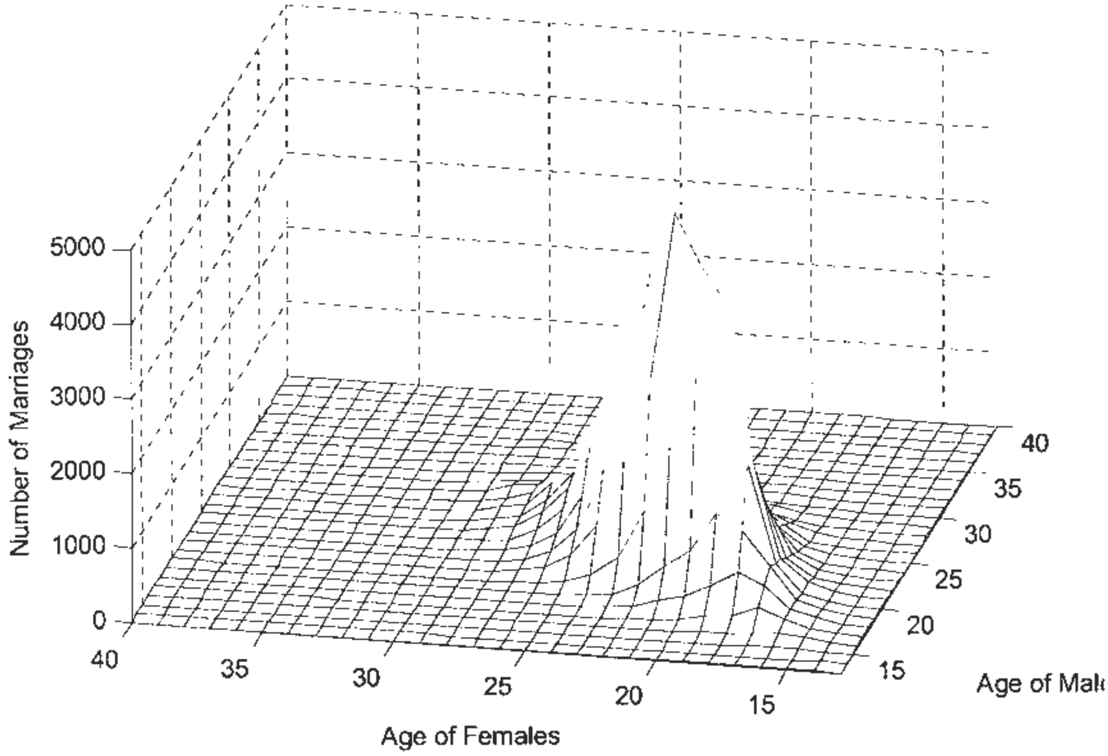
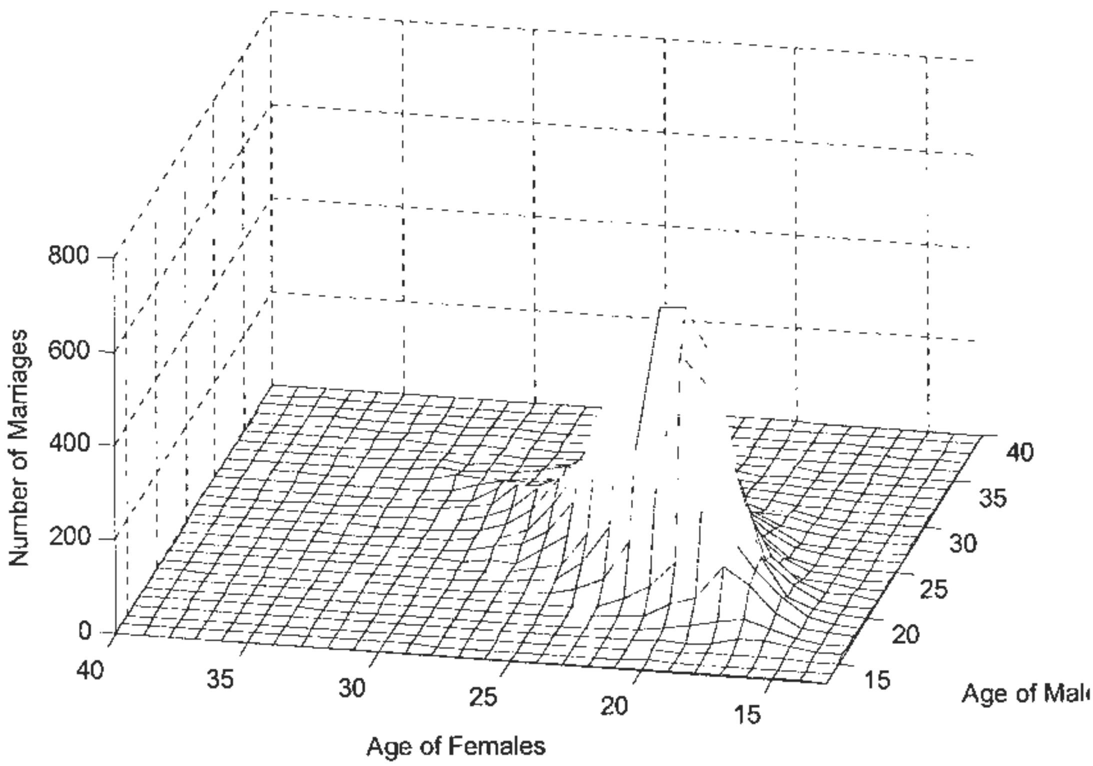
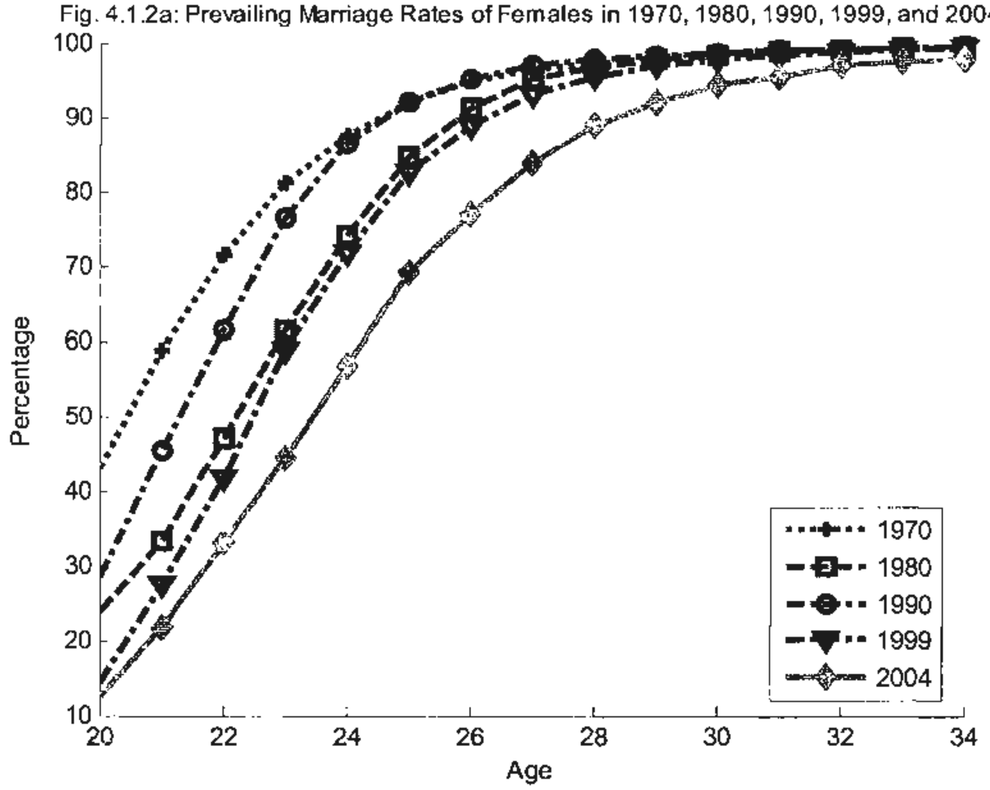


Fig. 4.1.1e: Distribution of New Marriages by Spouse Age in 2003/04



The following segments focus on the prevailing marriage rates of women and men for 1970, 1980, 1990, 1999, and 2004 (Figures 4.1.2a and b).[99] By the figures, more men and women tended to delay their marriage in 1990–2004. Thus, the findings are consistent with the expected result (1.1). Interestingly, the actual prevailing marriage rates for women and men are maintained at over 95% and 90% when women were over 30 years old and men were 35 years old or above for these 35-year interval.[100]

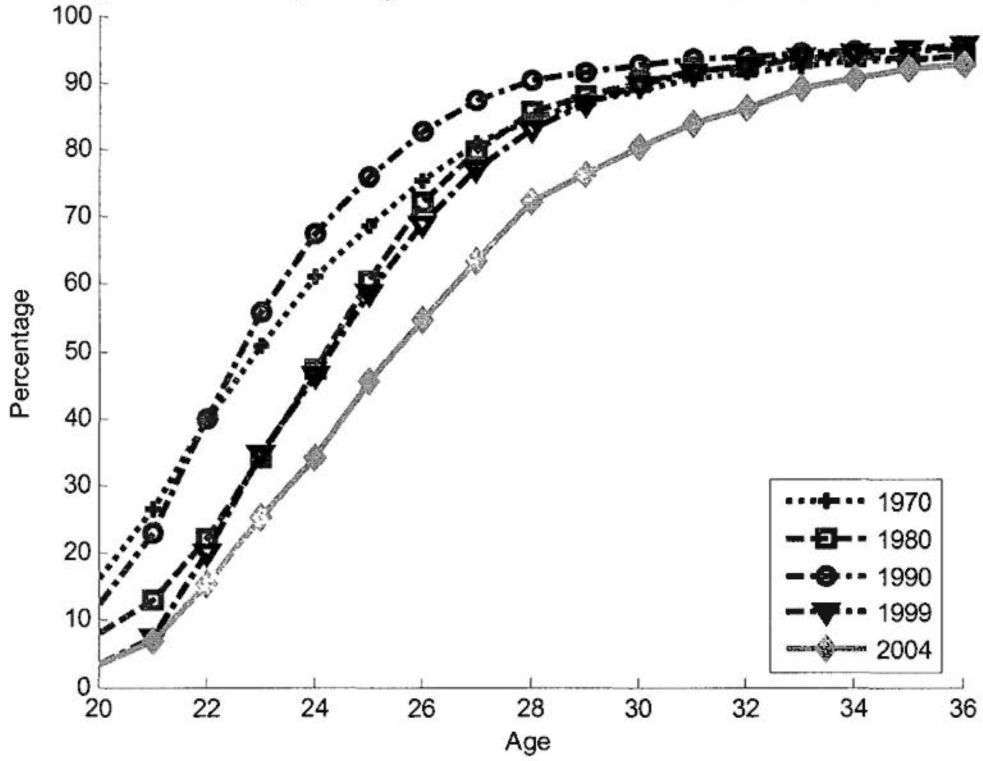
Fig. 4.1.2a: Prevailing Marriage Rates of Females in 1970, 1980, 1990, 1999, and 2004



[99] The information for prevailing marriage rate of women and men in 1970, 1980, 1990, and 1999 comes from 2000 census, and those in 2004 comes from 2005 sub-census.

[100] Evidence from other countries indicates that the marriage rate of men and women fall, and that the marriage age of men and women increases with economic development, expanding cohabitation, and increased complexity in their respective career. Several studies (Qian, 1998; Gould and Paserman, 2003; Kuo, 2005) point out that the marriage rates of Americans decreased greatly between 1970 and 2000. Ellas (2003) finds that the percentage of married women between the ages of 17 and 29 in Argentina fell from 37% in 1980 to 16% in 1999. Iwasawa and Mita (2008) indicate that the first marriage rates of Japanese people fell sharply continuously from 1970s onwards.

Fig. 4.1.2b: Prevailing Marriage Rates of Males in 1970, 1980, 1990, 1999, and 2004



Third, the present study focuses on the characteristics of age gap between spouses in 1970–2004. Figure 4.1.3a shows the average number of years newlywed grooms who are older than their brides with respect to the age of brides among newlyweds[101] in 1970, 1980, 1990, 2000, and 2004.[102] Similar to the findings in other countries like the US (Oppenheimer, 1988), the years of groom being older than brides fell when women's age at marriage increased. Such attribute persisted from 1970 to 2004. In particular, the average number of years wherein grooms are older than their brides is negative (from 0 to -2) for women who married at age 32–34 years in 2004. This indicates that the marriages where wives are older than their husbands appeared more frequently when women married at 32 years old onwards. Moreover, Figure 4.1.3b illustrates the mean number of years of grooms who are older than their brides with respect to grooms' age among newlyweds (1970, 1980, 1990, 2000, and 2004). Interestingly, the relationship between age gap and men's marriage age is positive, suggesting that even among men who marry late (i.e., in their late twenties or above), they prefer to find young women aged around the mid-twenties in general. Again,

[101] All were first marriages.

[102] Data from 2005 sub-census are used to plot Figures 4.1.3a and b. Data from 2000 census are used to plot and determine nearly the same characteristics in 1970, 1980, 1990, and 1999.

from the perspective of the men, while the pattern of finding younger women persists, the mean number of years for their wives to be younger fell over time. For instance, the mean age gap between spouses for men married at 30 years old in 2004 is lower than that in 1970 by approximately two years.

Fig. 4.1.3a: Average Number of Years Groom Older than Bride by Age of Bride between 1970 and 2004

Fig. 4.1.3b: Average Number of Years Groom Older than Bride by Age of Groom between 1970 and 2004

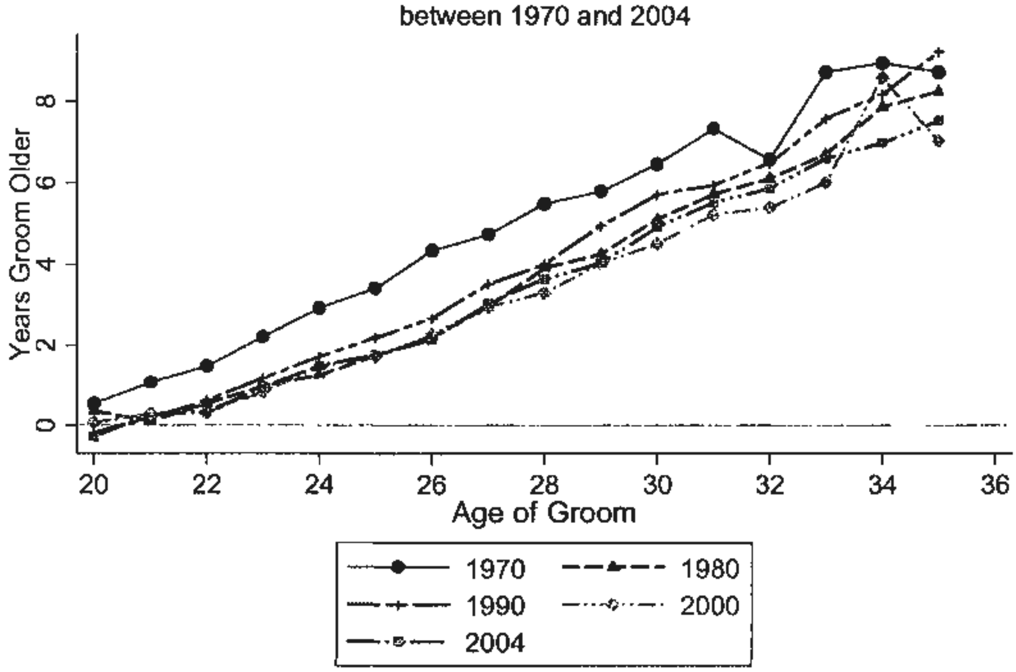


Fig. 4.1.4: Mean Age of Grooms & Brides and Age Gap between Spouses in Newlyweds between 1970 and 2004

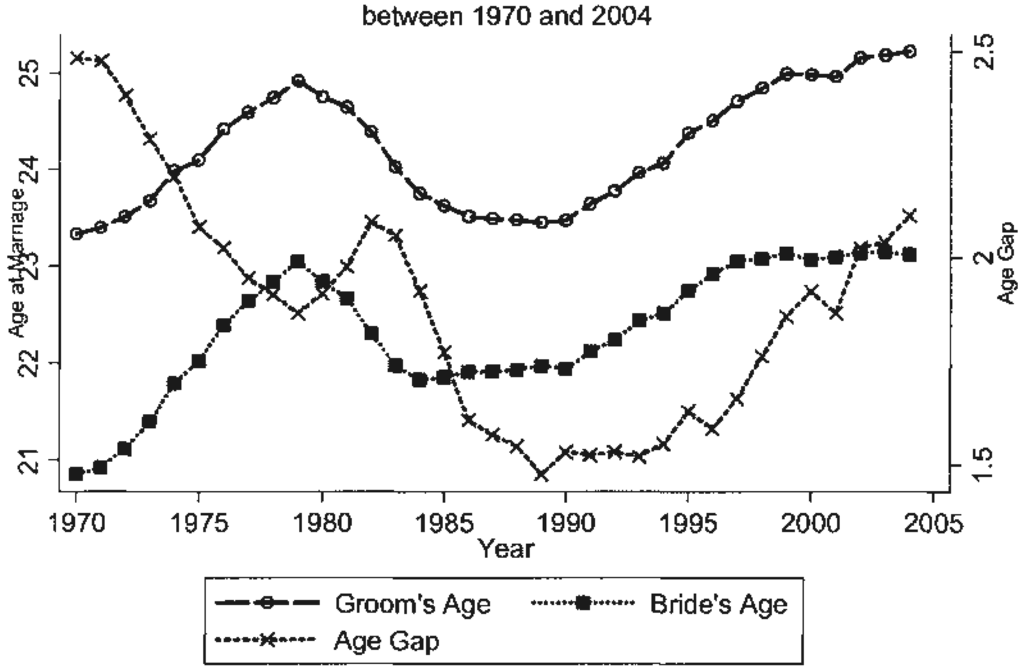


Figure 4.1.4 shows the trends on the mean ages of men and women, as well as the mean age gap between spouses in new marriages, from 1970 to 2004.[103] The trends on marriage age are similar for men and women, and can be divided into three stages. Throughout the 1970s, the mean marriage age increased continuously, from 23 to 25 years for men (see line with circles) and from 21 to 23 years for women (see line with squares). Such delay was obviously due to the governmental advocacy campaigns. Then, the marriage age for men fell gradually to 23.5 years old, close to the initial level in 1970, and flattened at this level until the late 1980s. The trend for women's marriage age was similar; however, the duration was shorter and the extent of the fall was smaller. Women's mean marriage age fell to 22 only in the mid-1980s (rather than to 21 at the beginning of 1970), and then almost flattened at this level until the late 1980s. The mean age at marriage of men and women increased in late 1980s–2004 from 23.5 to 25.5 and 22 to 23 for men and women, respectively. The positive age gap between spouses became smaller, from 2.5 years to approximately 1.9 years, in the 1970s [i.e., the fall is expected and consistent with expected result (1.2)]. When

[103] Data from 2000 census are used to compute and plot the trend of mean marriage ages and mean age gap between 1970 and 1999, and to obtain almost the same results.

men and women's marriage age fell, the positive age gap increased sharply in the early 1980s. This is predictable as more young men and women married during the period, with young women preferring to marry men who are a few years older. However, surprisingly, the age gap fell continuously from year 1984 until the late 1980s (from 2.1 years to 1.5 years). Meanwhile, the mean age at marriage of men and women varied only slightly over this period. Other exogenous factors might exist, attributing to the smaller age gap.[104] Age gap rose gradually from 1.5 years to 2.1 years between 1990 and 2004. This is likely due to the increase in the marriage age of men, which outweighs the rising marriage age of women on average. As a whole, the magnitude of fluctuation in the mean age gap was small at ±1 year during 1970–2004.

Fourth, to obtain a more precise estimate on the time effect on marriage age and age gap in 1970–2004, the current work utilizes OLS regression,[105] with data on new marriages acquired from 2005 sub-census.[106]

Table 4.3 displays the OLS estimates of the impact of time factor, educational attainment, obtaining an urban *hukou*, and living in urban areas on marriage age of males and females. The OLS estimates of year dummies for marriage age are consistent with findings, as shown in Figure 4.1.4. For instance, relative to 1970 (base year), the estimated coefficients in the 1970s are significantly positive by up to 1.6 years for men and 2.0 years for women in 1979. The OLS results also support people delaying their marriage in the 1990s and early 2000s relative to early 1980s. Moreover, significant positive coefficients of dummies for city, town, and urban *hukou* are expected. According to the results, people tend to marry later by approximately one year when living in urban areas than in rural areas. In addition, the significant positive estimates of dummies for female higher educational attainment indicate that higher educated females marry in their later years.

Table 4.4 shows the OLS regression results on the age gap between spouses over time. The OLS estimates of time dummies on age gap, even by controlling the educational

[104] Famine-born-cohorts (born between 1959 and 1961) were in their early twenties in the early 1980s when they entered the marriage markets. The distortion brought about by the Great Famine (1951–1961) led to a sudden decline on fertility, resulting in a sharp change in the sex ratio of marriageable men to women in the 1980s. This may be an interesting focus of future study.
[105] Tobit regressions are used, and results are qualitatively very similar.
[106] Data from 2000 census are used, and the regression results are very close for 1970–1999

achievement, *hukou* status, and residential areas of the couples, are consistent with the time trend shown in Figure 4 1 4 The coefficients of junior high school, high school, and college dummies for the husband and wife are significantly negative By controlling the educational level of a spouse, one's schooling level is evidently higher, while the age gap between spouses is smaller

Table 4 3 OLS Results on Marriage Age of Males and Females between 1970 and 2004

Dependent Variables	Marriage Age of Males			Marriage Age of Females		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	23 117***	23 141***	23 176***	20 469***	20 509***	20 475***
	(0 042)	(0 041)	(0 041)	(0 033)	(0 033)	(0 033)
Junior High School	-0 903***	-0 904***	-0 788***	0 224***	0 093***	0 186***
	(0 015)	(0 016)	(0 016)	(0 011)	(0 012)	(0 012)
High School	-0 473***	-0 539***	-0 055***	0 940***	0 792***	1 210***
	(0 020)	(0 020)	(0 020)	(0 018)	(0 018)	(0 017)
College or Above	0 079***	0 017	0 904***	1 369***	1 225***	1 843***
	(0 026)	(0 026)	(0 024)	(0 024)	(0 024)	(0 021)
Urban Hukou	1 783***	1 782***		1 278***	1 313***	
	(0 015)	(0 015)		(0 013)	(0 013)	
City			1 259***			0 966***
			(0 014)			(0 012)
Town			0 339***			0 342***
			(0 015)			(0 013)
Married in						
1971	0 081	0 065	0 059	0 078	0 069	0 072
	(0 063)	(0 063)	(0 063)	(0 050)	(0 049)	(0 049)
1972	0 253***	0 249***	0 238***	0 299***	0 310***	0 313***
	(0 060)	(0 059)	(0 059)	(0 048)	(0 047)	(0 047)
1973	0 435***	0 423***	0 383***	0 561***	0 580***	0 576***
	(0 060)	(0 059)	(0 059)	(0 048)	(0 047)	(0 047)
1974	0 753***	0 741***	0 693***	0 936***	0 933***	0 926***
	(0 059)	(0 058)	(0 058)	(0 048)	(0 047)	(0 047)
1975	0 909***	0 910***	0 835***	1 178***	1 152***	1 128***
	(0 055)	(0 055)	(0 055)	(0 046)	(0 045)	(0 045)
1976	1 220***	1 206***	1 133***	1 508***	1 484***	1 464***
	(0 055)	(0 054)	(0 054)	(0 046)	(0 045)	(0 045)
1977	1 392***	1 385***	1 291***	1 719***	1 679***	1 652***
	(0 056)	(0 055)	(0 055)	(0 047)	(0 046)	(0 046)
1978	1 583***	1 558***	1 463***	1 913***	1 891***	1 860***
	(0 053)	(0 052)	(0 053)	(0 044)	(0 043)	(0 043)
1979	1 722***	1 696***	1 598***	2 048***	2 022***	1 992***
	(0 052)	(0 051)	(0 051)	(0 044)	(0 043)	(0 043)
1980	1 567***	1 552***	1 450***	1 795***	1 774***	1 741***
	(0 050)	(0 049)	(0 050)	(0 042)	(0 041)	(0 041)
1981	1 405***	1 369***	1 272***	1 525***	1 498***	1 462***
	(0 051)	(0 050)	(0 051)	(0 043)	(0 043)	(0 043)
1982	1 208***	1 189***	1 060***	1 174***	1 186***	1 130***
	(0 052)	(0 051)	(0 052)	(0 044)	(0 043)	(0 043)

	(1)	(2)	(3)	(4)	(5)	(6)
1983	0.939***	0.927***	0.768***	0.895***	0.904***	0.835***
	(0.053)	(0.052)	(0.053)	(0.044)	(0.043)	(0.043)
1984	0.683***	0.669***	0.516***	0.761***	0.787***	0.719***
	(0.053)	(0.052)	(0.053)	(0.042)	(0.041)	(0.041)
1985	0.570***	0.571***	0.398***	0.780***	0.798***	0.722***
	(0.051)	(0.051)	(0.051)	(0.041)	(0.040)	(0.040)
1986	0.439***	0.438***	0.268***	0.805***	0.819***	0.739***
	(0.051)	(0.050)	(0.050)	(0.041)	(0.040)	(0.040)
1987	0.402***	0.393***	0.236***	0.801***	0.818***	0.750***
	(0.050)	(0.050)	(0.050)	(0.040)	(0.039)	(0.039)
1988	0.399***	0.398***	0.231***	0.837***	0.876***	0.800***
	(0.050)	(0.049)	(0.049)	(0.040)	(0.040)	(0.040)
1989	0.373***	0.377***	0.207***	0.872***	0.925***	0.845***
	(0.050)	(0.049)	(0.049)	(0.041)	(0.040)	(0.040)
1990	0.429***	0.433***	0.258***	0.875***	0.929***	0.843***
	(0.050)	(0.049)	(0.049)	(0.040)	(0.039)	(0.040)
1991	0.581***	0.590***	0.413***	1.030***	1.095***	1.004***
	(0.051)	(0.051)	(0.051)	(0.042)	(0.041)	(0.041)
1992	0.690***	0.699***	0.525***	1.123***	1.193***	1.104***
	(0.051)	(0.050)	(0.050)	(0.042)	(0.041)	(0.041)
1993	0.862***	0.864***	0.681***	1.290***	1.360***	1.267***
	(0.051)	(0.050)	(0.050)	(0.041)	(0.041)	(0.041)
1994	0.985***	0.977***	0.794***	1.385***	1.461***	1.367***
	(0.050)	(0.050)	(0.050)	(0.041)	(0.041)	(0.041)
1995	1.286***	1.269***	1.075***	1.603***	1.672***	1.564***
	(0.052)	(0.051)	(0.051)	(0.043)	(0.042)	(0.042)
1996	1.382***	1.372***	1.191***	1.720***	1.789***	1.691***
	(0.052)	(0.052)	(0.052)	(0.043)	(0.042)	(0.042)
1997	1.561***	1.568***	1.386***	1.811***	1.879***	1.779***
	(0.053)	(0.052)	(0.052)	(0.044)	(0.044)	(0.044)
1998	1.694***	1.683***	1.489***	1.842***	1.900***	1.783***
	(0.053)	(0.053)	(0.053)	(0.044)	(0.043)	(0.043)
1999	1.823***	1.810***	1.622***	1.863***	1.917***	1.791***
	(0.054)	(0.053)	(0.053)	(0.046)	(0.045)	(0.045)
2000	1.835***	1.818***	1.623***	1.812***	1.882***	1.747***
	(0.054)	(0.053)	(0.054)	(0.046)	(0.045)	(0.045)
2001	1.822***	1.814***	1.609***	1.833***	1.877***	1.739***
	(0.055)	(0.055)	(0.055)	(0.048)	(0.047)	(0.047)
2002	2.043***	2.031***	1.814***	1.892***	1.935***	1.781***
	(0.057)	(0.056)	(0.056)	(0.048)	(0.047)	(0.048)
2003	2.084***	2.068***	1.844***	1.903***	1.942***	1.773***
	(0.055)	(0.054)	(0.054)	(0.045)	(0.045)	(0.045)
2004	2.134***	2.092***	1.841***	1.880***	1.916***	1.734***
	(0.056)	(0.055)	(0.056)	(0.046)	(0.045)	(0.045)
Obs	403536	403536	403536	403536	403536	403536
R-square	0.109	0.145	0.128	0.129	0.169	0.159

Notes:
Robust standard errors are reported in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.
In Columns (2), (3), (5) and (6), OLS regressions control provincial dummies.

Table 4 4 OLS Results of Age Gap between Spouses between 1970 and 2004

Dependent Variable	Age Gap between Spouses		
	(1)	(2)	(3)
Constant	2 705***	2 705***	2 750***
	(0 039)	(0 039)	(0 039)
Husband's Junior High School Dummy	-0 779***	-0 779***	-0 752***
	(0 015)	(0 015)	(0 015)
Husband's High School Dummy	-0 634***	-0 634***	-0 507***
	(0 020)	(0 020)	(0 020)
Husband's College Dummy	-0 516***	-0 516***	-0 288***
	(0 028)	(0 028)	(0 027)
Wife's Junior High School Dummy	-0 310***	-0 310***	-0 258***
	(0 014)	(0 014)	(0 014)
Wife's High School Dummy	-0 499***	-0 499***	-0 339***
	(0 021)	(0 021)	(0 020)
Wife's College Dummy	-0 714***	-0 714***	-0 545***
	(0 030)	(0 030)	(0 029)
Husband's Urban Hukou	0 470***	0 470***	
	(0 024)	(0 024)	
Wife's Urban Hukou	0 073***	0 073***	
	(0 025)	(0 025)	
City			0 244***
			(0 013)
Town			-0 006
			(0 014)
Married in			
1971	-0 015	-0 015	-0 017
	(0 060)	(0 060)	(0 060)
1972	-0 073	-0 073	-0 078
	(0 056)	(0 056)	(0 056)
1973	-0 180***	-0 180***	-0 195***
	(0 055)	(0 055)	(0 055)
1974	-0 224***	-0 224***	-0 240***
	(0 055)	(0 055)	(0 055)
1975	-0 273***	-0 273***	-0 297***
	(0 052)	(0 052)	(0 052)
1976	-0 309***	-0 309***	-0 333***
	(0 052)	(0 052)	(0 052)
1977	-0 333***	-0 333***	-0 364***
	(0 052)	(0 052)	(0 052)
1978	-0 371***	-0 371***	-0 405***
	(0 050)	(0 050)	(0 050)
1979	-0 369***	-0 369***	-0 404***
	(0 048)	(0 048)	(0 048)
1980	-0 270***	-0 270***	-0 309***
	(0 047)	(0 047)	(0 047)
1981	-0 184***	-0 184***	-0 225***
	(0 048)	(0 048)	(0 048)
1982	-0 047	-0 047	-0 101**
	(0 048)	(0 048)	(0 048)

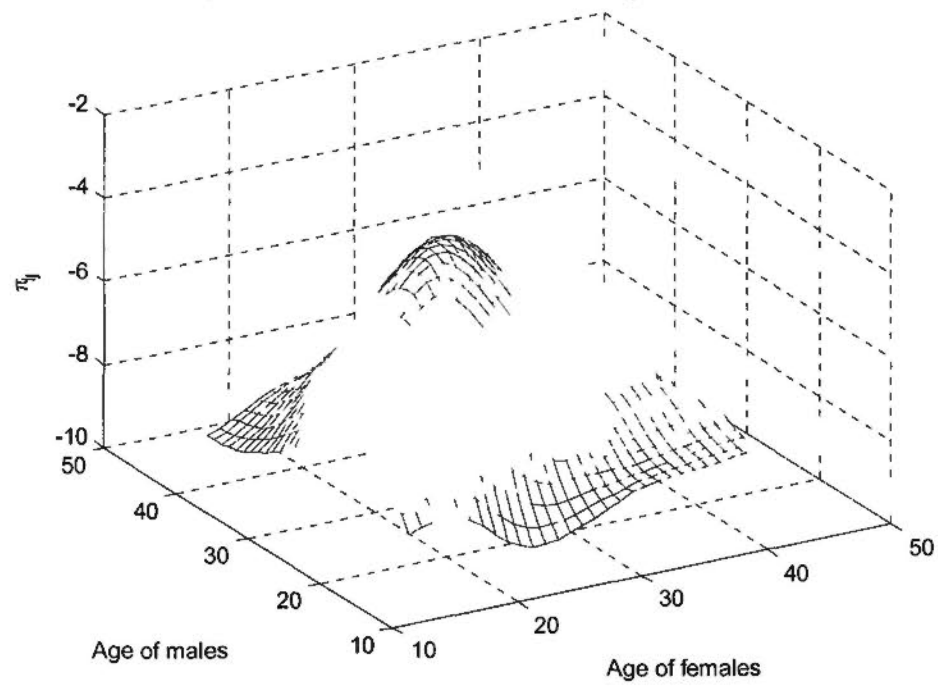
1983	-0.034	-0.034	-0.100**
	(0.049)	(0.049)	(0.049)
1984	-0.168***	-0.168***	-0.233***
	(0.049)	(0.049)	(0.049)
1985	-0.280***	-0.280***	-0.349***
	(0.047)	(0.047)	(0.047)
1986	-0.429***	-0.429***	-0.497***
	(0.047)	(0.047)	(0.047)
1987	-0.478***	-0.478***	-0.541***
	(0.047)	(0.047)	(0.047)
1988	-0.523***	-0.523***	-0.588***
	(0.046)	(0.046)	(0.046)
1989	-0.597***	-0.597***	-0.663***
	(0.046)	(0.046)	(0.046)
1990	-0.543***	-0.543***	-0.611***
	(0.046)	(0.046)	(0.046)
1991	-0.550***	-0.550***	-0.619***
	(0.048)	(0.048)	(0.048)
1992	-0.541***	-0.541***	-0.608***
	(0.047)	(0.047)	(0.047)
1993	-0.547***	-0.547***	-0.618***
	(0.047)	(0.047)	(0.047)
1994	-0.530***	-0.530***	-0.602***
	(0.047)	(0.047)	(0.047)
1995	-0.444***	-0.444***	-0.518***
	(0.048)	(0.048)	(0.048)
1996	-0.463***	-0.463***	-0.536***
	(0.048)	(0.048)	(0.048)
1997	-0.360***	-0.360***	-0.434***
	(0.048)	(0.048)	(0.048)
1998	-0.254***	-0.254***	-0.333***
	(0.049)	(0.049)	(0.049)
1999	-0.142***	-0.142***	-0.221***
	(0.050)	(0.050)	(0.050)
2000	-0.091*	-0.091*	-0.173***
	(0.050)	(0.050)	(0.050)
2001	-0.089*	-0.089*	-0.176***
	(0.051)	(0.051)	(0.051)
2002	0.08	0.08	-0.012
	(0.052)	(0.052)	(0.052)
2003	0.112**	0.112**	0.016
	(0.051)	(0.051)	(0.051)
2004	0.168***	0.168***	0.063
	(0.051)	(0.051)	(0.051)
Observations	403536	403536	403536
R-square	0.068	0.068	0.066

Notes:
Robust standard errors are reported in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.
OLS regressions control provincial dummies.

Fifth, the smoothed total gains from newlyweds in 1971/72 and 2003/04 are plotted in Figures 4.1.5a and b, respectively.[107] As illustrated earlier, intuitively speaking, total gains represent the systematic marital output of a marriage (i, j) minus the systematic output of both parties remaining single. Hence, on the average, the higher the total gains, the more attractive the mating.

In general, the distribution of total gains is displayed as coned-shaped. Total gains do not monotonically increase or decrease along with the marriage ages of either male or female, but instead depend on marriage age of both and the age gap between spouses. The total gains are higher for men and women married in their early to mid-twenties. This is expected, as many would like to marry within this age range. Total gains are lower for very young and very old couples, as these kinds of mating are less popular and less frequent among all possible (i, j) marriages. Moreover, the tradition for age gap normally pertains to grooms who are usually of the same age or slightly older (by a few years) than their brides. This is also the reason the total gains fall when the age gap of a couple widens.

Fig 4 1 5a Smoothed Total Gains from Newlyweds in 1971/72



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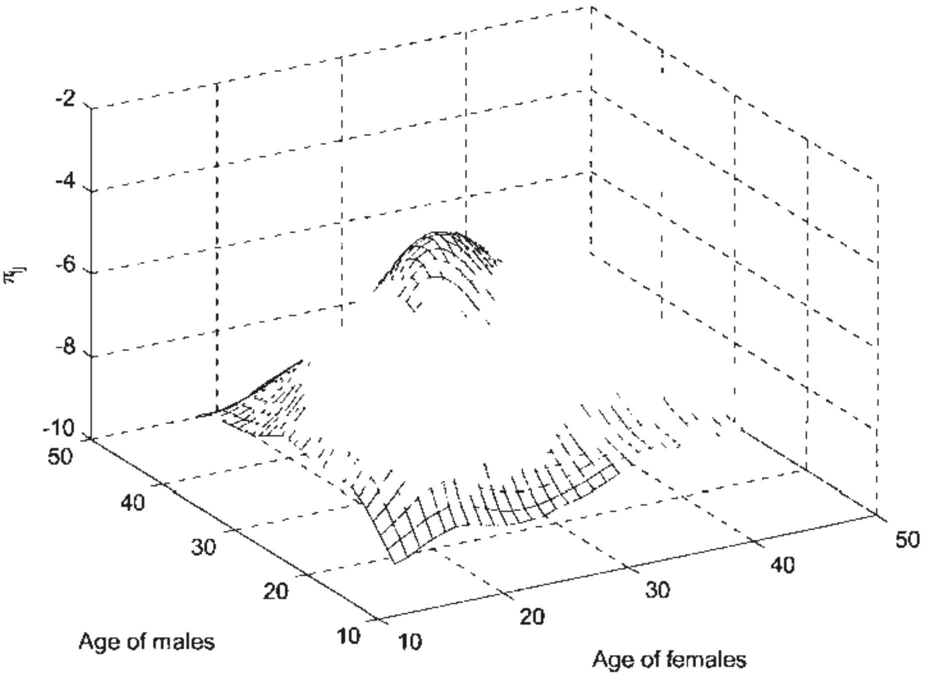
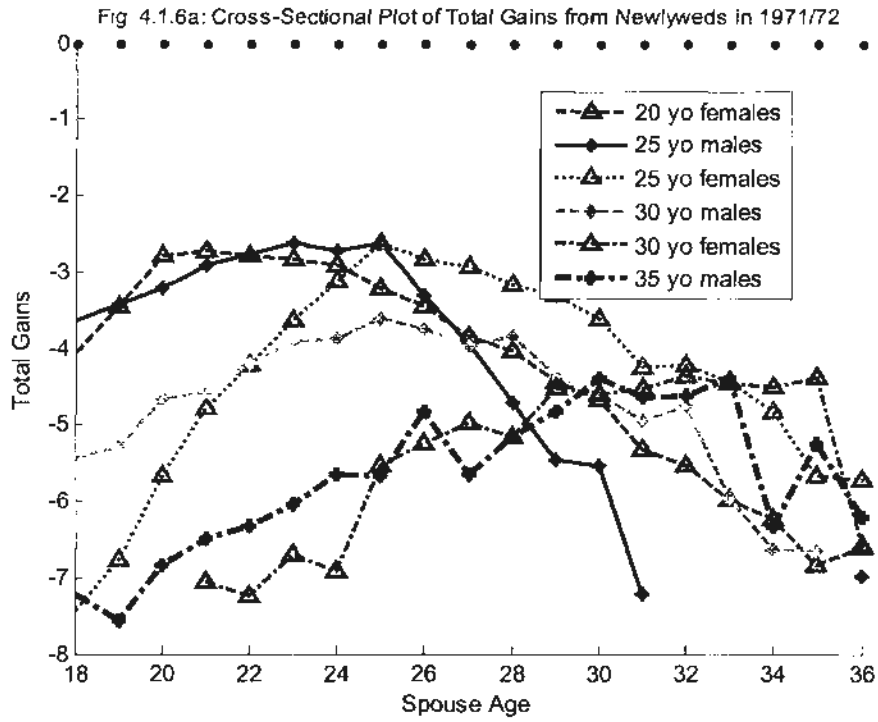
[107] The plots of total gains for 1981/82, 1991/92, and 1998/99 display similar qualitative characteristics and thus are not shown for brevity

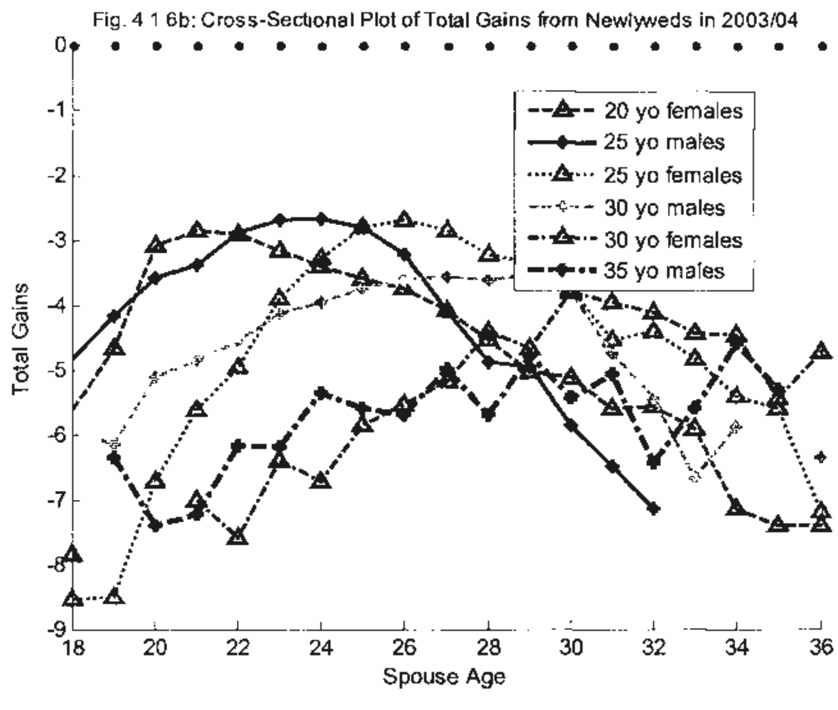
Fig 4 1 5b Smoothed Total Gains from Newlyweds in 2003/04



The cross-sectional plot of total gains from newlyweds for women and men at specific ages in 1971/72 and 2003/04 are shown in Figures 4.1.6a and b, respectively.[108] The total gains have an inverted U-shape for men and women married in their early twenties. When their spouses are relatively too old or too young, the total gain from the marriage falls. This suggests that young women (men) want to find husbands (wives) that are only slightly older (younger) (i.e., by a very few years). Interestingly, the shape of total gains becomes flatter and more dispersed for women aged 30 and men aged 35. This suggests that the when women (men) marry late, they are not strict on finding spouses who are slightly older (younger).

[108] The characteristics of the cross-sectional plot of total gains are very similar over time, thus, for the sake of brevity, figures for other periods are not shown The horizontal axis represents age of spouses When discussing total gains from female's (male's) side, the spouse age represents groom (bride)'s age

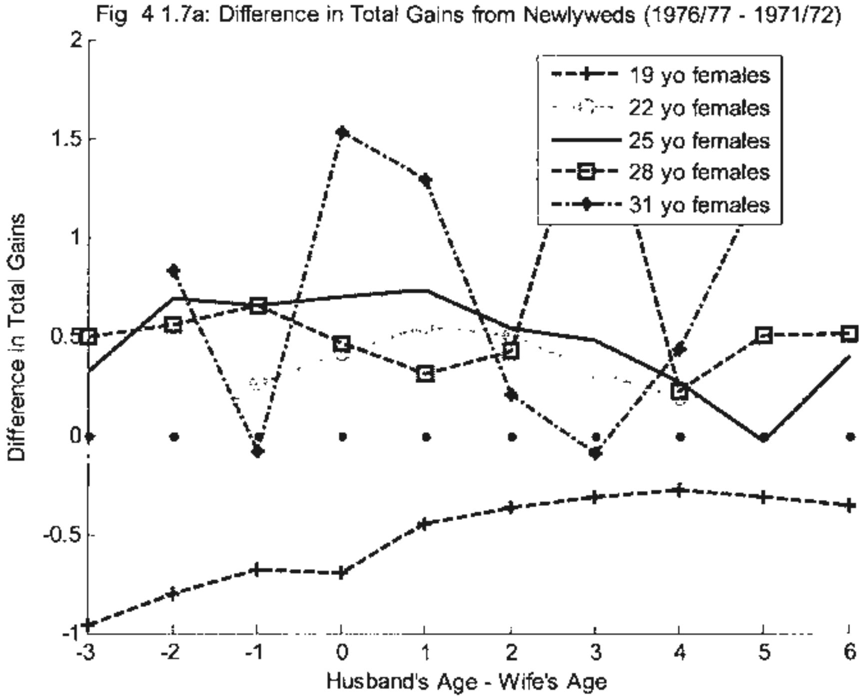




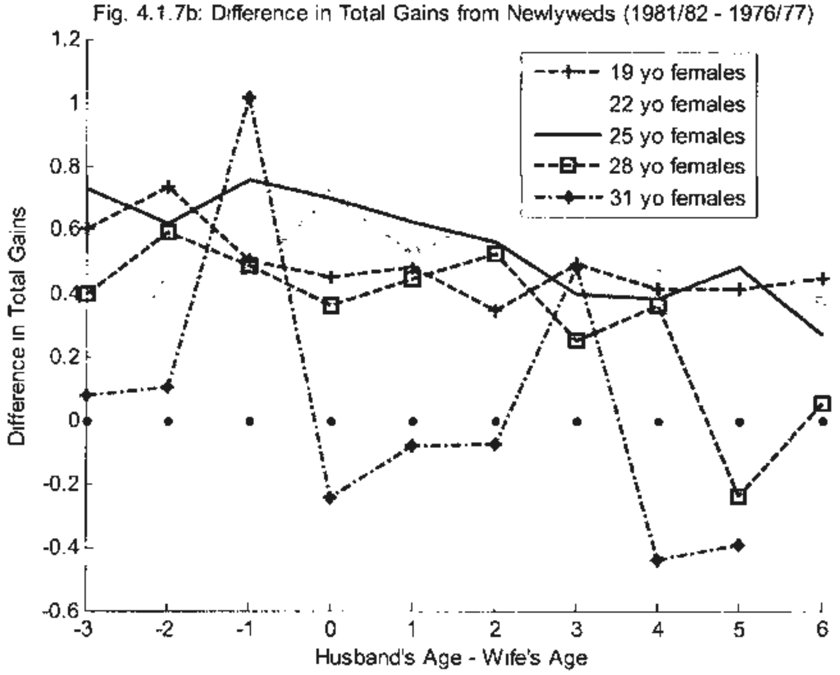
Sixth, to examine further the changes of the timing of marriage and the assortative mating on age in 1970–2004, the differences in total gains from newlyweds over time are plotted.[109] If people tend to marry later eventually, then the differences in total gains between 1991/92 and 1998/99, and between 1998/99 and 2003/04, would be negative for men and women who married in their early twenties, and positive for men and women marrying around 25 years old or above. Moreover, for changes in assortative mating vis-à-vis age over time, a regular and consistent pattern is expected on changes in total gains over some specific types of matches. For instance, if men were more willing to marry same-age women compared in previous years, then there would be observable positive changes in total gains for same-age matches over time.

Figure 4.1.7a illustrates the changes in total gains from new marriages between 1971/72 and 1976/77 by women in their twenties. Married couples show a positive change in total gains after delaying marriage from early twenties to mid-twenties during this period. This indicates that more people delayed their marriages. Moreover, changes in total gains are mainly positive for age gap [0, 2], indicating that more marriages occurred in which grooms were of the same age or older than their brides by one to two years.

Fig 4 1.7a: Difference in Total Gains from Newlyweds (1976/77 - 1971/72)



[109] The change in total gains across 1971/72–1976/77, 1976/77–1981/82, 1981/82–1986/87, 1986/87–1991/92, and 1991/92–1998/99 are computed from the data of the 2000 census. The change in total gains across 1998/99–2003/04 is computed from the data of the 2005 sub-census.



Between 1976/77 and 1981/82, as shown in Figure 4.1.7b, the changes in total gains were positive for people who married in their late teens to their late twenties. This indicates that many became inclined to marry, especially among young people in their early twenties, as soon as the barriers from the government were removed in the early 1980s. However, no particular change in total gains on any specific types of age mating could be found.

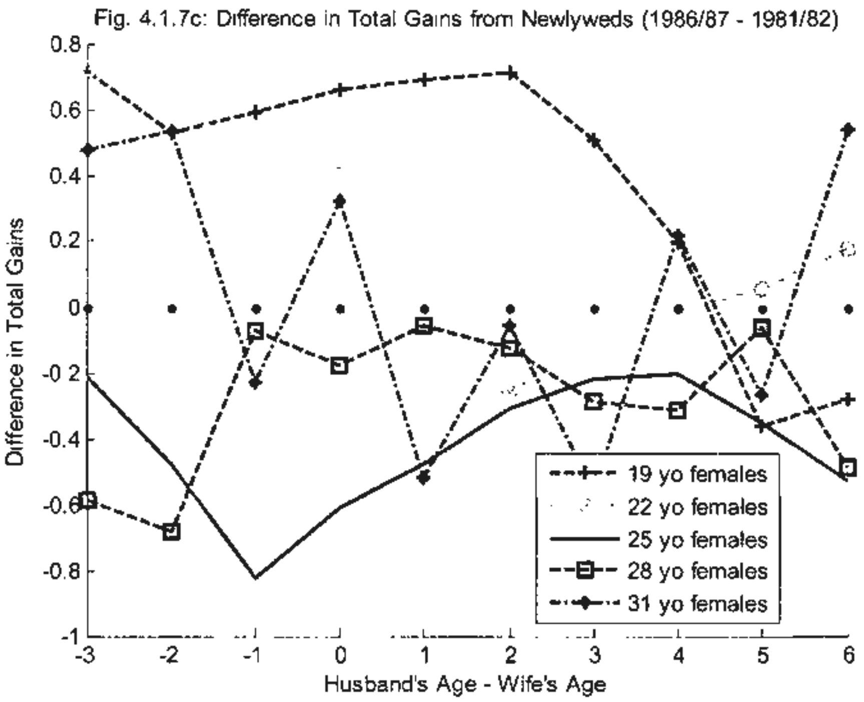
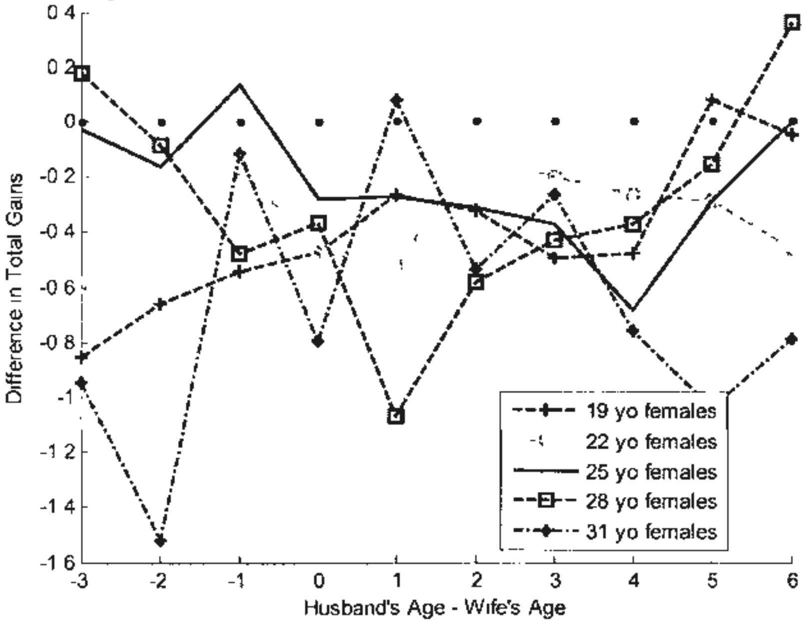
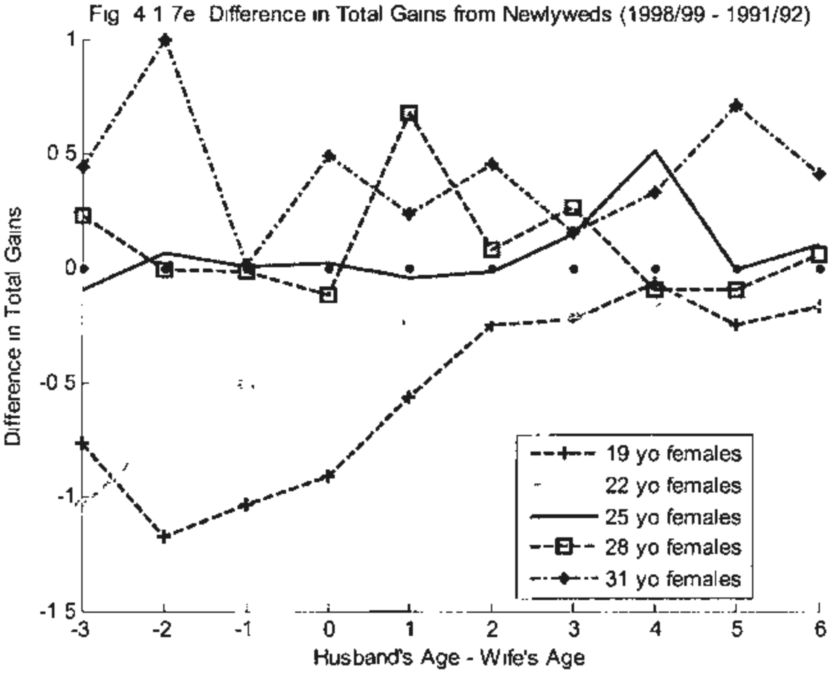


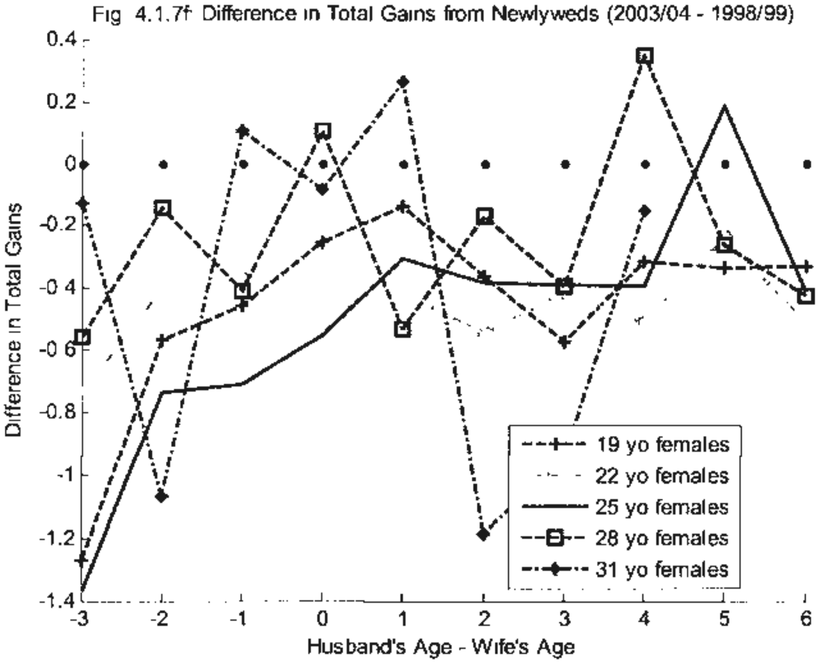
Fig 4 1 7d Difference in Total Gains from Newlyweds (1991/92 - 1986/87)



Based on Figure 4.1.7c, between 1981/82 and 1986/87, people tended to marry earlier over this period (i.e., in their early twenties), as reflected by the positive changes in total gains for people married in their late teens and early twenties, and by the negative changes in total gains for people marrying in their mid-twenties onwards. According to Figure 4.1.7d, between 1986/87 and 1991/92, the changes in total gains from people's marriages are mainly negative. No highlight features could be found over this period.

Fig 4 1 7e Difference in Total Gains from Newlyweds (1998/99 - 1991/92)





Interestingly, as seen in Figure 4.1.7e, people who married in their early twenties had lower total gains; in contrast, people who married 25 years old or above had higher total gains between 1991/92 and 1998/99. This suggests that the attractiveness of early marriage fell; however, the attractiveness increased for late marriage in the 1990s [i.e., expected result (1.1)]. According to Figure 4.1.7f, changes in total gains mainly fluctuated around zero level for people who married in their late twenties and early thirties; however, the changes were mainly negative for people who married in their early to mid-twenties between 1998/99 and 2003/04. This suggests that more people tended to delay marriage consistently over this period.

As a whole, based on the changes in total gains across periods, the present study does not find any regular, consistent, and significant changes in total gains on any particular types of age mating; rather, the changes in total gains over time were mainly related to the marriage age of men and women.

In short, the mean marriage age fluctuated between 1970 and 2004. The marriage age of men and women was deferred by the government's encouragement in the 1970s. As women who delayed marriage tended to marry men of similar age, the overall positive age gap between spouses became continuously smaller in the 1970s. In the 1980s, many were inclined to marry in their early twenties. From 1990 to 2004, an increasing number of people delayed marriage by a few years, eventually marrying in their mid-twenties and onwards. Interestingly, prevailing marriage rates on men and women over 35 years old remained at very high levels from the 1970s to the early 2000s, despite China becoming more prosperous. This suggests that the Chinese people's willingness to marry was preserved, even though they had become more affluent. Overall, the positive assortative mating on age was maintained from 1970 to 2004; no significant changes could be found in total gains on any particular types of age mating over time.

4.4.2. Results of the Impact of the One-Child Policy

This section reports and discusses the impact of the one-child policy on marriage rate, marriage age, and assortative mating on age by applying DiD estimations on the marital behavior of Zhuang people before and after being subjected to the policy in 1989 relative to the rest of minority groups (excluding Man people).

Figure 4.2.1 plots the DiD estimates on newlywed rates of men and women. If the one-child policy does not affect the marriage rate of people, then the DiD estimates on newlywed rates are expected to lie at the zero level at the marriage ages. The DiD estimates on the newlywed rate of men (see line with circles) are negative and below the zero line generally over the early twenties; however, in general, the estimates increase and become positive when the age of men exceeds age of 24. This means that the one-child policy induces men to marry after they reach 24 years old. Similarly, the DiD estimates on the newlywed rate of women are negative across the early twenties; the DiD estimates become positive from 24 years old onwards (except 25 and 27 years old). Hence, the findings suggest that, because of the one-child policy, more men and women delay to marry [i.e., expected result (2.1)].

Fig. 4.2.1: DiD New Marriage Rates of Males and Females (1994/95 - 1987/88)

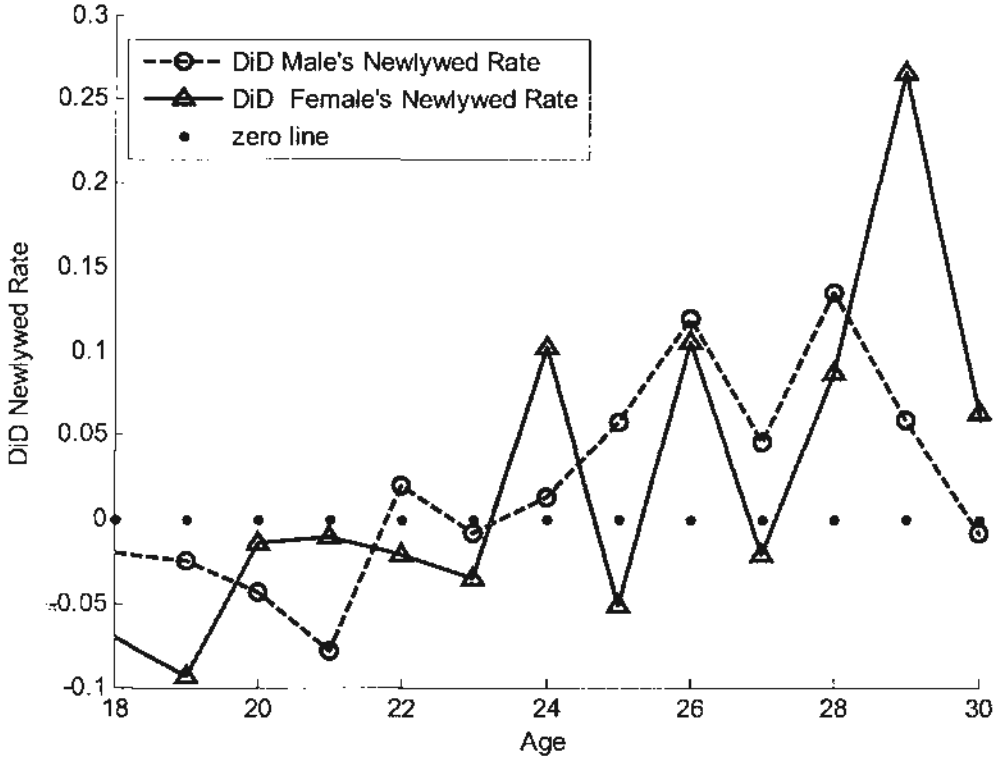
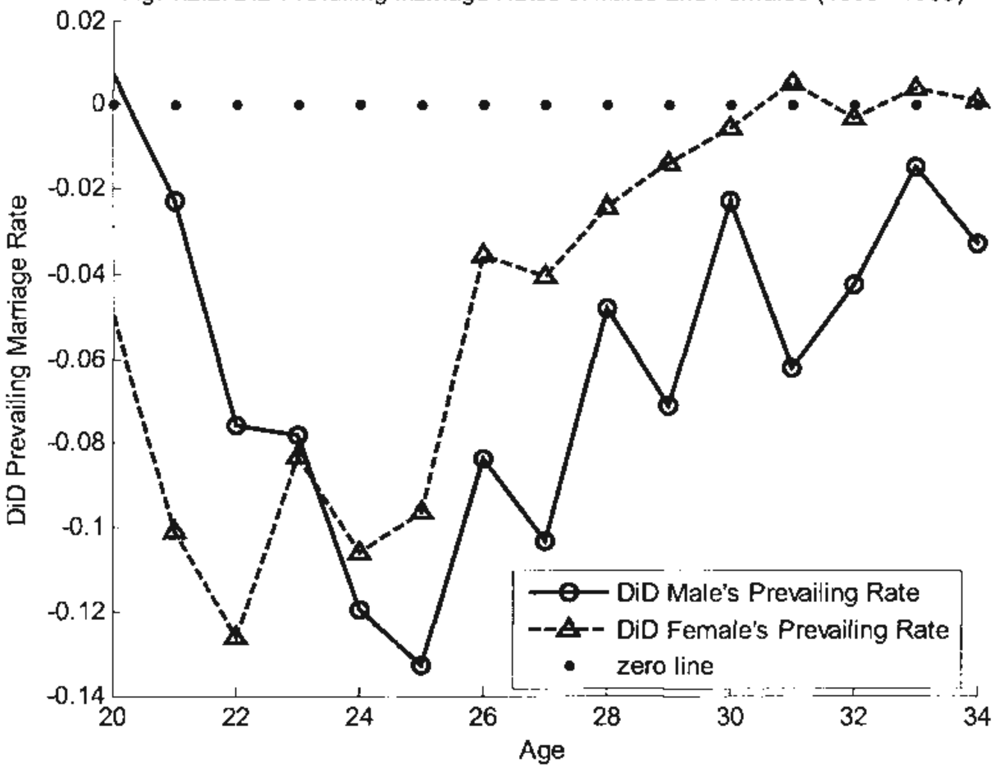
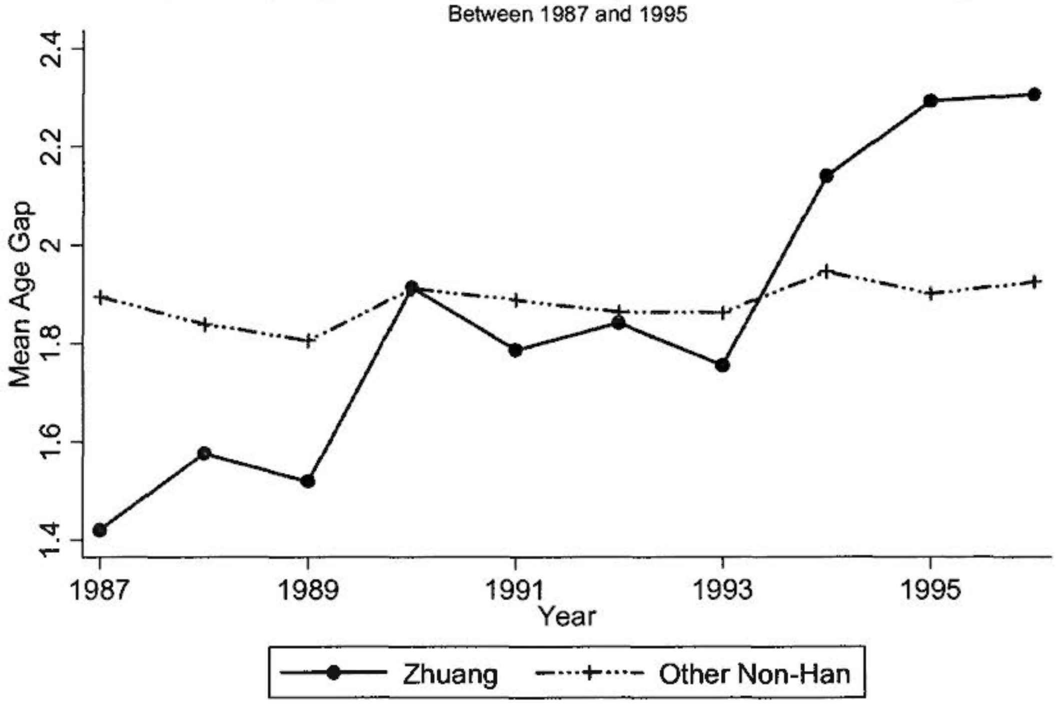


Fig. 4.2.2: DiD Prevailing Marriage Rates of Males and Females (1999 - 1988)



Second, we apply the DiD estimation on the prevailing marriage rates of men and women before (1988) and after (1999) being subjected to the policy. The DiD estimates on prevailing marriage rates are expected to be close to zero if the one-child policy does not affect people's desire to marry and their marriage age. Results in Figure 4.2.2 are consistent with the findings on newlywed rates. DiD estimates on prevailing marriage rate of men (see line with circles) are negative in the range of early twenties. The estimates begin to increase from 25 years old, and eventually approaches zero (e.g. -0.02) at 33 years old. A similar pattern is found on the DiD estimates for the prevailing rate of females (see line with triangles). This suggests that more men and women delay marriage after having been subjected to the policy, leading to negative DiD estimates of the prevailing rates of men and women who are in their early twenties. Later still, many would marry in their mid-twenties onwards, leading to increases in DiD estimates of prevailing rates. The DiD estimates converge to zero, especially on women's side, indicating that the people's desire to marry was preserved; however, they became more willing to delay marriage after being subjected to the policy.

Fig. 4.2 3· Age Gap Between Spouses in Zhuang and other Non-Han's New Marriages Between 1987 and 1995



Third, the mean age gaps between grooms and brides in new marriages of Zhuang and other non-Han groups between 1987 and 1995 are compared, as shown in Figure 4.2.3. Interestingly, the mean age gap between spouses for other non-Han couples (see line with pluses) was maintained at approximately 1.8 and 1.9 years. In contrast, the mean age gap between spouses for Zhuang people's new marriages (see line with circles) was 1.4 years in 1987, increasing to almost 2.3 years in 1995. Such result indicates the impact of the one-child policy, which may have a positive influence on the mean age gap between spouses. Subsequently, DiD regression on age gap between spouses is performed in the current work.

Fourth, to investigate the impact of the policy on the assortative mating on age, the current work employs a DiD estimation on total gains. We plot the positive and negative DiD estimates in two separate figures in order to display the results more clearly. The positive DiD estimates on the total gains are shown in Figure 4.2.4a. As mentioned earlier, a positive DiD estimate on a specific match (i, j) means that the policy favors this particular mating. Interestingly, the positive DiD estimates mainly appear in two areas: men aged between 25 and 30 years old with women in their early twenties, and men aged 25 to 30 with women 25 years old or slightly above. These results seem to suggest that more men and women delay marriage [i.e., expected result (2.1)] and most of men who marry late continue to marry younger women [i.e., expected result (2.4)]. However, the distribution of negative DiD estimates on total gains, as shown in Figure 4.2.4b, is not clear.

Overall, based on the diagrams (Figures 4.2.4a and b), the results on the influence of the policy on age mating are unclear. Thus, DiD regressions are conducted to derive more precise implications on the impact of the policy.

Fig. 4.2.4a Positive DiD Total Gains from Newlyweds (1994/95 - 1987/88)

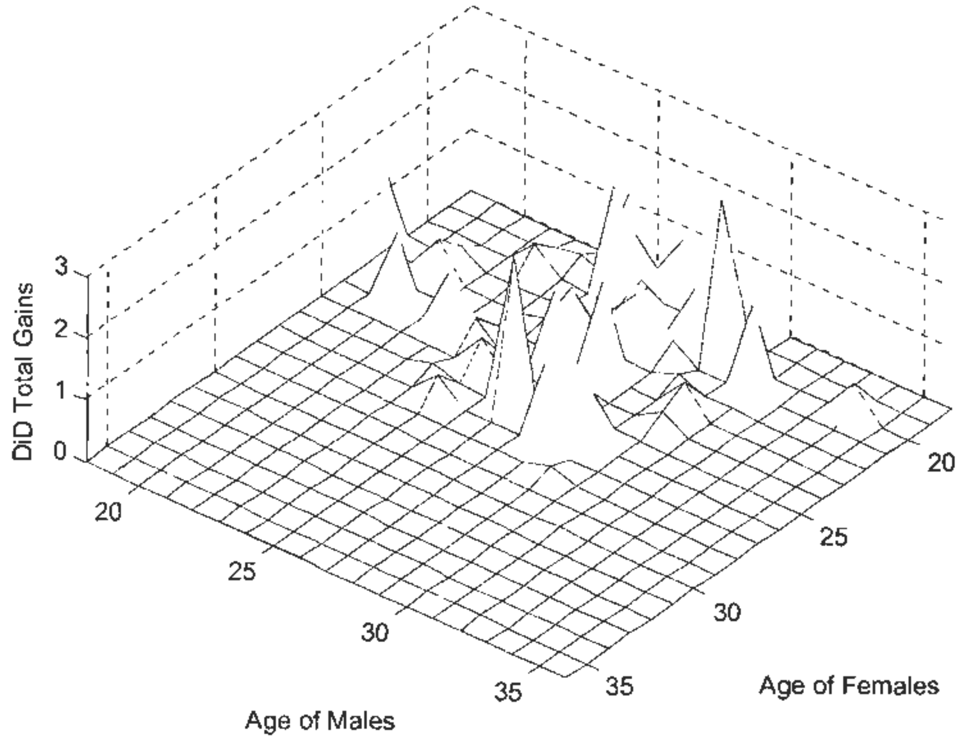


Fig. 4.2.4b Negative DiD Total Gains from Newlyweds (1994/95 - 1987/88)

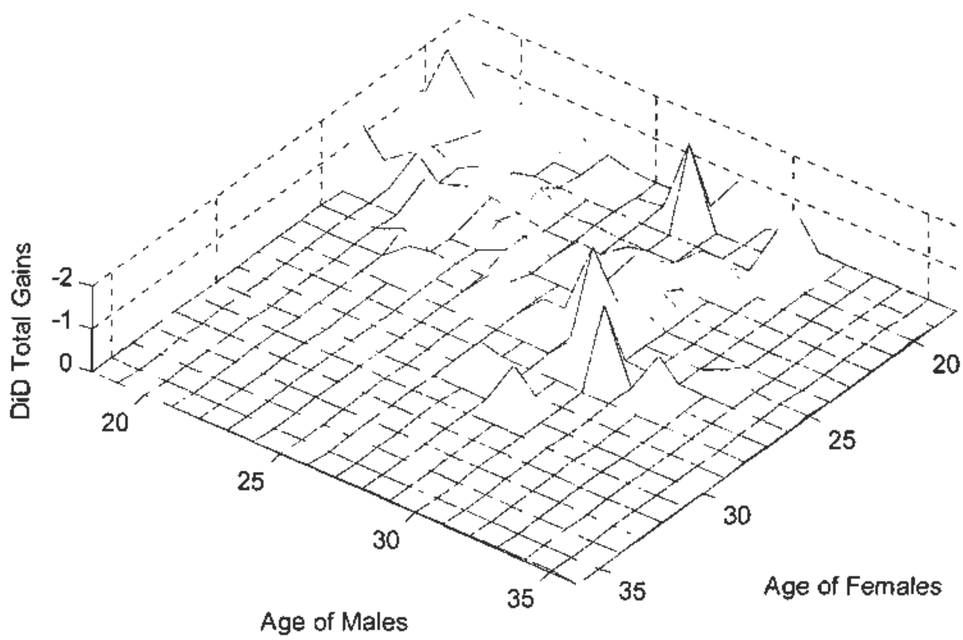


Table 4 5 summarizes the DiD regression results on marriage age by gender The study focuses on the coefficient of the interaction term of Zhuang and time dummies for 1989 onwards (D_{89}^z or D_t^z), which estimates the impact of the policy on marriage age According to the estimates of interaction terms (D_{89}^z) in Columns (3) and (8), on the average, men delay marriage by seven months while women delay marriage by two months To investigate further such effect over time, the interaction terms between Zhuang and year dummies from 1989 to 1995 are added into the regressions, as shown in Columns (4)-(5) and (9)-(10) Interestingly, the coefficients (D_t^z) are significantly positive from 1990 onwards on the men's side, while they are significantly positive on women's side from 1991 onwards On the average, the policy leads men to delay marriage from 0 5 year in 1991 to 1 3 years in 1995, meanwhile, the policy leads women to delay marriage from three months in 1991 to six months in 1995 Interestingly, the effect on delaying marriage is more significant for men, the effect of which increases over time

Table 4 6 displays the DiD regression results on the age gap between spouses According to Columns (1) to (3), the coefficients of interaction terms are significantly positive (0 44) with or without controlling the educational level of the spouse, *hukou*, and residential areas Similarly, based on Columns (4) to (6), the coefficients of the interaction terms between Zhuang and time dummies from 1990 to 1995 are significantly positive in all specifications Results suggest that the policy increases the overall age gap between spouses on their first marriages, from approximately five months to ten months between 1990 and 1995

Table 4 7 shows the DiD results for newlywed and prevailing marriage rates [110] Based on Columns (1) and (2), the new marriage rate for males, nearly all coefficients of the interaction term (age x post-1989 x Zhuang) are significantly negative between 20 and 26 years old (except 21 years old) The study finds similar results on the women's side for 20–25 years old In Column (3) on prevailing rates, the coefficients of the interaction terms are significant and negative on men's side from early twenties to mid-twenties, the coefficients become insignificant continuously as men's age

[110] As noted earlier, the regressions include newlywed rates from 1985 to 1995, and prevailing marriage rates from 1985 to 1999 by ethnicity and age

increases. Similar results are found on the women's side. The aforementioned further supports that the policy results in more men and women delaying their marriages.

To examine the impact of the one-child policy on assortative mating on age further, the current work uses total gains as dependent variable and applies DiD regression analysis. The estimate of the interaction term (D^{z}_{m89}) is expected to measure the effect on the attractiveness of specific types of age mating. If the estimate for a specific age mating is significantly positive, presumably, the policy leads this type to become more favorable.

Table 4.8a reports the estimates of the coefficients of interaction terms (D^{z}_{m89}) for the possible matches by age of spouse in the first set. The estimates are significantly negative for the following matches: (17–19; 17–19), (20–22; 17–19), (20–22; 20–22), (20–22; 23–26), (23–26; 17–19), (23–26; 20–22), (23–26; 23–26), (27–29; 20–22), and (27–29; 23–26).[111] As a whole, the significant negative estimates mainly appear on marriages in which people marry in their late teens to mid-twenties. This finding indicates that the policy encourages more men and women to marry in their later years [i.e., expected result (2.1)]. Moreover, the estimates are significantly positive on the following matches: (17–19; 23–26), (17–19; 27–29), (20–22; 27–29), (23–26; 27–29), (23–26; 30 or above), and (27–29; 30 or above). The findings support the argument that the policy leads to more marriages, with grooms being younger than their brides [i.e., expected result (2.2)].

[111] The first element in the parenthesis denotes the age range of grooms, while the second element denotes the age range of brides.

Table 4 5 Results of Impact of the One-Child Policy on Marriage Age of Males and Females

Dependent Variables	Marriage Age of Males					Marriage Age of Females				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Post Dummy (for first marriages in 1989 and after)	0 423***	0 308***	0 349***			0 411***	0 371***	0 373***		
	(0 032)	(0 035)	(0 034)			(0 026)	(0 029)	(0 028)		
Zhuang Dummy	0 785***	0 364***	0 367***	0 364***	0 366***	0 945***	0 795***	0 704***	0 795***	0 706***
	(0 043)	(0 067)	(0 066)	(0 067)	(0 066)	(0 033)	(0 051)	(0 051)	(0 051)	(0 051)
Post x Zhuang		0 689***	0 616***				0 245***	0 202***		
		(0 087)	(0 086)				(0 066)	(0 066)		
Year Dummies (1989 to 1995)	-	-	-	Yes	Yes	-	-	-	Yes	Yes
Year 1989 x Zhuang				0 137	0 093				-0 008	-0 025
				(0 138)	(0 135)				(0 107)	(0 106)
Year 1990 x Zhuang				0 523***	0 490***				0 088	0 077
				(0 146)	(0 144)				(0 113)	(0 111)
Year 1991 x Zhuang				0 615***	0 544***				0 286**	0 251**
				(0 200)	(0 196)				(0 129)	(0 125)
Year 1992 x Zhuang				0 668***	0 578***				0 258**	0 206*
				(0 167)	(0 165)				(0 125)	(0 123)
Year 1993 x Zhuang				0 548***	0 487***				0 223*	0 194
				(0 148)	(0 144)				(0 126)	(0 124)
Year 1994 x Zhuang				0 995***	0 902***				0 368***	0 311**
				(0 157)	(0 155)				(0 125)	(0 123)
Year 1995 x Zhuang				1 387***	1 259***				0 562***	0 461***
				(0 181)	(0 180)				(0 137)	(0 136)
Years of Schooling			0 089***		0 089***			0 112***		0 111***
			(0 006)		(0 006)			(0 004)		(0 004)
Urban Hukou			1 365***		1 355***			1 020***		1 016***
			(0 058)		(0 058)			(0 049)		(0 049)
City			0 538***		0 551***			0 527***		0 539***
			(0 057)		(0 057)			(0 048)		(0 048)
Town			0 211***		0 212***			0 182***		0 185***
			(0 054)		(0 053)			(0 043)		(0 043)
Observations	56862	56862	56862	56862	56862	56862	56862	56862	56862	56862
R-square	0 009	0 01	0 055	0 014	0 059	0 017	0 017	0 081	0 02	0 083

Notes
Robust standard errors are reported in parentheses
* significant at 10%, ** significant at 5%, *** significant at 1%
The sample includes all Zhuang and other non-Han couples (excluding Man people) married (first marriage) during 1985-1995
In Columns (4)-(5) and (9)-(10), a set of year dummies (1989-1995) is added

Table 4 6 Results of The Impact of the One-Child Policy on Age Gap Between Spouses

Dependent Variable	Age Gap Between Spouses					
	(1)	(2)	(3)	(4)	(5)	(6)
Post Dummy (for first marriages in 1989 and after)	-0 062**	-0 055*	-0 05			
	(0 031)	(0 031)	(0 031)			
Zhuang Dummy	-0 432***	-0 410***	-0 405***	-0 432***	-0 410***	-0 405***
	(0 057)	(0 057)	(0 057)	(0 057)	(0 057)	(0 057)
Post x Zhuang	0 444***	0 441***	0 431***			
	(0 076)	(0 076)	(0 075)			
Year Dummies (1989 to 1995)	-	-	-	Yes	Yes	Yes
Year 1989 x Zhuang				0 144	0 139	0 135
				(0 122)	(0 122)	(0 122)
Year 1990 x Zhuang				0 435***	0 430***	0 428***
				(0 130)	(0 130)	(0 130)
Year 1991 x Zhuang				0 330*	0 323*	0 313*
				(0 181)	(0 181)	(0 181)
Year 1992 x Zhuang				0 410***	0 408***	0 391***
				(0 148)	(0 148)	(0 148)
Year 1993 x Zhuang				0 325***	0 322**	0 314**
				(0 125)	(0 125)	(0 125)
Year 1994 x Zhuang				0 627***	0 623***	0 609***
				(0 141)	(0 140)	(0 140)
Year 1995 x Zhuang				0 824***	0 827***	0 808***
				(0 159)	(0 159)	(0 159)
Husband's Years of Schooling		0 025***			0 025***	
		(0 006)			(0 006)	
Wife's Years of Schooling		-0 033***			-0 033***	
		(0 005)			(0 005)	
Education Gap between Spouses			0 029***			0 030***
			(0 005)			(0 005)
Husband's Urban Hukou			0 525***			0 524***
			(0 080)			(0 080)
Wife's Urban Hukou			-0 192**			-0 194**
			(0 085)			(0 085)
City			-0 146***			-0 143***
			(0 055)			(0 055)
Town			-0 033			-0 033
			(0 051)			(0 051)
Observations	56862	56862	56862	56862	56862	56862
R-square	0 001	0 002	0 003	0 002	0 002	0 004

Notes
Robust standard errors are reported in parentheses
* significant at 10%, ** significant at 5%, *** significant at 1%
The sample includes all Zhuang and other non-Han couples (excluding Man people) married during 1985-1995
In Columns (4)-(6), a set of year dummies (1989-1995) is added

Table 4 7 Results of The Impact of the One-Child Policy on Newlywed and Prevailing Marriage Rates

Dependent Variables	Newlywed Rate (%)		Prevailing Marriage Rate (%)	
	Males	Females	Males	Females
	(1)	(2)	(3)	(4)
Post Dummy (for first marriages in 1989 and after)	-3 347***	-3 815***	-3 965***	-4 064***
	(0 300)	(0 748)	(0 345)	(0 473)
Zhuang Dummy	-2 324***	5 690***	-3 136***	-4 516***
	(0 385)	(1 850)	(0 292)	(0 578)
Age20 x Post x Zhuang	-1 928***	-6 547***	-5 808***	-10 811***
	(0 728)	(2 262)	(1 154)	(2 208)
Age21 x Post x Zhuang	-0 086	-7 265***	-8 537***	-10 493***
	(1 084)	(1 961)	(1 839)	(2 470)
Age22 x Post x Zhuang	-2 331*	-6 665***	-11 099***	-8 639***
	(1 193)	(2 360)	(2 510)	(2 920)
Age23 x Post x Zhuang	-3 189**	-6 765***	-12 193***	-6 164**
	(1 292)	(2 482)	(3 000)	(2 750)
Age24 x Post x Zhuang	-3 347**	-7 526***	-12 200***	-3 73
	(1 365)	(2 363)	(3 271)	(2 401)
Age25 x Post x Zhuang	-2 683**	-4 901*	-10 574***	-0 82
	(1 189)	(2 560)	(3 158)	(1 955)
Age26 x Post x Zhuang	-4 118***	-0 719	-8 806***	1 823
	(1 387)	(2 152)	(2 934)	(1 473)
Age27 x Post x Zhuang	-1 127	-0 065	-6 531**	3 284***
	(1 316)	(3 009)	(2 576)	(1 129)
Age28 x Post x Zhuang	-0 501	-0 815	-4 734**	4 366***
	(1 493)	(3 342)	(2 189)	(0 926)
Age29 x Post x Zhuang	0 572	-0 104	-3 302**	4 873***
	(1 038)	(3 797)	(1 652)	(0 792)
Age30 x Post x Zhuang	-0 732	-0 61	-1 717	5 196***
	(1 394)	(5 342)	(1 307)	(0 740)
Age31 x Post x Zhuang	0 103	6 146**	-1 073	5 518***
	(1 315)	(2 748)	(1 045)	(0 732)
Age32 x Post x Zhuang	-0 436	1 587	-0 217	5 601***
	(2 126)	(5 423)	(0 870)	(0 734)
Age33 x Post x Zhuang	1 925	3 013	0 538	5 788***
	(1 379)	(6 392)	(0 853)	(0 730)
Age34 x Post x Zhuang	0 604	-8 752	1 206**	5 828***
	(0 826)	(6 771)	(0 480)	(0 630)
Observations	396	396	570	570
R-square	0 87	0 478	0 982	0 983

Notes

Robust standard errors are reported in parentheses

* significant at 10%, ** significant at 5%, *** significant at 1%

All regressions include age dummies for marriage ages from 20 to 34 or above

In Columns (1)-(2), the sample includes newlywed rates over ages from 20 to 34 or above during 1985-1995

In Columns (3)-(4), the sample includes prevailing marriage rates over ages from 20 to 34 or above during 1985-1999

In addition, interestingly, the estimates are significantly positive for mating in which grooms are 30 years old or above, and brides are in their late teens and onwards. This supports the observation that most men who marry late prefer to marry younger women [i.e., expected result (2.4)]. Meanwhile, the estimate is significantly positive on mating in which both spouses are 30 years old or above. This may support the expected result (2.3), showing that some men and women who marry late at 30 years old onwards are more likely to find spouses of similar ages.

Table 4.8b reports the DiD estimates of interaction terms for the possible mating in the second set. The distribution of significantly negative and positive estimates in Table 4.8b is close to those in Table 4.8a. Thus, the results give similar implications to those obtained in Table 4.8a.

The aforementioned findings from DiD regressions are consistent with the implications shown in Figures 4.2.1 and 4.2.2 based on information across two periods (1987/88 and 1994/95). The current study finds that the one-child policy leads more men and women to marry in their later years, especially men. Moreover, we find implications that are more precise on the assortative age mating, as depicted by DiD regression results on total gains.

The two key characteristics of the policy effect on age mating can be summarized as follows. First, more young men in their late teens to mid-twenties marry older women. Second, more men and women who marry at 30 years old or above choose spouses of similar ages. Third, when more men marry at 30 years old onwards, most prefer to marry younger women in their twenties. The third dominates the changes in age mating. Overall, the positive mean age gap between spouses increases after being subjected to the one-child policy.

Table 4.8a: Results of The Impact of the One-Child Policy on Assortative Age Mating (First Set)

	Female					
Male	15 16	17 18 19	20 21 22	23 24 25 26	27 28 29	>=30
15 16						
17 18 19		-0.840*** (0.125)	-0.208 (0.132)	0.383*** (0.123)	1.296*** (0.070)	
20 21 22		-0.987*** (0.149)	-0.526*** (0.105)	-0.310** (0.125)	0.420*** (0.110)	
23 24 25 26		-0.641*** (0.102)	-0.418*** (0.085)	-0.341*** (0.079)	0.495*** (0.115)	0.714*** (0.129)
27 28 29		-0.023 (0.110)	-0.257** (0.114)	-0.155* (0.088)	0.072 (0.104)	0.638*** (0.098)
>=30		0.670*** (0.119)	0.448*** (0.081)	0.322*** (0.078)	0.558*** (0.082)	0.948*** (0.093)

Notes:

There are no observations for marriages in which males aged 17 to 19 and females aged 30 or above as well as marriages in which males aged 20 to 22 and females aged 30 or above.

There are 4,794 observations for total gains computed from newlyweds between 1985 and 1995.

Table 4 8b Results of The Impact of the One-Child Policy on Assortative Age Mating (Second Set)

Male \ Female	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	>=30
15																
16																
17																
18			-1 009*** (0 215)	-0 996*** (0 289)	-1 074*** (0 245)	-0 418* (0 235)	-0 014 (0 279)	-0 005 (0 281)	0 533*** (0 128)							
19			-0 957*** (0 236)	-1 167*** (0 249)	-0 835*** (0 257)	-0 784*** (0 106)	-0 680*** (0 169)	-0 951*** (0 222)	-0 589*** (0 120)	0 720*** (0 204)						
20			-1 593*** (0 347)	-1 568*** (0 234)	-0 919*** (0 183)	-0 791*** (0 160)	-0 689*** (0 138)	-0 854*** (0 265)	-0 706*** (0 251)	-0 511** (0 227)	-0 067 (0 097)					
21			-1 261*** (0 254)	-0 823*** (0 171)	-0 534*** (0 191)	-0 451*** (0 136)	-0 404*** (0 090)	-0 157 (0 141)	-0 388** (0 184)	-0 159 (0 167)	-0 221 (0 175)	0 332 (0 202)				
22			-1 294*** (0 299)	-0 783** (0 310)	-0 968*** (0 191)	-0 233** (0 106)	-0 403*** (0 096)	-0 457*** (0 090)	-0 489*** (0 149)	-0 553** (0 270)	-0 657*** (0 218)	-0 234 (0 234)	0 312** (0 132)			
23			-0 353* (0 191)	-0 905*** (0 254)	-1 224*** (0 221)	-0 439*** (0 112)	-0 655*** (0 096)	-0 382*** (0 086)	-0 304*** (0 090)	-0 404*** (0 133)	-0 228 (0 210)	-0 489** (0 217)	0 389 (0 259)	0 995*** (0 194)		
24			-0 768*** (0 168)	-0 684** (0 284)	-0 411 (0 256)	-0 626*** (0 151)	-0 567*** (0 120)	-0 351*** (0 099)	-0 409*** (0 118)	-0 585** (0 260)	-0 069 (0 114)	0 072 (0 204)	-0 196 (0 201)	0 368* (0 197)	0 633*** (0 146)	
25			-0 274 (0 238)	-0 580* (0 314)	-0 680** (0 330)	-0 095 (0 219)	-0 302** (0 136)	-0 201* (0 112)	-0 339** (0 145)	-0 226* (0 117)	-0 244* (0 126)	-0 119 (0 295)	0 052 (0 162)	0 689* (0 358)	1 180*** (0 303)	0 630*** (0 152)
26			-0 449*** (0 108)	-0 690*** (0 204)	-0 542** (0 273)	-0 229 (0 393)	-0 15 (0 212)	-0 660*** (0 193)	-0 511*** (0 151)	-0 279 (0 175)	-0 280*** (0 106)	-0 14 (0 115)	0 279 (0 227)	0 214 (0 193)	0 638** (0 313)	0 905*** (0 211)
27			-0 059 (0 174)		-0 278 (0 260)	-0 528* (0 320)	0 086 (0 213)	-0 399* (0 213)	-0 108 (0 202)	-0 362 (0 294)	0 088 (0 168)	-0 133 (0 233)	0 156 (0 197)	0 075 (0 250)	0 075 (0 273)	0 772*** (0 114)
28			-0 034 (0 162)			-0 476* (0 271)	-0 414 (0 295)	-0 450* (0 256)	0 023 (0 148)	-0 335 (0 356)	-0 527*** (0 180)	0 184 (0 163)	0 075 (0 183)	0 203 (0 232)	0 357* (0 192)	0 533*** (0 165)
29			0 089 (0 185)				0 492 (0 311)	-0 007 (0 288)	-0 124 (0 215)	-0 415* (0 244)	-0 129 (0 288)	0 287 (0 238)	-0 262 (0 297)	0 312 (0 295)	0 102 (0 316)	0 644*** (0 118)
30			0 514*** (0 185)					0 674*** (0 253)	-0 212 (0 266)	-0 256 (0 198)	-0 386 (0 255)	0 226 (0 283)	0 018 (0 233)	0 071 (0 283)	0 485** (0 206)	0 768*** (0 209)
31			0 344** (0 149)						0 000 (0 226)	-0 035 (0 236)	-0 086 (0 188)	0 336 (0 247)	0 14 (0 213)	0 198 (0 270)	0 774* (0 470)	0 829*** (0 195)
32			0 379*** (0 132)							0 196 (0 185)						0 885*** (0 152)
>=33			0 794*** (0 081)								0 923*** (0 097)					1 153*** (0 120)

Note There are 4 794 observations for total gains computed from newlyweds between 1985 and 1995

4.5. Concluding Remarks

In this study, trends in marital behavior of the Chinese for the period 1970–2004 are analyzed, and impact of the one-child policy is explored in terms of marriage age, marriage rate, and assortative mating on age. As far as we know, this is the first to investigate the trends on these attributes using data from the 1990s and early 2000s, and if and how the one-child policy affects these traits. The main findings are concluded as follows.

First, the marriage age of men and women fluctuated from 1970 to 2004. The marriage age of men and women rose in the 1970s and then fell in the 1980s. From the early 1990s onwards, more men and women opted to delay their marriages. As a whole, the mean average age increased from 23 to 25 for men and from 20.5 to 22.5 for women in rural areas between 1970 and 2004. People living in urban areas tended to marry a year later than those living in rural areas on the average. Interestingly, unlike in other countries, the prevailing marriage rates for Chinese men and women after 35 years old were maintained at very high levels and were almost the same from 1970 to 2004. This suggests that, since 1979, despite Chinese people becoming more affluent, their desire to marry has persisted.

Next, the pattern of assortative mating on age has been preserved more or less over time. In general, Chinese women in their early twenties prefer to marry men a few years older, while women over 25 prefer to marry men of similar age. On the average, Chinese men who marry at 30 years old or older prefer to marry women a few years younger. In addition, the fluctuation of mean age difference between spouses between 1970 and 2004 is only within ± 1 year.

Finally, in terms of investigating the impact of the one-child policy, this study is the first to compare the marital behavior of Zhuang people and the rest of minority groups (excluding Man people) around 1989. Results suggest that more men and women delay marriage after being subjected to the one-child policy. Moreover, the policy affects assortative mating on age. When more men marry late (i.e., 30 years old or above), most marry younger women in their twenties. Surprisingly, more young men in their late teens to mid-twenties are more willing to marry women who are older than they are by a few years. Overall, the one-child policy tends to increase the positive mean age gap between spouses by several months.

References for Chapter 4

Almond, D., Edlund, L., Li, H. & Zhang, J. (2007). Long-term effects of the 1959-1961 China famine: Mainland China and Hong Kong. *NBER Working Paper,* 13384.

Brandt, L., Siow, A. & Vogel, C. (2008). Large shocks and small changes in the marriage market for famine born cohorts in China. *University of Toronto Working Paper,* 334.

Becker, G. (1973). A theory of marriage: Part I. *Journal of Political Economy, 81*(4), 813-846.

Becker, G. (1974). A theory of marriage: Part II. *Journal of Political Economy, 82*(2, part 2), S11-S26.

Becker, G. (1991). *A treatise on the family.* Cambridge, Mass.: Harvard University Press.

Bergstrom, T & Bagnoli, M. (1993). Courtship as a waiting game. *Journal of Political economy, 101*(1), 185-202.

Bergstrom, T. & Schoeni, R.F. (1996). Income prospects and age-at-marriage. *Journal of Population Economics, 9*(2), 115-130.

Chen, Y. & Zhou, L. (2007). The long-term health and economic consequence of the 1959-61 Famine in China. *Journal of Health Economics, 26*(4), 659-681.

China population statistics yearbook. (1996-2006). Beijing: Zhongguo zhan wang chu ban she.

Choo, E. & Siow, A. (2006a). Who marries whom and why. *Journal of Political Economy, 114*(1), 175-201.

Choo, E. & Siow, A. (2006b). Estimating a marriage matching model with spillover effects. *Demography, 43*(3), 463-488.

Dagsvik, K., Brunborg, H. & Flaatten, A. (2001). A behavioral two-sex marriage model. *Math. Population Studies, 9*(2), 97-121.

Edlund, L., Li, H., Yi, J. & Zhang, J. (2007). More men, more crime: Evidence from China's one-child policy. *IZA Working Paper,* 3214.

Elías, J. J. (2003). The link between unemployment and the Marriage rate: Buenos aires, Argentina, 1980-1999. *Cuadernos de economía 40*(121), 505-513.

Esteve, A., Cortina, C., Cabre, A. (2009). Long term trends in marital age homogamy patterns: Spain, 1922-2006. *Population Economics, 64*(1), 173-202.

Giolito, E. (2003). A search model of marriages with differential fecundity. *IZA Working Paper,* 1082.

Gould, E. D. & Paserman, M. D. (2003). Waiting for Mr. Right: Rising inequality and declining marriage rates. *Journal of Urban Economics, 53*(2), 257-281.

Iwasawa, M. & Mita, F. (2008). Boom and bust in marriages between coworkers and the marriage decline in Japan. *Japanese Economy, 34*(4), 3-24.

Keeley, M.C. (1977). The economics of family formation. Economic Inquiry, 15(2), 238-250.

Kuo, Y.C. (2006). Non-married motherhood and labor market prospects in the United States, 1960-2000. Feng Chia University Working Paper.

Li, G. (2003). The impact of the One-child policy on child-wellbeing and gender differential. *Center for Research on Families Working Paper,* 2003-02.

Li, W. & Yang, T. (2005). The Great Leap Forward: Anatomy of a central planning disaster. *Journal of Political Economy, 113*(4), 840-877.

Li, H. & Zhang, J. (2009). Testing the external effect of household behavior: The case of the demand for children. *Journal of Human Resources, 44*(4), 890-915.

Lin, Y. & Yang, T. (1998). On the causes of China's agricultural crisis and the Great Leap Famine. *China Economic Review, 9*(20), 125-140.

Meng, Xi & Qian, N. (2006). The Long run impact of childhood malnutrition: Evidence from China's Great Famine. *IZA Discussion Paper,* 2471.

Oppenheimer, V.K. (1988). A theory of marriage timing. *American Journal of Sociology, 94*(3), 563-591.

Peng, X. (1987). Demographic consequences of the Great Leap Forward in China's provinces. *Population and Development Review, 13*(4), 639-670.

Porter, M. (2007). The effects of sex ratio imbalance on marriage & household decision. *University of Chicago working paper.*

Qian, Z. (1998). Changes in assortative mating: The impact of age and education, 1970-1990. *Demography, 35*(3), 279-292.

Rosenzweig, M.R. & Zhang, J. (2009). Do population control policies induce more human capital investment? Twins, birthweight and China's 'one-child policy'. *Review of Economic Studies*, *76*(3), 1149-1174.

Short, S., Zhai, F., Xu, S. & Yang, M. (2001). China's one-child policy and the care of children: An analysis of qualitative and quantitative data. *Social Forces*, *79*(3), 913-943.

Siow, A. (1998). Differential fecundity, markets, and gender roles. *Journal of Political Economy*, *106*(2), 334-354.

Siow, A. (2008). How does the marriage market clear? An empirical framework preview. *Canadian Journal of Economics*, *41*(4), 1121-1155.

Tue, G., Xin, M. & Vaithianathan, R. (2005). Stunting and selection effects of famine: A case study of the Great Chinese Famine. *IZA Discussion Papers*, 2543.

Xu, L., Qiang, Z. & Wang, L. (2003). The timing of marriage in China. *Annals of Economics and Finance*, *4*(2), 343-357.

Yang, T. & Chen, D. (2004). Transformations in China's population policies and demographic structure. *Pacific Economic Review*, *9*(3), 269-290.

Yang, J. (2007). China's one-child policy and overweight children in the 1990s. *Social Science & Medicine*, *64*(10), 20-43.

Appendix Table 4 1 Characteristics of Han, Man, Zhuang, and Other Non-Han Ethics (15 Years old or Above) in 1982

	Male				Female			
	Han	Non-Han			Han	Non-Han		
		Man	Zhuang	Other NH		Man	Zhuang	Other NH
Mean Age	35 92	35 42	35 52	35 57	36 57	33 90	36 88	35 97
Education Level (%)								
Primary or Below	56 44	48 93	59 97	70 24	73 47	58 5	80 15	83 2
Junior High School	30 04	34 02	27 73	20 91	18 05	27 85	14 07	11 36
High School/Technical School	12 17	15 4	11 67	7 96	7 99	12 82	5 67	5 11
College or Above	1 35	1 65	0 64	0 88	0 49	0 82	0 11	0 33
Working People (%)	86 03	83 4	85 19	86 56	69 69	50 72	79 94	76 66
Industry (%)								
Primary	71 99	66 01	88 02	83 26	77 92	60 45	95 67	89 62
Manufacturing, Production & Transport	21 37	25 64	6 51	10 4	17 61	29 85	2 95	7 28
Services	4 43	5 53	3 78	3 87	3 69	8 16	1 16	2 47
Government Agencies	2 16	2 76	1 65	2 4	0 73	1 45	0 19	0 61
Other	0 06	0 06	0 03	0 08	0 05	0 09	0 02	0 03
Occupation (%)								
Workers in Primary Sector	67 27	58 74	86 05	79 86	76 28	57 79	95 34	88 86
Workers in Manufacturing Sector	18 91	23 85	5 38	9 41	13 52	20 77	1 97	5 05
Workers in Services Sector	5 61	6 86	2 76	3 94	5 2	9 93	1 35	2 97
Administrators in Gov't/Technical Staff	8 11	10 48	5 79	6 72	4 92	11 39	1 33	3 06
Other	0 09	0 07	0 01	0 07	0 08	0 12	0 02	0 06
Marital Status (%)								
Single	32 82	32 22	32 73	29 44	24 27	30 85	24 91	21 71
Married	61 83	62 27	61 43	64 76	65 53	61 74	63 55	67 55
Divorced/Widowed	5 35	5 51	5 85	5 8	10 19	7 41	11 54	10 74
Total Observations	3205793	15580	40410	150965	3050253	12807	41090	146773

Note The summary statistics are generated from 1982 census

Appendix Table 4 2 Characteristics of Han Man Zhuang and Other Non-Han Ethics (15 Years old or Above) in 1990

		Male				Female			
		Han	Non-Han			Han	Non-Han		
			Man	Zhuang	Other NH		Man	Zhuang	Other NH
Mean Age		36 50	35 26	35 18	35 10	37 09	34 25	37 05	35 46
Hukou (%)	Urban	24 61	26 45	11 21	16 53	20 58	24 62	6 59	13 93
	Rural	75 39	73 55	88 79	83 47	79 42	75 38	93 41	86 07
Residential Area (%)	Urban Area	30 16	36 05	24 26	21 35	29 29	36 70	25 21	21 29
	Rural Area	69 84	63 95	75 74	78 65	70 71	63 30	74 79	78 71
Education Level (%)									
	Primary or Below	47 19	40 79	55 72	63 97	64 73	52 16	75 74	78 07
	Junior High School	36 85	41 71	33 24	25 11	25 12	33 99	19 22	15 03
	High School/Technical School	13 14	14 44	10 12	9 21	8 87	11 9	4 8	6 05
	College or Above	2 83	3 05	0 91	1 71	1 28	1 96	0 24	0 85
Working People (%)		83 89	84 45	82 26	84 16	71 53	60 5	79 14	76 37
Industry (%)									
	Primary	69 96	70 07	88 59	82 8	75 44	70 21	92 83	88 76
	Manufacturing Production & Transport	18 69	16 75	4 11	7 16	14 46	14 45	3 1	4 54
	Service	8 61	9 53	5 43	7 23	9 05	13 35	3 74	5 83
	Government Agencies	2 72	3 63	1 87	2 8	1 04	1 98	0 33	0 86
	Other	0 02	0 02	0	0 01	0 01	0 01	0	0
Occupation (%)									
	Workers in Primary Sector	65 11	64 93	87 69	80 78	73 82	68 2	92 76	88 23
	Workers in Manufacturing Sector	18 98	17 65	4 18	7 56	12 8	12 09	2 89	3 89
	Workers in Services Sector	7 52	7 58	3 31	4 48	7 29	8 94	2 65	3 83
	Administrators in Gov't/Technical Staff	8 34	9 78	4 82	7 13	6 06	10 69	1 7	4 02
	Other	0 04	0 07	0	0 04	0 04	0 08	0	0 03
Marital Status (%)									
	Single	29 86	28 43	35 33	32 29	21 94	23 46	24 53	24 12
	Married	65 64	67 22	59 92	62 65	69 31	70 69	65 57	66 43
	Divorced/Widowed	4 5	4 35	4 75	5 06	8 75	5 85	9 9	9 45
Total Observations		4000794	36230	55838	226561	3792536	32284	56562	216514

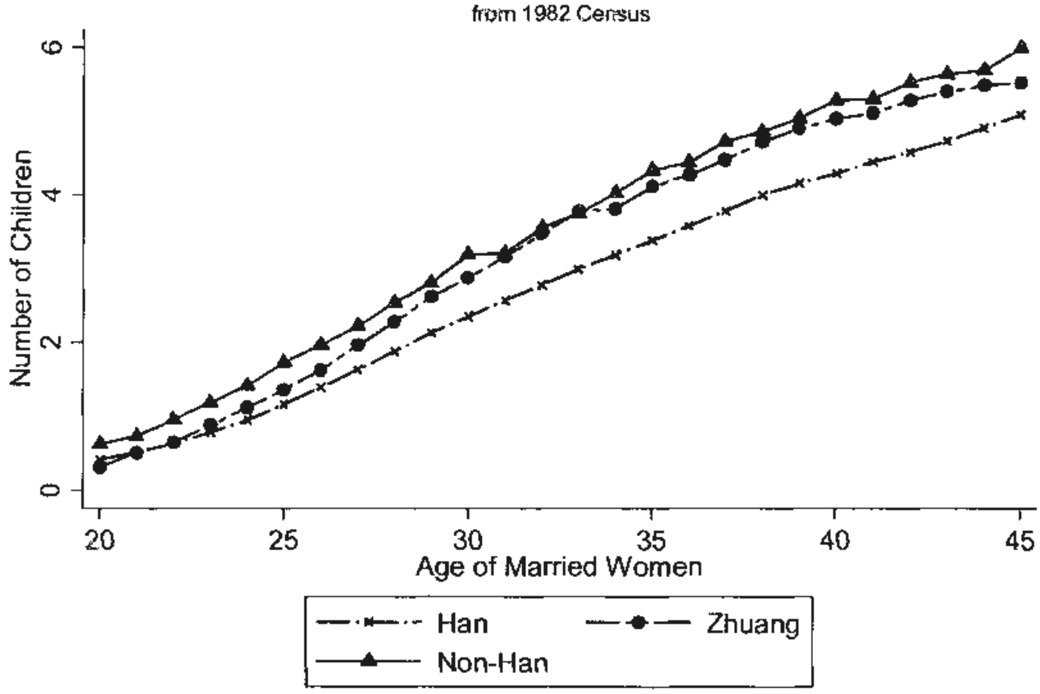
Note The summary statistics are generated from 1990 census

Appendix Table 4 3 Characteristics of Han, Man Zhuang and Other Non-Han Ethics (15 Years Old or Above) in 2000

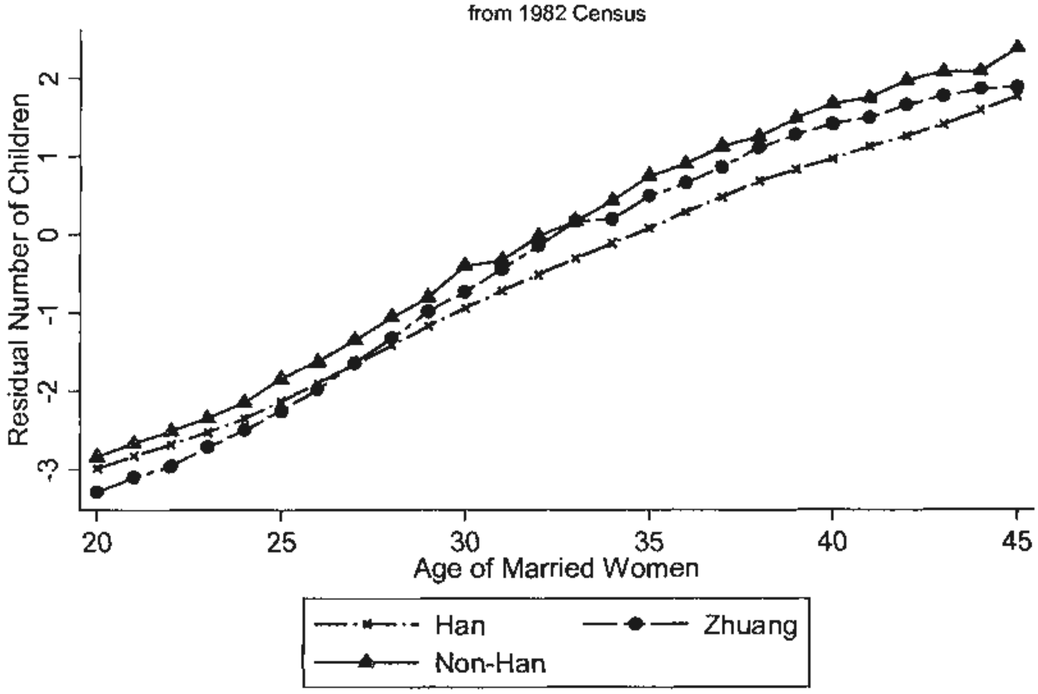
		Male				Female			
		Han	Non-Han			Han	Non-Han		
			Man	Zhuang	Other NH		Man	Zhuang	Other NH
Mean Age		39 71	38 65	37 35	37 01	40 12	38 01	38 92	37 53
		16 22	15 63	16 57	16 16	16 77	15 70	17 52	16 44
Hukou (%)	Urban	28 52	29 68	16 07	19 47	26 44	29 37	12 65	18 03
	Rural	71 48	70 32	83 93	80 53	73 56	70 63	87 35	81 97
Residential Area (%)	Urban Area	39 53	35 44	22 66	22 47	40 17	37 84	23 72	23 91
	Rural Area	60 47	64 56	77 34	77 53	59 83	62 16	76 28	76 09
Education Level (%)									
	Primary or Below	33 44	30 46	38 48	52 67	48 79	40 69	57 81	65 7
	Junior High School	44 29	47 63	44 84	31 66	34 82	40 07	31 95	22 28
	High School/Technical School	16 33	15 17	13 3	11 72	12 59	13 54	8 59	9 26
	College or Above	5 95	6 73	3 38	3 95	3 81	5 7	1 64	2 75
Working People (%)		79 49	80 07	83 38	83 15	67 17	62 48	79 21	74 52
Industry (%)									
	Primary	60 89	65 87	79 26	78 65	68 05	70 61	82 47	83 68
	Manufacturing, Production & Transport	22 62	17 7	10 67	9 44	15 5	10 46	7 96	5 33
	Service	13 08	12 51	7 59	8 58	14 81	16 87	8 62	9 48
	Government Agencies	3 32	3 88	2 33	3 24	1 59	2 01	0 85	1 46
	Other	0 08	0 04	0 14	0 09	0 05	0 04	0 09	0 05
Occupation (%)									
	Workers in Primary Sector	59 35	63 44	78 18	77 62	67 77	69 99	82 12	83 42
	Workers in Manufacturing Sector	20 13	17 3	10 22	8 92	12 31	7 85	7 17	4 18
	Workers in Services Sector	12 75	11 11	6 27	7 29	12 6	12 45	6 91	7 18
	Administrators in Gov't/Technical Staff	7 69	8 09	5 18	6 09	7 27	9 68	3 69	5 18
	Other	0 08	0 06	0 14	0 08	0 05	0 02	0 11	0 04
Marital Status (%)									
	Single	26 91	26 74	37 74	32 4	24 54	24 54	30 37	26 9
	Married	71 99	71 9	61 38	66 15	74 81	74 43	69 24	71 81
	Divorced/Widowed	1 09	1 36	0 87	1 45	0 64	1 04	0 39	1 29
Total Observations		4196693	41720	60232	274663	4100603	39603	58174	269532

Note The summary statistics are generated from 2000 census

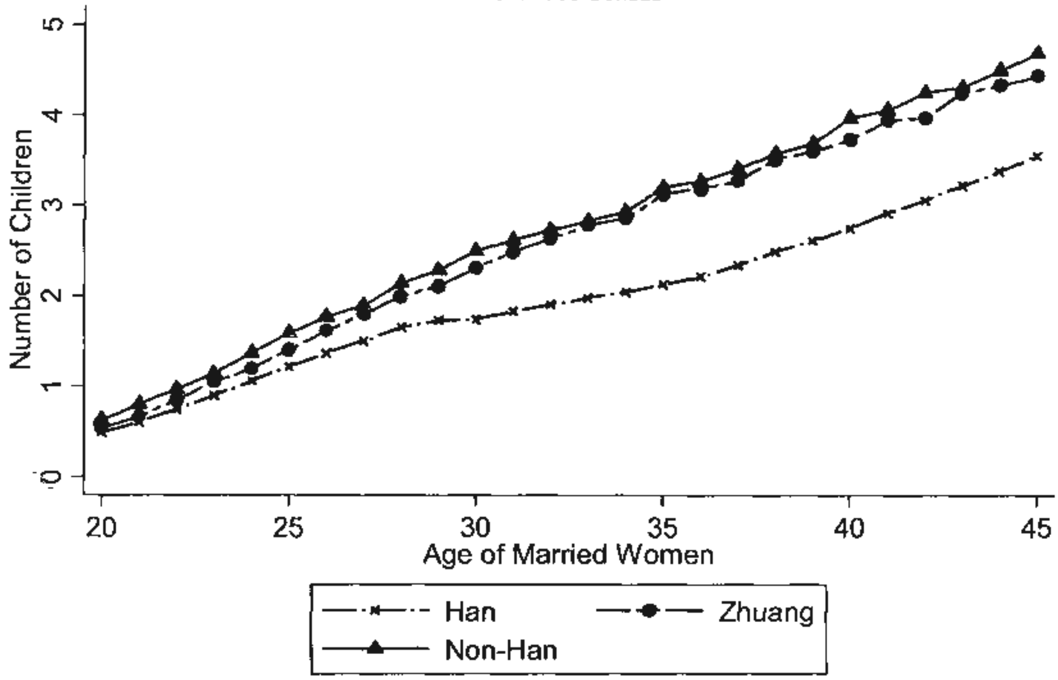
App Fig 4 2 1a No of Children of Married Women in 1982
from 1982 Census



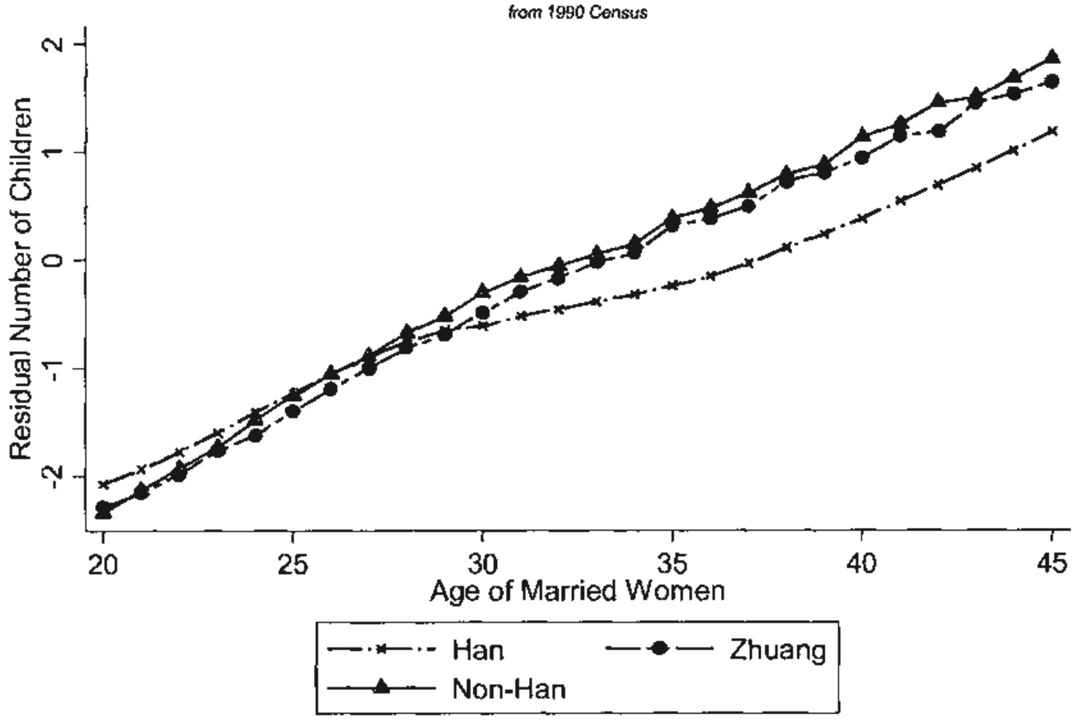
App Fig 4 2 1b No of Children of Married Women (Excluding Effects from Provinces) in 1982
from 1982 Census



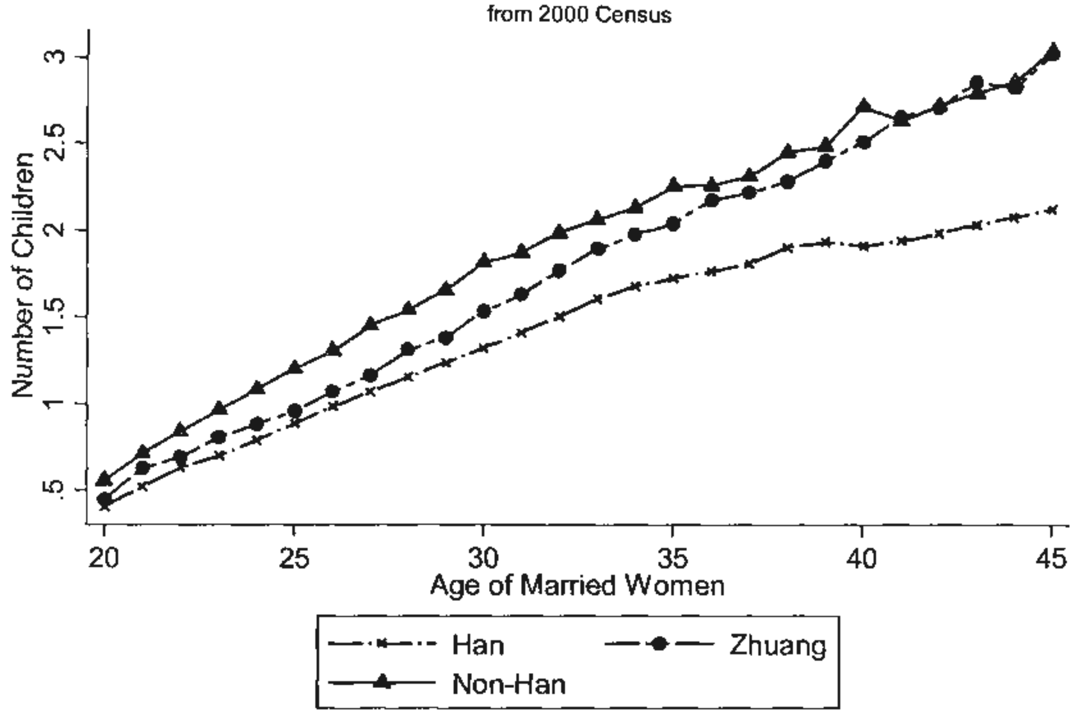
App Fig 4 2 2a No of Children of Married Women in 1990
from 1990 Census



App Fig 4 2 2b No of Children of Married Women (Excluding Effects from Provinces & Urban Hukou) in 1990
from 1990 Census



App Fig. 4.2.3a. No of Children of Married Women in 2000
from 2000 Census



App Fig 4 2 3b No of Children of Married Women (Excluding Effects from Provinces & Urban Hukou) in 2000
from 2000 Census