Economic Growth, Comparative Advantage, and Gender Differences in Schooling Outcomes: Evidence from the Birthweight Differences of Chinese Twins

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Abstract

Data from two surveys of twins in China are used to contribute to an improved understanding of the role of economic development in affecting gender differences in the trends in, levels of, and returns to schooling observed in China and in many developing countries in recent decades. In particular, we explore the hypothesis that these phenomena reflect differences in comparative advantage with respect to skill and brawn between men and women in the context of changes in incomes, returns to skill, and/or nutritional improvements that are the result of economic development and growth.

An emerging worldwide phenomenon is the rise in the schooling attainment of women relative to men, resulting in the level of schooling being higher for women than men in many countries of the world. China is a prominent example. Figure 1, based on data from the 2005 Chinese Mini-census, displays the mean number of years of schooling, by gender and rural-urban categories, across different birth cohorts by the year each reached the age of 22. As can be seen, at least since 1965, women's schooling has risen faster than that of men in both rural and urban areas, and by 2002 in urban areas women's schooling attainment is higher than that of men. In rural areas, men and women's schooling in the most recent cohort is almost at parity by 2002, despite women's schooling being half of that of men in the 1960's.

Another common finding is that the estimated rate of return to schooling for women, conventionally estimated using log-linear wage functions, is higher than that of men. This is true in almost all developed countries (Trostel *et al.,* 2002), and is true also for a majority of all countries of world (Psacharopoulos and Patrinos, 2004). Here again, at least in urban areas where there are superior data on earnings, China is not an exception. Zhang *et al.* (2005) used successive annual urban surveys from six provinces of China from 1988 through 2001 to estimate the rates of return to schooling separately for men and women by year. Figure 2, produced from the reported annual estimates from their study, shows three phenomena: (i) a higher rate of return for women in every year, (ii) rising rates of return for both men and women, and (iii) a faster rise in the return for women than for men.

In this paper, data from two surveys of twins in China, the 2002 Adult Twins Survey and the 2002 Child Twins Survey, supplemented with data from the 2005 Chinese Census are used to contribute to an improved understanding of the role of economic development in affecting gender differences in the trends in, levels of, and returns to schooling observed in China and in many developing countries in recent decades. In particular, we explore the hypothesis that these phenomena reflect differences in comparative advantage with respect to skill and brawn between men and women in the context of changes in incomes, returns to skill, and/or nutritional improvements that are the result of economic development and growth. We employ a framework that describes optimal human capital investments in an economy in which brawn and skill contribute to production and workers sort among occupations according to their comparative advantage in the two attributes (Roy sorting). The model incorporates two biological differences

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between men and women established in the medical literature - that men have substantially more brawn than women (e.g., Mathiowetz *et al.,* 1985; Günther *et al.*, 2008) and that increases in nutritional inputs that augment body mass increase brawn substantially more for males than for females (e.g., Round *et al.*, 1999).

The idea that the relative rise in female schooling reflects comparative advantage in a dynamic setting was explored by Deolalikar (1993) in his study of gender-specific schooling levels in Indonesia, but due to lack of information on occupations it was not possible to rule out other explanations. Thomas and Strauss (1997) also suggested comparative advantage as an explanation for their findings on the gender-specific effects of body mass on urban wages and the higher returns to schooling for women in their study of the Brazilian labor market. Pitt *et al.* (forthcoming) formulated a model that we build on here to assess how comparative advantage of women in skill could account for the overtaking of women's schooling relative to that of men in rural Bangladesh as a result of widespread improvements in health and nutrition. That study also provided independent evidence on the differences in the effect of nutrition on measured strength between men and women.

The comparative advantage explanation for the phenomena exhibited in Figures 1 and 2 is that a rise in the skill-intensity of production (a decline in the value of brawn) leads to an increase in schooling investment overall, higher levels of schooling for workers with a comparative advantage in skill (women), and higher measured returns to schooling overall. Occupational sorting by comparative advantage means that women will be disproportionally represented in skill-intensive occupations so that the average productivity of schooling for women will be higher than that of men, and increasingly so as the occupational division of labor by gender increases.[1] It is difficult to test directly this explanation given that all of these characteristics of an economy are endogenous equilibrium outcomes. Instead, we test the predictions of the model for how exogenous variation in body mass differentially affects schooling investment and wages for males and females, as these reflect both the operation of comparative advantage in occupational choice and the differential effects by gender of nutrition on brawn. We do so by obtaining gender-specific estimates of the effects of differences in

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[1]Zhang *et al.* (2005) show that the selectivity of labor-force participation cannot account for the gender-specific differences in levels or trends in Figure 2.

birthweight within same-sex twin pairs on schooling, health and wages. These estimates by themselves are also useful in assessing directly how nutritional improvements in a population will affect schooling levels and returns by gender.[2]

Birthweight is known to reflect nutritional intake in the womb and to have substantial effects on child and adult health. Differences in birthweight across individuals, however, may reflect parental preferences for investments in human capital and thus any correlation between birthweight and subsequent (post-birth) investments in human capital in the general population are not informative with respect to how an exogenous early increase in nutrition affects post-birth human capital. In contrast, within-twin-pair differences in birthweight cannot reflect parental preferences. A number of studies have estimated the effects of birthweight on longer-term human capital and health outcomes using within-twin pair birthweight variation, exploiting the fact that this variation is orthogonal to parental preferences and constraints (Behrman and Rosenzweig, 2004; Black *et al.*, 2007; Currie and Moretti, 2007; Oreopoulos *et al.*, 2008; Royer, 2009). There are two limitations to these studies, however. First, none compares birthweight effects by gender.[3] Yet, recent studies of the effects of randomized interventions improving the nutrition of children have found that such interventions increase schooling investment significantly more for girls (Bobonis *et al.*, 2006; Maluccio *et al.*, 2009; Miguel and Kremer, 2004) and wage rates significantly more for boys (Hoddinott *et al.*, 2008), results consistent with the framework we employ here. Second, none of these studies provides a theoretical framework linking early nutritional advantages to human capital investments.[4]

The framework we use builds on the model in Pitt *et al.* (forthcoming). That study was the first to estimate the relationships between nutrition endowments and schooling by gender and

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[2]Pitt *et al.* (forthcoming) document the rise in BMI between 1982 and 2002 in Bangladesh resulting from nutritional improvements associated with public health interventions. In urban, but not rural China, BMI has also increased, for both males and females. Figures A and B in the Appendix show mean BMI by gender and rural-urban for individuals aged 17-19 in 1992 and 2002 in China.

[3]Behrman and Rosenzweig (2004), Currie and Moretti (2007) and Royer (2009) use data on female twin pairs only. Black *et al.* (2007) combine same-sex twin pairs when they have common information for both; Oreopoulos *et al.* (2008) combine twins of both sexes for all outcomes.

[4]Glewwe and Miguel (2007) provide such a framework in their review article, but because the model they describe does not incorporate gender differences in brawn or link brawn to labor market outcomes, the model does not provide any mechanisms by which nutrition affects school investments differently by gender.

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between schooling and wages using a specification embodying brawn and skill and that is consistent with the Roy model. The study has two limitations, however. First, the empirical implementation of the model was based on estimates of nutrition production functions to identify body mass endowments. Any biases in the estimates of the production functions, from incorrect functional-form assumptions, for example, will be carried over to the endowment measures used to assess the model. Birthweight differences within twin pairs are less sensitive to functional form assumptions. Second, the estimates were obtained from rural Bangladesh, which has experienced little structural change or wage growth since the early 1980's. As a consequence, it is not possible to assess to what extent changes in the returns to skill or incomes alter gender-specific human capital investment decisions. We explore these effects within the context of the model and empirically by exploiting the multiple birth cohorts represented in our data, the changing urban occupational structure in China, rural urban differences in occupational structures, and variation in household incomes across households making schooling decisions. We are thus better able to assess how economic growth affects gender differences in schooling acquisition as a consequence of gender differences in comparative advantage.

In section 1 we set out the model. Parents choose the optimal amount of schooling for children who differ in gender and are heterogeneous in endowed body mass in a labor market in which brawn and skill are differentially productive across occupations. The body mass endowment affects the returns to schooling and, for males, brawn and thus male wages directly. Implications of the model are derived for how variation in the body mass endowment differentially affects schooling for males and females and how changes in the overall productivity of schooling differentially affects gender-specific schooling investments. The effects of parent income and changes in the return to schooling on the differentials in the relationship between body mass and schooling are also derived. Section 2 describes the data and constructs a new times-series of a measure of the brawn-intensity of urban occupations in five cities in China from the 1970's to 2002 based on unique information from the survey data. These show a monotonic rise in the overall skill-intensity of occupations since the start of reforms in the early 1980's, consistent with the general rise in schooling levels in urban China. In accord with the comparative advantage hypothesis, the skill-intensity of occupations for women is higher than that of men, and the difference in skill-intensity increases during the period. The

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increase in the average skill intensity in the occupations of women relative to that of men thus can account for the rising estimated urban "returns" to schooling for women compared with men depicted in Figure 2.

In section 3 the methods for using twins pairs to estimate birthweight effects under varying occupation distributions in the labor market and by parental income are described. In section 4 we report the estimates by gender of the effects of within-twin pair differences in birthweight on body mass, schooling attainment, and wages for adult (same-sex) twins aged 18-29 in 2002 and on schooling performance, homework time and parental expectations of schooling attainment and health for same-sex child twins aged 12-15. In accord with the predictions of the model, increased birthweight increases attained schooling, schooling performance, parent's expected schooling attainment and homework time significantly more for females and than for males, while having no differential effect on body mass. Increased birthweight also significantly increases the adult wage rates of men, despite having no effect on their schooling level, indicating the importance of brawn in the economy. We also find that the differences in the effect of birthweight by gender on attained schooling increases as the skill-intensity of the occupational mix increases but is smaller at higher levels of parental income, as is consistent with the model.

The schooling investment responses to birthweight variation appear to reflect decisions by households to invest in schooling that are attentive to the differential net returns to such investments by gender but are also constrained by available resources. The theoretical results by income moreover suggest that it is not possible to predict how economic growth will affect gender differentials in the effects of body mass endowments on schooling investment, as income growth by itself shrinks the differential while the rise in the demand for skill increases the differential. However, the finding that in the adult urban sample as the occupational mix became more skill-intensive the differential effects became sharper by gender, despite the accompanying rise in incomes that occurred in the five cities over the twenty-year period, suggests that on net economic growth that is characterized by income growth, increased body mass, and increasing skill intensity, as in China, will increase the gap in the levels of and returns to schooling between men and women.

1. Theory

We are interested in knowing how gender differences in brawn affect the occupational distribution of workers by gender and how the responses by gender of schooling investment to changes in nutrition and changes in the returns to schooling vary by level of development, as characterized by the skill-intensity of production (returns to skill) and income levels. We assume that each worker provides a bundle of skill H and brawn B to perform tasks in a Roy economy in which there is a continuum of tasks indexed by i. Firms in the economy produce outputs that are the sum of the individual outputs of workers from each task. The marginal contribution of a worker to the total output of any firm is thus the worker's task output.

If the Cobb-Douglas technology characterizes the task function, the adult worker wage (the value of a worker's contribution to task output) is given by:

(1) $$W = \pi(i)v(i)(\kappa H)^{\alpha(i)}B^{(1-\alpha(i))},$$

where $\pi(i)$ = the equilibrium price of the output of task i, $v(i)$ = a task-specific productivity parameter, and κ = is a scalar that converts H into units of brawn.

We can order without any loss of generality occupations/tasks by skill intensity, as in Ohnsorge and Trefler (2007), so that $\alpha_i > 0$, where $\alpha_i = \partial\alpha/\partial i$. Thus a higher i means a more-skill-intensive task. That is,

$$\text{if } i' > i, \text{ then } \alpha(i') > \alpha(i).$$

For a worker with attributes B and H, (1) is maximized when occupation i is chosen such that

(2) $$\log(\kappa H/B) = -(\pi_i + v_i)/\alpha_i\pi(i)v(i)$$

Expression (2) gives the standard Roy-model result: activity choice depends on a worker's relative amounts of brawn and skill - comparative advantage. Those persons with a comparative advantage in skill (women) will thus be in more skill-intensive (higher skill return) occupations, where skill has a higher marginal product.[5]

Each individual is endowed with a body mass endowment m and an endowment of brawn b. For males, m determines the amount of brawn the worker has, as described by

(3) $$B = B(\gamma m) + b,$$

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[5]This property of the model is true as long as the task function is CRS. Note that in an economy in which the ratio of skill to brawn is less than one (a brawn-based economy), the task price or task productivity must rise as skill-intensity rises ($\pi_i > 0$ or $v_i > 0$, where $\pi_i = d\pi/di$ and $v_i = dv/di$). This is because for a worker for whom $\log(\kappa H/B) < 0$, a shift to a higher $\alpha(i)$ activity would lower his or her output and thus wage, so either the task price or task productivity must be higher to compensate a move. Pitt *et al.* (forthcoming) found this to be true empirically in rural Bangladesh.

where $\gamma \geq 0$, $B_m > 0$, $B_{mm} < 0$.[6] γ is a parameter that reflects gender differences in the relationship between body mass and brawn. Consistent with the biomedical literature and the findings in Pitt *et al.* (forthcoming), we assume that increased body mass increases brawn for males, and not for females ($\gamma = 0$). The brawn of females is thus given by the endowment *b*.

Skill is produced by spending time *S* in school. The production of skill is given by

(4) $$H = H\ (S,\ m),$$

where $H_S > 0$, $H_m > 0$. We assume that a higher body mass endowment increases the return to schooling *S* in augmenting skill, so that $H_{Sm} > 0$. Schooling and health are complements in the production of skill, equally for males and females.

Workers when young work for a wage ω when not in school, which is a positive function of brawn, but not skill:

(5) $$\omega = \omega(B),$$

where $\omega_B > 0$, $\omega_{BB} < 0$.

To fix ideas about how schooling investment is shaped by these fundamental gender differences in brawn under different economic conditions, we set out a simple behavioral model: parents with income *F* are altruistic with respect to their children's adult wage *W* and choose optimally the amount of schooling of their children and family consumption *C*, maximizing

(6) $$U(\ C\ ,\ W\ )$$

subject to (3) - (5) and the budget constraint

(7) $$F + (1 - S)\omega - S\rho = C,$$

where ρ is the direct cost of schooling.

If (6) is separable, this programming problem is equivalent to choosing *S* to maximize lifetime income

(8) $$(1 - S)\omega - S\rho + W.$$

We will initially work with (8), as it simplifies notation. Using (6) one can additionally derive effects of changes in parent income and we will discuss these effects below.

We now show that differences in the level of brawn between men and women and differences in γ, the gender-specific relationship between nutritional intake (body mass) and

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[6]Body mass is a function of nutritional intake, which reflects endogenous diet choices. In our empirical work we use a measure of body mass that is independent of investment allocation decisions made by parents. In the brawn-based model in Pitt *et al.* (forthcoming), body mass reflects both endowments and optimal food allocations.

brawn, are reflected not only in gender differences in occupational choice, as in (2), but also in how exogenous changes in nutrition and changes in the skill-intensity of production (returns to skill) in the economy differentially affect schooling investments by gender.

The first-order condition that maximizes (8), subject to the constraints, is

(9) $$H_S = (\omega + \rho)H/W\alpha(i).$$

From (9), we see that lower levels of schooling investment (higher marginal product of schooling H_S in skill production) for males relative to females can be explained by a higher opportunity cost of schooling ω and lower marginal return to skill for males due to their choosing an occupation with a lower $\alpha(i)$, as in (2).

We now show that the effect of an equal change in the body mass endowment has a different effect on schooling for females from that for males, the difference depending on the value of α. The effect of an increase in m on schooling for females ($\gamma = 0$) is given by:

(10) $$dS/dm = -[HH_{Sm} + (\alpha(i)-1)H_SH_m]/\Theta,$$

where $\Theta = (\alpha(i)-1)H_S^2 + H_{SS}H<0$. Thus, if schooling and nutrition are complements in production and the direct effect of nutrition on skill (H_m) is small, girls endowed with better nutrition will obtain more schooling. This is the standard hypothesized effect of the consequence for schooling of nutritional supplementation that has been the focus of field experiments.

Expression (10) characterizes the relationship between schooling and body mass for males as well if brawn is also not increased for men. But, even in that case expression (10) is more positive for women than men because of the fact that, due to comparative advantage, women choose more skill-intensive occupations. That is, expression (10) is greater the higher is α:

(11) $$d(dS/dm)/d\alpha = -[H_mH_S + H_S^2dS/dm]/\Theta>0,$$

Expression (11) not only implies that schooling will be more responsive to body mass endowments for workers choosing higher-α occupations (women), but also that as occupations in general become more skill intensive over time due to economic development, schooling will be more strongly related to nutrition and health for women.

What happens if we also account for the fact that for males increased body mass also increases brawn ($\gamma > 0$)? The effect of the body mass endowment on schooling is then:

(12) $$dS/dm = -[HH_{Sm} + (\alpha(i)-1)H_SH_m]/\Theta - \gamma B_m[(\alpha(i)-1)H_S/B - (H/W)\omega_B/\alpha(i)]/\Theta.$$

The first term is the same as expression (10) - the effect of a change in the body mass endowment on schooling for females. There are two additional components to the effect of a change in m on S in (12) compared to (10) that arises from the fact that for males body mass is positively related to brawn ($\gamma B_m > 0$). The first is that an increase in brawn raises the return to schooling because of the complementarity of skill and brawn in the wage function (1). The second is that the opportunity cost of schooling ω is increased, which lowers the net return to schooling investment for males. This latter effect will offset the positive effect on schooling due to the complementarity of schooling and nutrition in the production of skill.

Will this gender gap in the effects of body mass on schooling be larger or smaller in an economy with a higher return to skill - where all workers on average are in higher-α jobs? Denote the added term in (12), the difference in the effects of m on S between males and females arising from brawn-increasing with nutrition for males, as Γ. The effect of a change in α on Γ is given by

(13) $$\mathrm{d}\Gamma/\mathrm{d}\alpha = \{\gamma B_m[H_S/B + (\omega_B/\alpha)(\gamma/\alpha - H/W(\log(\kappa H) - \log B))] - \Gamma H_S^2\}/\Theta,$$

where we have suppressed the i index for compactness. The first term in (13) is negative. The sign of the second term depends on both the brawn-intensity of male workers ($\log(\kappa H) - \log B$) and the average skill-intensity of their occupations α. If men are "brawny", such that $\kappa H/B < 1$, the effect is more likely to be negative. If $\Gamma < 0$ - the difference in the effects of the body mass endowment on schooling between women and men is negative due to the increased brawn of men - then the last term in expression (13) is also negative. Thus, an exogenous increase in the overall level of skill-intensity in the production technology is likely to increase the gap in the response of schooling to changes in body mass between men and women as long as male workers are on average brawny.

The model also implies that the direct response of schooling to a change in the overall return to skill α depends on the skill-intensity of workers. The effect of a shift in α on S is given by

(14) $$\mathrm{d}S/\mathrm{d}\alpha = -H_S(W/H\alpha(i))[1 + \alpha(\log(\kappa H) - \log B)]/\Theta.$$

Expression (14) indicates that if workers are brawny, the effect of an increase in occupational skill-intensity (returns to skill) on schooling investment is ambiguous. Although an increase in α directly increases the payoffs from schooling investment, the relative decline in the returns to

brawn, for brawny workers, directly lowers the adult wage. In that case spending less time in school and earning more when young (at unchanged wage ω) can maximize total lifetime income. Of course, as an economy develops, the opportunity cost of schooling for unskilled workers may decline as well which would increase schooling investment.

The key implication of (14) is that because the response of schooling to a change in the return to skill depends on the brawn-intensity of the worker, the change in schooling investment for males and females when the return to schooling changes will be different because of the gender difference in brawn intensities. Another concomitant of economic development, apart from changes in nutrition and in the demand for skill, is income growth. To assess the effects of changes in (parent) income on gender differences in schooling investment, we return to the utility model.

In Appendix A we show that in the separable version of the model, increases in income increase schooling investment, but even in the absence of parental favoritism with respect to gender the income effect will differ by gender due to the differing comparative advantages of men and women with respect to brawn and skill. Knowing that men will occupy jobs lower in skill intensity than those of women and have a comparative advantage in brawn, however, is not sufficient to sign the difference in income effects by gender. More interestingly, the model yields the result that the gap between males and females in the response of schooling investment to a change in the body mass endowment shrinks as parental incomes rise. This is because the utility gain from increased parental consumption derived from higher child wages for brawnier boys is smaller at higher incomes. The utility returns from child work (non school attendance) are thus lower.

2. Data

   a. Samples for analysis

We use data from four surveys to characterize gender-specific occupational distributions by rural and urban locations and over time in China and to assess how differences in endowed body mass affect schooling investments, accomplishments and attainment differentially by gender across rural and urban areas and by cohort.

The first data source is the Chinese Twins Survey (CTS), which was carried out by the Urban Survey Unit (USU) of the National Bureau of Statistics (NBS) in June and July 2002 in

five cities of China - Chengdu, Chongqing, Harbin, Hefei, and Wuhan. The local Statistical Bureaus identified same-sex twins aged between 18 and 65 using a variety of channels, including colleagues, friends, relatives, newspaper advertising, neighborhood notices, neighborhood management committees, and household records from the local public security bureau. Overall, these channels permitted a roughly equal probability of contacting all of the twins in these cities, and thus the twins sample that was obtained is approximately representative. Questionnaires were completed through face-to-face personal interviews. The data set provides information on 1,495 matched pairs of twins (2,990 respondents). For our analysis, we focus on twins aged 18-29 whose schooling investment decisions were made after the Cultural Revolution and in the reform era when labor markets were rapidly evolving and there was sustained economic growth. In this subsample there are 611 male and 326 female twin pairs.

As a counterpart to the twins survey, the same questionnaire was also administered to a probability sample of 1,665 non-twin individuals aged 25-60 in the same five cities based on the sample frame of the regular urban household surveys. These data are meant to be representative of the urban population in those cities and provide historical information on the changing occupational mix in the five cities, as discussed below.

We also use data from the Chinese Child Twins Survey (CCTS), the first large-scale survey based on a sample of child twins. The survey 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. Households with child twins aged between 7 and 18 in both rural and urban areas were the target population, initially identified by USU according to whether children had the same birth year and month in the age interval and the same relation with the household head using data from the 2000 population census for Kunming. The addresses of the eligible households were obtained from the census office and actual child twins were then determined by household visits. From the population census 2,300 pairs of potential twins were identified. As for the CTS, households with non-twin children in the same age group were also surveyed.[7] The CTS data set provides information for the 1,694 households with twins who were successfully

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[7] For every child twin household identified, the fourth household on the right hand side of the same block was chosen to locate a non-twin child household. (If the fourth household was not an eligible household, interviewers would continue to go to the fifth, sixth etc.).

interviewed, and 1,693 households (with 1,892 children) with no twin children in the eligible age group.[8]

From the CCTS data we examine schooling investment for the subsample of twins in the age group 12-15. We focus on this narrow age group for two reasons. First, we require children old enough to have accumulated achievements in school and for parents to be able to make more realistic assessments of their progress to assess their future. However, children above 15 in the sample are highly selective by schooling because of the sampling design that included only twins in the target age range who were co-residing with parents. Inspection of the data indicated that there was sharp fall-off in sample size for children above 15, and in the sampled twins aged 16-18 there were almost no children not attending school. These attendance rates are substantially above those for the comparable age group in Census data. Clearly most school drop-outs had left home. For the restricted age group, there are 194 male and 222 female rural twin pairs and 205 male and 211 female urban twin pairs in this non-selective and relatively mature age group.

Both the CTS and the CCTS provide information on the birthweight, current height and weight and educational attainment of all respondents. The survey of adult twins additionally provides information on occupation, and monthly earnings. The CCTS provides for the child twins information on performance in school (grades in mathematics and language) and number of honors, child study time at home, and parental expectations of each child's achievement and health, and parental homework assistance and health expenditures on each child. There is also information on household income, which will permit an assessment of the variation in estimates for different income levels.

Tables 1 and 2 provide descriptive statistics for the CTS and CCTS twins sub-samples, by gender (and location for the CCTS), respectively. Both of these data sets indicate that in urban areas, the average birthweight of males is higher than that of females, but all measures of schooling attainment and achievement favor females in both rural and urban areas. Among the adults aged 18-29 in the CTS sub-sample, the schooling attainment of women exceeds that of men, by a half a year. In the sample of children in the CCTS, girls spend more time doing homework than boys, the difference of 10 minutes per day being statistically significant in the urban sample, and achieve higher average math and language grades and more cumulative school

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[8]Both respondent parents and children were interviewed, in separate rooms.

honors, the differences being statistically significant in rural areas. Parents also expect girls to eventually obtain more years of schooling, by about half a year (the same difference in actual schooling attainment in the CTS), and to be more likely to attend university than boys in both urban and rural areas, with the difference statistically significant in urban areas. Indeed, parents in urban areas think the likelihood of girls attending university is 35% higher for girls. In contrast, gender differences in parental expectations about children's "good" health are not significantly different in either the rural or urban population. Interestingly, parents spend more time assisting boys with their homework than girls in both areas, but the results are not statistically significant.

b. Contrasts and changes in occupational distributions

The model suggests that returns to skill affect schooling investment and the responses of schooling investment to variation in endowed health. Both the CTS and the CCTS provide information permitting the examination of educational investments in labor markets with different relative returns to brawn, as reflected in the occupational distribution. The CCTS provides information for both rural and urban households. Residents in the two areas face very different labor market demand structures, especially in terms of the relative returns to brawn, although brawn-intensive occupations are important in both areas. Table 3 provides the distribution of occupations for three sets of workers aged 25-34 - rural residents, migrants from rural areas working in urban areas and non-migrant urban residents - from the 1% sample of the 2005 Chinese mini-census. The table shows how dramatically different the occupational mix is between urban and rural areas. If we assume that the occupational categories farming and fishery and production and transportation are occupations that are relatively brawn intensive, then, as can be seen from the table, in rural areas more than 86% of occupations are brawn-intensive while in urban areas among non-migrants, 30-42% of occupations are brawn-intensive. Even among rural migrants in urban areas the occupational mix is substantially less brawn-intensive than that of rural residents. Note too that in urban areas, where there are proportionally a large number of skill-intensive jobs, female workers are 12% more likely to be in a skill-intensive occupation than are male workers, consistent with comparative advantage. In contrast, in rural areas, where there are few skill-intensive jobs, gender difference in the occupational mix are negligible.

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Because there is information on many birth cohorts in the CTS and because the urban labor market environment in China has changed substantially over time, the different birth cohorts represented in the CTS undertook educational investments under different labor-market settings. We use a unique feature of the non-twin CTS to depict the temporal changes in the occupational mix (brawn-intensity) for the five cities and to reconstruct the occupational distribution facing each cohort in each city at the time educational investments were made. Ordinarily it is not possible to reconstruct a time-series of the aggregate occupational structure based on the current occupations of different age cohorts in a single cross-section. This is because workers may have shifted occupations over time in response to changes in the economic environment. The current occupational distribution by age reflects both life-cycle and cohort effects. What is needed is a time-series of occupations for people of the same age in each year.

The CTS provides the occupation of each respondent when he or she was first married and the year of that marriage. As almost all respondents married, and almost all married within the age range 20-29,[9] we can use the at-marriage information to construct a time series of occupations by year, based on year of marriage, for young workers. Figure 3 displays the change in the proportion of occupations that are non-brawn, based on the same criterion and occupational categories as used in Table 3, derived from the occupation-at-marriage information in the non-twin CTS. As can be seen, in the five cities represented in the CTS, there has been a dramatic rise in the skill-intensity of the occupations of young workers since the early 1980's, reversing a trend downward in the preceding 15 years, with the start of the upward trend coinciding with the introduction of economic reforms. In particular, over the twenty year period beginning in 1982 the proportion of skill-intensive jobs rose from 46% to almost 65% in the five cities by 2002, the latter figure being roughly in line with that from the 2005 Chinese mini-census for all urban areas in China.

Schooling decisions made by the older cohorts in the CTS when they were young were evidently taking place in a setting where returns to brawn were substantially greater than those faced by the younger cohorts. Based on the construction of a variable characterizing the brawn-intensity of the occupational mix by city and (marriage) year, we will examine below whether

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[9] 98.8% of women and 91.0% of men married between age 20 and 29 for marriages taking place after 1981. There were also no significant changes in age of marriage over the period 1982-2002. In 1982, mean age at marriage for women (men) was 24.1 (25.9); in 2002 the mean age was 24.4 (26.0).

and how gender-specific educational investment decisions varied by the relative returns to skill, as suggested by the model. Differential trends in the occupational mix across men and women, however, suggest the operation of occupational selectivity by comparative advantage in skill indicated by the model. While the trends in the overall occupational structure reflect mainly changes in demand resulting from market reforms and other changing economic conditions as well as changes in technology, the differences in the mix of occupations by gender reflect the choices of workers. In the context of the Roy model incorporating brawn and skill, we would expect female workers to shift towards the newer skill-intensive jobs relative to males.

Figure 4 depicts, using the same at-marriage information, the trends over the same time period, separately for men and women, in the skill-intensity of occupations held by young workers in the five cities. As is consistent with the comparative advantage model and the gender difference in brawn, the occupational mix for women has not only been more skill-intensive than that of men in every year since 1982, it has become more so over time. In 1982, 42% of young men and 50% of young women were in skill-intensive jobs. By 2002 the participation rate in skill-intensive jobs for young men had risen by 10 percentage points to 50%; that for young women, however, rose by 40 percentage points, to almost 90%.

These trends in gender-specific occupational choices exhibited in the five CCT cities also provide one explanation for the differential levels of and trends in the urban gender-specific rates of return to schooling reported in Figure 2 based on the Roy-model incorporating brawn, if the trends in the occupational mix are typical of those in the six provinces. In the model, and consistent with the econometric evidence in Pitt *et al.* (forthcoming), the returns to schooling are higher in skill-intensive (high α) occupations, so the growth in the average return to schooling follows from the decline in the importance in urban areas of brawn-intensive activities. Similarly, the relative rise in female returns to schooling follows from their increasing specialization in skill-intensive jobs relative to men, as is consistent with their comparative advantage.

3. Estimating the Effects of Body Mass Endowments on Schooling, Wages and Nutritional Status

The correlation between the urban trends in the gender-specific skill-intensity of occupations and the estimated returns to schooling is implied by the brawn-based Roy-model

incorporating gender differences in brawn levels and the response of brawn to variation in endowments of body mass. But the association between these aggregate statistics is not a rigorous test of the model because the direction of causation is not established. To better assess the model and the role of gender differences in brawn, we proceed to carry out tests of the implications of the framework for how variations in nutrition endowments affect schooling investments by gender, where causation is more transparent. In linear form, the main equation we seek to estimate, based on the reduced-form of the model, is:

(15) $$S_{ijk} = \beta_k m_{ijk} + \eta_k F_j + \lambda_k \alpha_j + \mu_j + \varepsilon_{ijk},$$

where S_{ijk} = the schooling attainment of child i of gender k (g,b) in household j; m_{ijk} = that child's body mass endowment; F_j = household j's per-capita income; α_j = the average skill intensity of occupations in the local economy; β_k, η_k, and λ_k are gender-specific parameters; μ_j = household-specific error term; and ε_{ijk} = a child-specific error term. The latter two components of equation (14) capture variation in unmeasured determinants of schooling across households and children. These include, for example, parental preferences or costs of schooling. We are interested in testing if $\beta_g > \beta_b$ and $\lambda_g > \lambda_b$, as implied by the model.

The model also implied that the effects of changes in the endowment m on schooling may differ by parental income and by the average skill-intensity of activities. To test for this, we want to estimate the interactive equation

(16) $$S_{ijk} = \beta_k m_{ijk} + \beta_{k2} m_{ijk} F_j + \beta_{k3} m_{ijk} \alpha_j + \eta_k F_j + \lambda_k \alpha_j + \mu_j + \varepsilon_{ijk}.$$

Birthweight is the earliest measured indicator of the nutrition endowment m_{ijk}. The problem estimating (15) or (16) using birthweight to measure m_{ijk} is that birthweight is likely to be correlated with the unobserved household factors μ_j. The most obvious is that parents who prefer human capital investment relative to their own consumption will also invest more in the prenatal and postnatal periods, creating a spurious positive correlation of birthweight and schooling. If these preferences for human capital investment differ by the gender of the child it is possible that the coefficients β_k will differ by gender, but not because of the mechanisms highlighted in the model. As originally noted by Behrman and Rosenzweig (2004), differences in birthweight across twins are independent of parental preferences or resources, resulting from, among other factors beyond the control of parents, womb position. Yet these differences in

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birthweight within twin pairs are sufficiently large and variable to provide reliable estimates of the long-term effects of birthweight variation.

With our twins data sets, we estimate the differenced versions of (15) and (16):

(17) $$\Delta S_{ijk} = \beta_k \Delta m_{ijk} + \Delta \varepsilon_{ijk}$$

(18) $$\Delta S_{ijk} = \beta_k \Delta m_{ijk} + \beta_{k2} \Delta m_{ijk} F_j + \beta_{k3} \Delta m_{ijk} \alpha_j + \varepsilon_{ijk},$$

where Δ is the within-twin pair difference operator. These sweep out the household unobservables that jointly affect the outcomes and birthweight. Note that by only using the variation within twin pairs to identify the β_k we cannot identify the direct effect of variation in parental income F_j or average skill-intensity (skill return) α_j. However, we can still identify the effects of the interaction of these variables with the endowment β_{k2} and β_{k3}. In fact, we will estimate a more general form of (18) in which we obtain local-area (Lowess) estimates of the β_k for each value of F_j or α_j to observe how differences in the effects of birthweight on schooling over the full span of the sample income and α_j distributions.

4. Estimates

   a. Adult twins sample

The first column of Table 4 displays the within-twin pair estimate of birthweight on attained years of schooling for adults aged 18-29 combing the samples of male and female twin-pairs. The effect is not statistically significantly different from zero. In the second column the estimates are provided separately for males and females. Consistent with the model, the birthweight effect on schooling is positive and significant for females, but is essentially zero - the point estimate is negative - for males. The gender difference in birthweight effects is statistically significant at the .05 level. These results are similar to those obtained by Pitt *et al.* (forthcoming) for rural Bangladesh using their production-function-based estimates of body-mass endowments, except that in their sample the male endowment was negative and statistically significant and the female endowment effect was positive but not statistically significantly different from zero.

The model suggested that the gender-specific effects of birthweight variation on schooling attainment may differ across labor markets with differing demands for skill-intensive workers. In Figure 5, we show the locally-weighted, within-twin-pair Lowess estimates of the gender-specific effects of birthweight on attained schooling β_k across the labor markets conditions faced by each cohort as it carried out schooling investment decisions. The x-axis

displays the fraction of occupations that are brawn-intensive in each city at the time each respondent was aged 25, based on the marriage-age estimates obtained from the adult non-twins data set from the same five cities. As can be seen and as predicted by the model, the effect of birthweight on schooling is not only positive for females over the full historical/spatial range of the α_j variable but is substantially higher in labor markets where skill-intensive occupations are dominant. In contrast, the effect of birthweight on schooling for males is always lower than that of males and falls as the skill-intensity of the labor market increases, with the male birthweight effect negative in labor markets where over 55% of the jobs are skill-intensive. Thus, it appears that development that favors skill increases the gap in the effects of endowed body mass on schooling investment between men and women.

A key assumption of the theoretical framework is that body mass for males has a direct positive effect on wages in an economy in which brawn plays a role in production. The fourth column of Table 4 reports the within-twin pair estimates of birthweight on the log of the monthly wage.[10] The estimates indicate that higher-birthweight males have significantly higher wage rates: a one standard deviation in birthweight is associated with a 12% increase in the wage. It is important to note that because birthweight for males did not increase schooling (column 2) the effect of birthweight on the male wage is not due to higher-birthweight males being more skilled but reflects their greater brawn. In contrast, for women, the birthweight effect is also positive but is one-fourth as large as that for men despite higher-birthweight women receiving more schooling. These results together are thus consistent with brawn being an important determinant of productivity in urban China and with body mass not being related to brawn for females. The estimates in the last two columns of Table 4 indeed show that birthweight and adult body mass are positively related for both females and males, although the body mass effect point estimate is not precise for women.

b. Child twins sample

Tables 5-7 report within-twin pair gender-specific estimates from the samples of child twins aged 12-15 of the effects of birthweight, by urban and rural location, for measures of

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[10]80% of the twin pairs (79% of males and 81% of females) reported a wage. The selectivity of twin pairs earning wages does not bias the estimates obtained from within-pair variation unless one twin but not the other reports a wage. In both the male and female samples less than 10% of the pairs had one of the pair participating and not the other.

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school performance and body mass, parents' expectations of children's schooling attainment and health, and child and parental school and health inputs, respectively. Although the Lowess estimates displayed in Figure 5 suggested that the effects of birthweight on skill are higher in more skill-intensive labor markets for females, we could not reject the hypothesis that either the male or the female estimates of birthweight effects for any dependent variable are the same across rural and urban areas, despite the very different skill-intensities of the occupations in the two areas, as exhibited in Table 3. Our discussion of the results is thus relevant for both settings, but we will discuss the point estimates only for the combined sample unless there is a notable difference by residence.

The estimates in Table 5 indicate that increased birthweight significantly increases school performance for boys and girls, as measured by both math and language grades and number of honors, but significantly more so for girls. The point estimates (combined sample) indicate that a one standard deviation in school performance is associated with a 3.5% increase in grades for girls but only a 2.3% increases for boys.[11] The same increase in birthweight increases the average number of honors achieved per year over all prior school years by 18.3% for girls and by only 6.5% for boys. However, birthweight increases body mass equally across boys and girls aged 12-15, in both rural and rural areas, consistent with the results from the urban adult sample.

As noted, none of the sample of children in the age group 12-15 had completed their schooling. However, parents were asked about their expectation of their children's ultimate schooling attainment. Consistent with our estimates from the adult sample of twins on the relationship between birthweight and actual school attainment, our within-twin pair estimates from the child sample, reported in the first six columns of Table 6, indicate that parents believe that children with higher birthweight will attain more schooling, as measured both by total years of schooling and the probability of attending university, but again significantly more so for girls. The point estimates, reported in the columns one and four of the table for the combined sample, indicate that a one standard deviation increase in birthweight is associated with an increase in

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[11]We use the standard deviation of 0.5 for the combined rural and urban samples across boys and girls. As can be seen in Table 2, there are only small differences in the birthweight standard deviation across males and females and across areas. For the percentage calculations we also use averages computed across the gender and area samples.

parent's expectation of completed schooling of .2 years for girls and .15 years for boys;[12] and an increase in the expected probability of attending university of 33% (rural) and 13.3% (urban) for girls and 26% (rural) and 9.8% (urban) for boys.[13] In contrast, as seen in the last three columns of the table, while variation in birthweight is also positively related to parent's expectations of the future health status of their children, the relationship does not differ by gender, just as for measured body mass.

One important alternative interpretation of the results indicating that birthweight increases schooling attainment and performance for girls but much less so for boys is that increased nutrition somehow increases girl's ability more than it does that of boys. There is no biological evidence for this link, unlike for gender differences in the augmentation of brawn.[14] But the question remains whether the differential effect of birthweight on schooling by gender reflects differences in ability effects or, as depicted in the model, the optimal choice of effort given brawn differences by gender and market rewards for brawn.

Table 2 indicated that in urban areas, girls spend significantly more time doing homework than boys, although homework time is not different by gender in rural areas. The first three columns of Table 7 report within-twin pair estimates of the effects of birthweight on homework time per school day for boys and girls and by urban and rural location. These estimates indicate that higher birthweight is associated positively with more homework time (effort) for both boys and girls (column one), with the effect stronger for girls. But these effects appear to be confined to rural areas. In those areas, the point estimates suggest that a one standard-deviation increase in birthweight increases homework time for girls by 27% more than it does for boys, increasing the time spent on schoolwork by 7 minutes (15%) for girls and by 5.5

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[12]To place these point estimates in perspective, the estimated overall effect of the Mexican *Progresa* conditional cash transfer program was .66 years (Schultz, 2004) and the estimate of the effect on school years of the massive INPRES school building program in Indonesia was .3 years (Duflo, 2004).

[13]Rural and urban percentages were computed separately because of the large differences in the expected fractions attending university across the two areas in Table 2.

[14]Pitt *et al.* (forthcoming) show that their measure of the body mass endowment was unrelated to one measure of ability, performance on the Raven's Colored progressive Matrices test, for either men or women, but was significantly related to measures of strength for men. They also found that among school-age children, there were no gender differences in performance on the test.

minutes (12%) for boys. These estimates imply that over the course of a school year (9 months) the larger girls would have studied a total of 4.5 more hours than boys.

The homework measure of schooling inputs provided in the survey evidently cannot account for all of the differences between the school performance of boys and girls (and none in urban areas), but it does provide some direct evidence of effort choice. The data also suggest, however, that parents are responding to the difference in school effort. In rural areas, where we find that birthweight differentially affects homework time by gender, but not urban areas where we do not, we find that parents are more likely to assist a boy with a larger birthweight than a girl with a larger birthweight. The within-twin pair point estimates indicate that a one standard deviation increase in birthweight increases the probability of parental help for a girl by 8%; for a boy the probability increases by 57%. The reversal by gender with respect to parent's effort suggests that parents are not merely maximizing the adult incomes of the children, but are perhaps concerned with inequality by gender in schooling that evidently results from birthweight increasing schooling for girls more than boys. This differential does not appear to reflect a general form of favoritism in providing assistance that is biased towards boys; in columns 7-9 our estimates of the effects of birthweight on medical expenditures indicate that expenditures augmenting health or ameliorating illness are allocated equally in response to birthweight differences across boys and girls.

Although we could not statistically reject the hypothesis that the estimates of birthweight effects by gender in rural and urban areas for each specific outcome measure were the same, it is notable that for all schooling measures the results are more precisely estimated in rural areas. The model suggests that birthweight effects may differ by parent income with, in particular, the gender differential in the effect of birthweight narrowing as incomes rise. And, in our sample, per-capita family income is one third less in rural than in urban households. To assess whether this income differential may account for the stronger estimates in lower-income rural areas, we obtained locally-weighted, within-twin pair estimates of birthweight effects for the two contemporaneous schooling variables - average grades in language and math and homework time - by per-capita family income for the rural subsmaple, where birthweight effects are precisely estimated. By restricting the sample to rural areas we are also implicitly holding constant the occupational structure and thus the returns to skill.

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Figures 6 and 7 present the locally-weighted estimates by income for language and math scores and homework time, respectively, where in each graph the x-axis is per-capita household income and the y-axis the estimated birthweight effect at each income level. For both the achievement and input variables, the effects of birthweight are positive and higher for girls than for boys over the full range of incomes, but the birthweight effects diminish as incomes rise and the gender difference in the effects favoring girls narrow, as predicted by the model. To assess whether these non-linearities in income for the schooling investment variables merely reflect non-linearities in the relationship between birthweight and current body mass, we also obtained locally-weighted estimates by household income for the body mass measure. These are depicted in Figure 8, where it can be seen that the positive effect of birthweight on body mass measured at the time of the survey varies little by household income and the differences in estimated effects by gender are not only small but also do not vary across households with different income levels.

The patterns of differential schooling investment responses to birthweight variation by income appear to reflect decisions by households to invest in schooling that are attentive to the differential net returns to such investments by gender but are also constrained by available resources. The results by income suggest that it is not possible to predict how economic growth will affect gender differentials in the effects of body mass endowments on schooling investment. On the one hand, the "pure" effect of increases in income will diminish the gender differential and the effect of the nutrition endowment on schooling, as seen in Figures 6 and 7; on the other hand, we saw from the adult urban sample, and as implied by the model, as the occupational mix became more skill-intensive the differential effects became sharper by gender (Figure 5), despite the accompanying rise in incomes that occurred in the five cities over the twenty-year period.

5. Conclusion

In this paper, estimates of the gender-specific effects of birthweight on a variety of schooling and labor market outcomes obtained from data from two surveys of twins in China were used to contribute to an improved understanding of gender differences in the trends in, levels of and returns to schooling observed in many developing countries in recent decades. In China, these include the rise in the levels of female schooling relative to male schooling, the higher level of female schooling, and the higher and rising returns to female schooling compared to male schooling in the urban labor market. Using a simple model of schooling and occupational

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choice incorporating well-established biological differences in brawn between males and females, we showed that the comparative advantage of women in skill is reflected in their greater schooling investment and the selection of more skill-intensive occupations than men. We also showed that comparative advantage in skill is manifested in differences in the relationship between birthweight and schooling between males and females and that these differences reflect changes in the skill-intensity of the occupational structure in the aggregate economy as well as income change.

In the case of China, we showed, using unique information on the time-of-marriage occupations of birth-cohorts spanning the period between the early 1970's and 2002, that China's occupational structure since the 1980's has become more skill-intensive in urban areas. The model we used indicated that the rise in the relative value of skill to brawn would increase the schooling of females relative to males, increase specialization according to comparative advantage, with women entering the skill-intensive occupations at a faster rate than men, and increase the effects of early nutritional advantages on schooling for females relative to males. We showed that all of these phenomena are observed in China. The greater and rising participation of women in skill-intensive occupations is also consistent with the relative rise in the estimated returns to schooling of women in urban areas of China.

Our framework and findings have implications for the effects of growth policy on the male-female wage gap. For example, economic growth policies that stress industrialization will alter the occupational mix in favor of less brawn-intensive jobs, which favors women, who have a comparative advantage in skill. If economic development increases the relative demand for skill-based work, the gender wage gap should diminish. However, our estimates also indicated that in urban China brawn is still valued in the labor market. Given that men have an absolute advantage in brawn, this means that despite the higher levels of schooling of women compared to men, men may continue to earn higher wages than women even where industrialization has taken place. However, it is important to note that not all economic growth strategies devalue brawn relative to skill. Growth facilitated by improvements in the productivity of seeds in agriculture, for example, in the absence of other changes, increases the demand for manual labor and thus may not reduce the male-female wage gap.

Finally, a unique feature of our study was to use micro evidence on the relationship between birthweight, an early measure of nutritional advantage, and schooling outcomes in different contexts to make inferences about the relationships between specific aspects of economic growth and schooling investments and returns. Even our very simple model of schooling investment and occupational selection, consistent with our findings, indicates that estimates of the effects of childhood nutrition on measures of human capital investment, whether based on randomized interventions or natural experiments, will not only differ by gender but also by context. Simple linear estimates obtained from a particular country on the outcomes of early-childhood nutritional interventions will thus not be generalizable unless care is taken to understand both the level of development and the macro structure.

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Proofs for separable utility model:

The objective function is

(A1) $$U(C) + V(W)$$

and the constraints are (1), (3), (4), (5) and (7).

1. *The income effect on schooling is positive and differs by gender*

The first-order condition for schooling is:

(A2) $$V_W(\alpha(i)H_S W/H) = U_C(\omega + \rho).$$

The income effect on schooling is:

(A3) $$dS/dF = -U_{CC}(\omega + \rho)/\Psi\alpha(i),$$

where $\Psi = V_W[(\alpha(i)-1)H_S W/H^2 + H_{SS}W/H] + V_{WW}\alpha(i)(H_S W/H)^2 + U_{CC}(\omega + \rho)^2/\alpha(i)<0$. Because men and women differ in comparative advantage with respect to brawn and skill, $\alpha(i)$ will be lower and W/H higher for males. Thus, even if preferences for schooling investment do not differ by the gender of a child, the income effect (A3) will not be identical for schooling investments for males and females. However, it is not possible to sign the difference between the income effects.

2. *The effect of income changes on the body mass endowment effect on schooling for females is zero*:

The effect of the body mass endowment on schooling for females is:

(A4) $$dS/dm = -V_W(W/H)[H_{Sm} + H_S H_m]/\Psi > 0.$$

Assuming third derivatives of the utility function U are negligible, there is no effect of changes in F on (A4).

3. *The effect of an income change on the gender difference in body mass endowment effects on schooling is positive*:

The effect of the body mass endowment on schooling for males is:

(A5) $$dS/dm = -V_W(W/H)[H_{Sm} + H_S H_m]/\Psi - \{(\gamma/\alpha(i))B_m[\alpha(i)(\alpha(i)-1)(H_S/W)V_W + U_C\omega_B - SU_{CC}(\omega + \rho)]\}/\Psi.$$

Subtracting (A4) from (A5) and assuming third derivatives of the utility function U are negligible, the effect of a change in income on the gender difference is $-\gamma/\alpha(i))B_m U_{CC}\omega_B/\Psi > 0$.

Figure 1. Mean Years of Schooling by Gender and Urban-Rural and Year Attained Age 22, 1967-2005 (Source: 2005 Chinese Census)
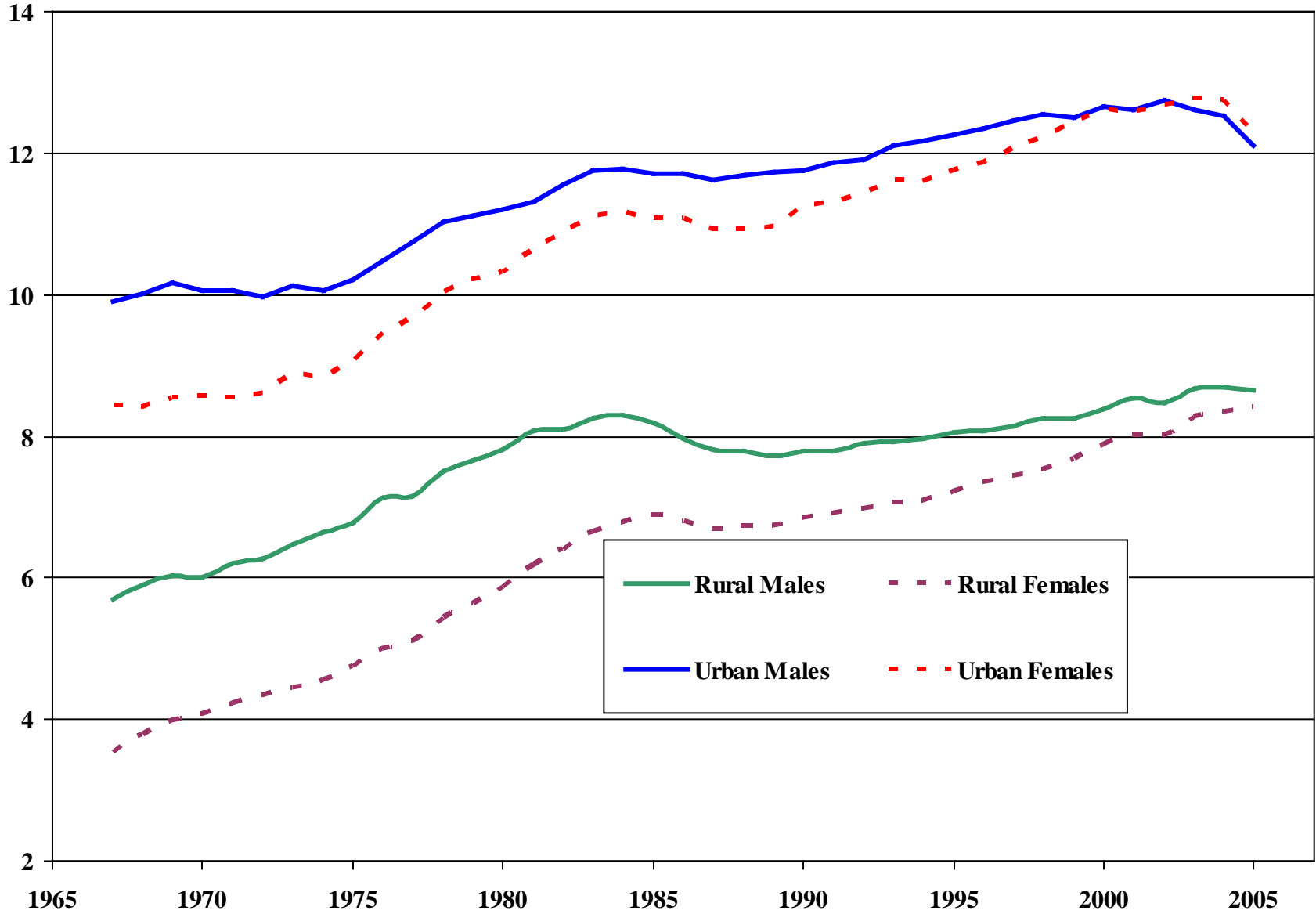
Figure 2. Estimated Rates of Return to Schooling, by Gender and Year, 1988-2001: in Five Chinese Cities (Source: Zhang *et al*., 2005)
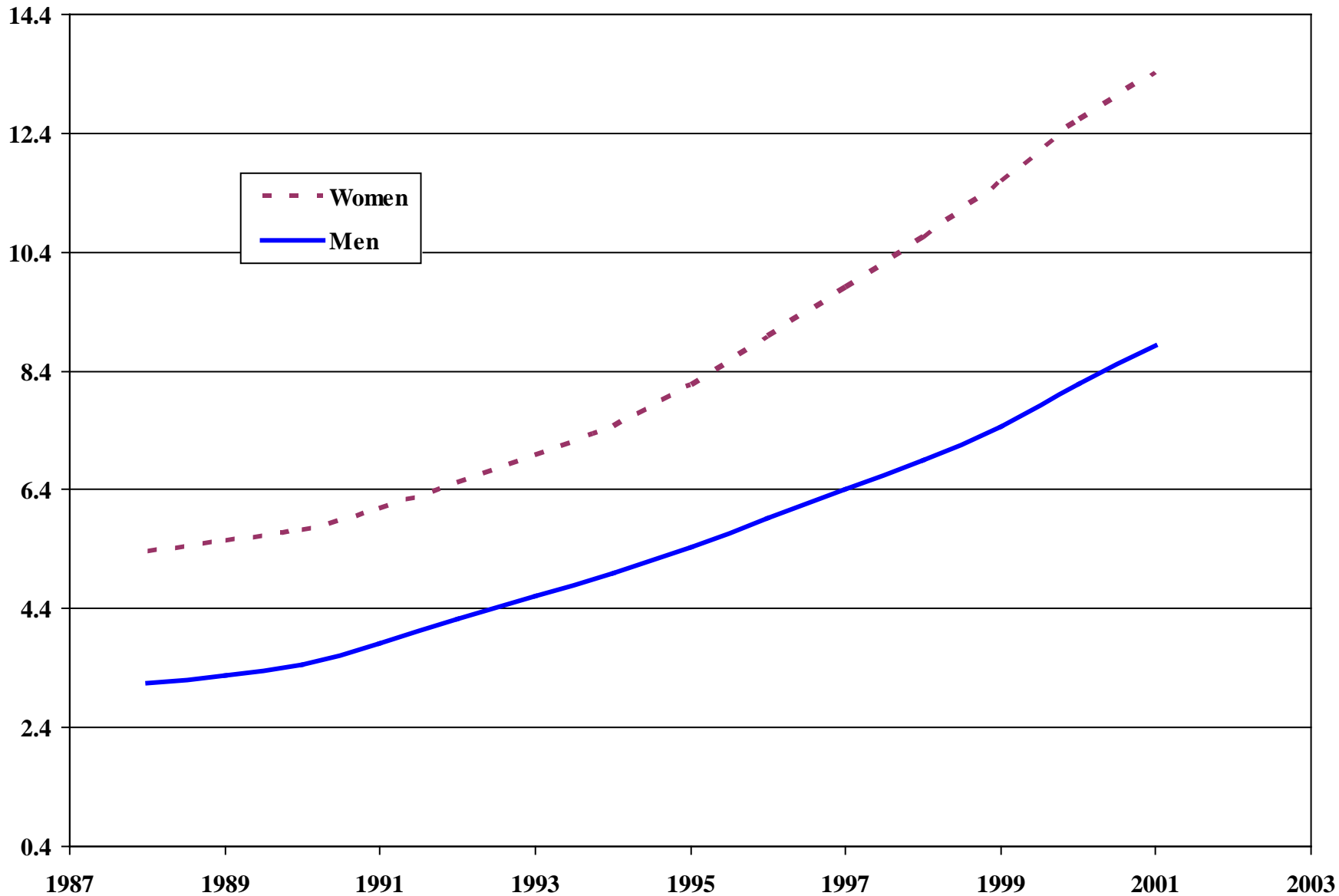
Figure 3. Proportion of Employment in in Non-Brawn Occupations, by Year, 1968-2002: in Five Chinese Cities (Source: 2002 Adult Nontwin Survey)
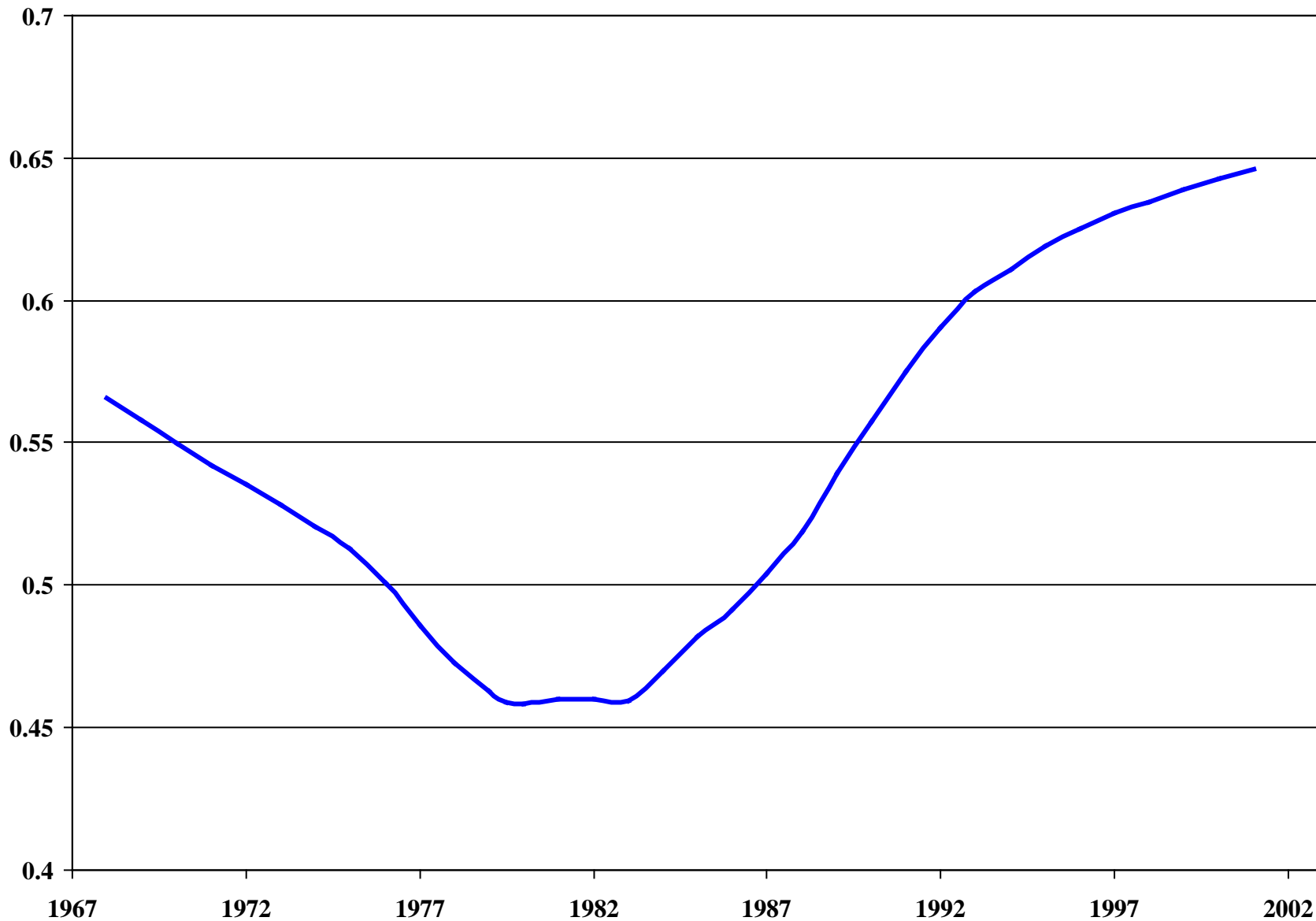
Figure 4. Proportion of Employment in in Non-Brawn Occupations, by Gender and Year, 1968-2002: in Five Chinese Cities (Source: 2002 Adult Nontwin Survey)
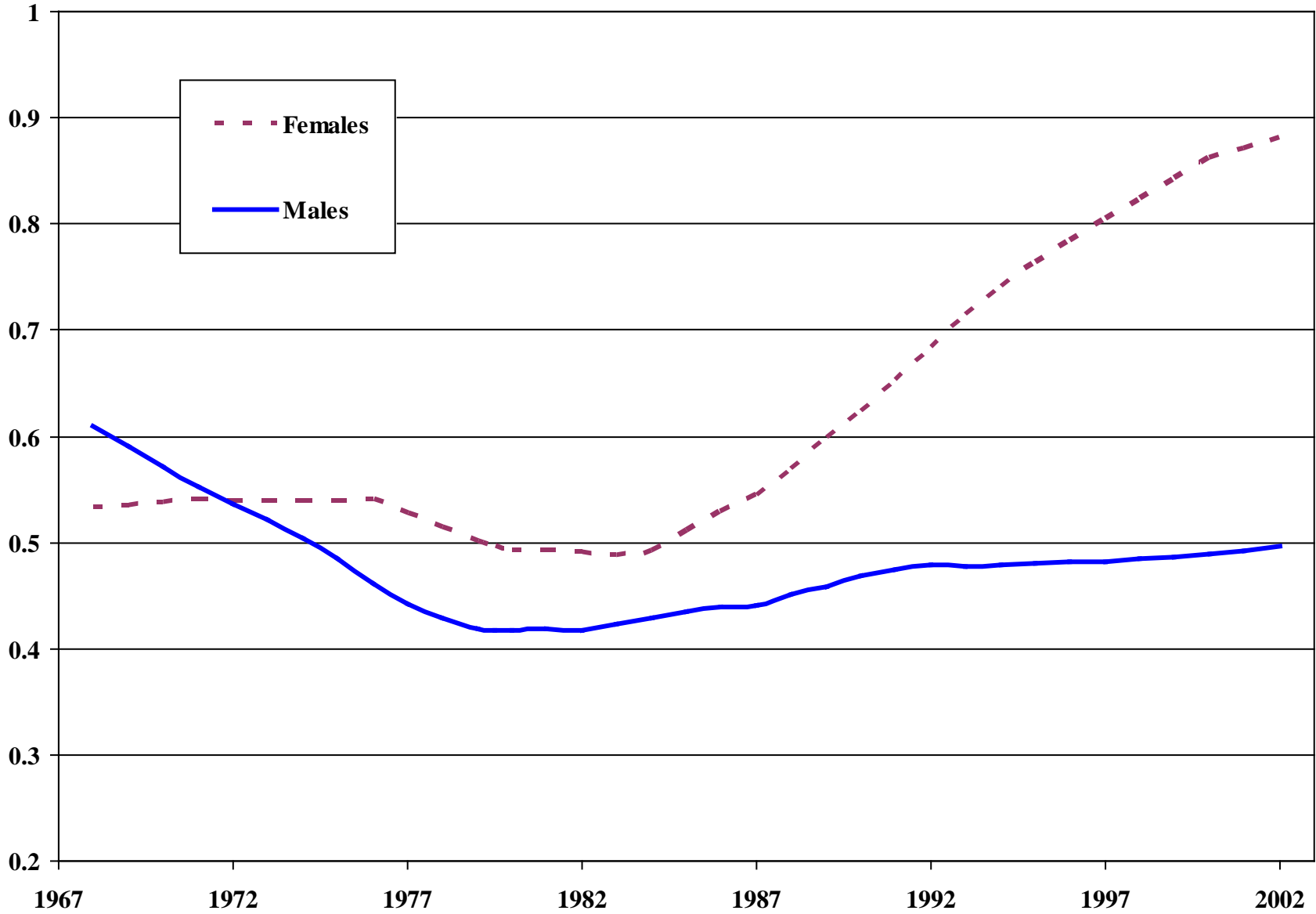
Figure 5. Locally-weighted Within-Twin Estimated Effects of Birthweight on Attained Schooling (Years), by Gender and the Brawn-Intensity of Occupations in Five Chinese Cities

Figure 6. Locally-weighted Within-Twin Estimated Effects of Birthweight on Average Language and Math Grades, by Gender and Per-capita Family Income
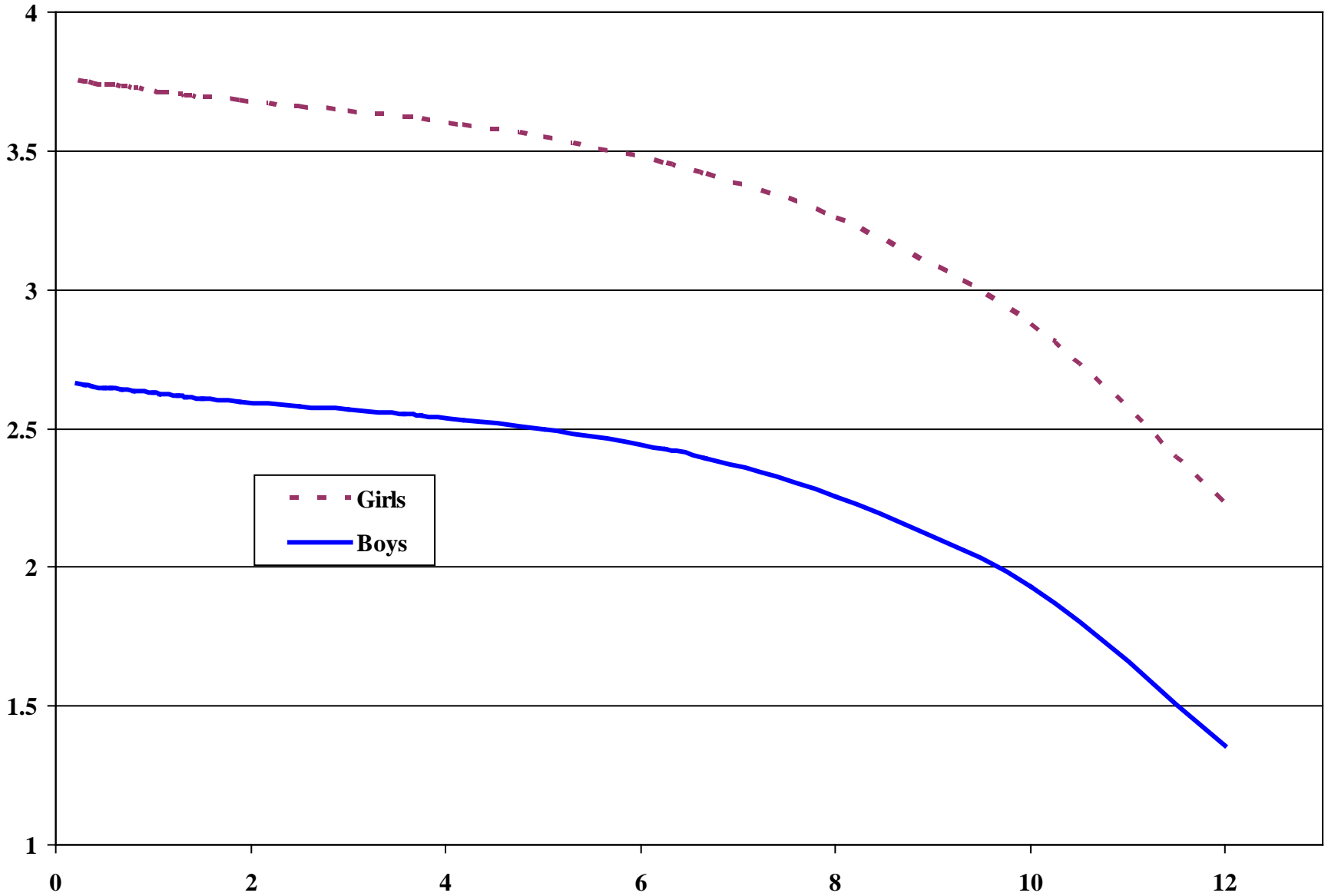
Figure 7. Locally-weighted Within-Twin Estimated Effects of Birthweight on Homework Time (Minutes per School Week Day), by Gender and Per-capita Family Income (Rural Sample)

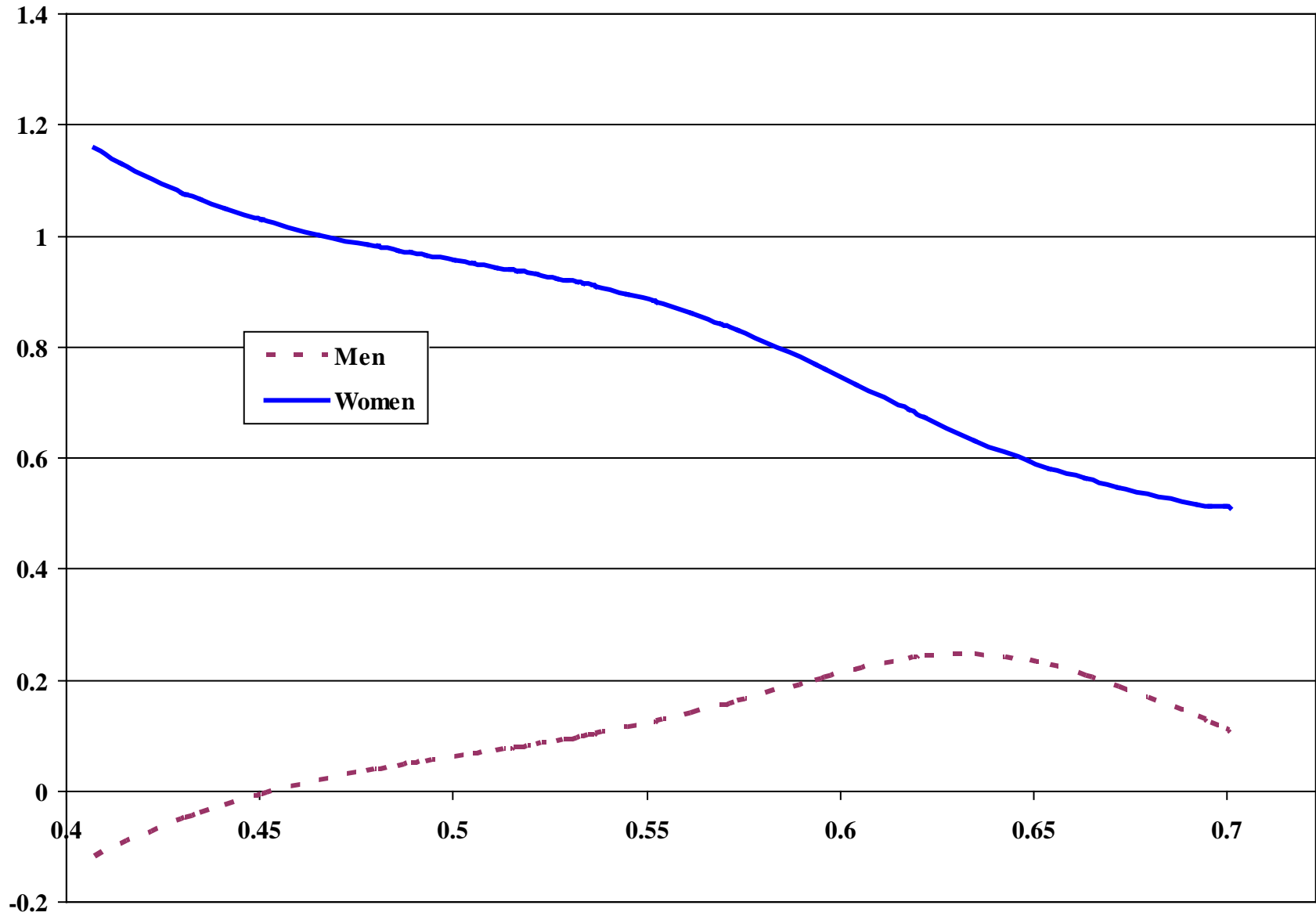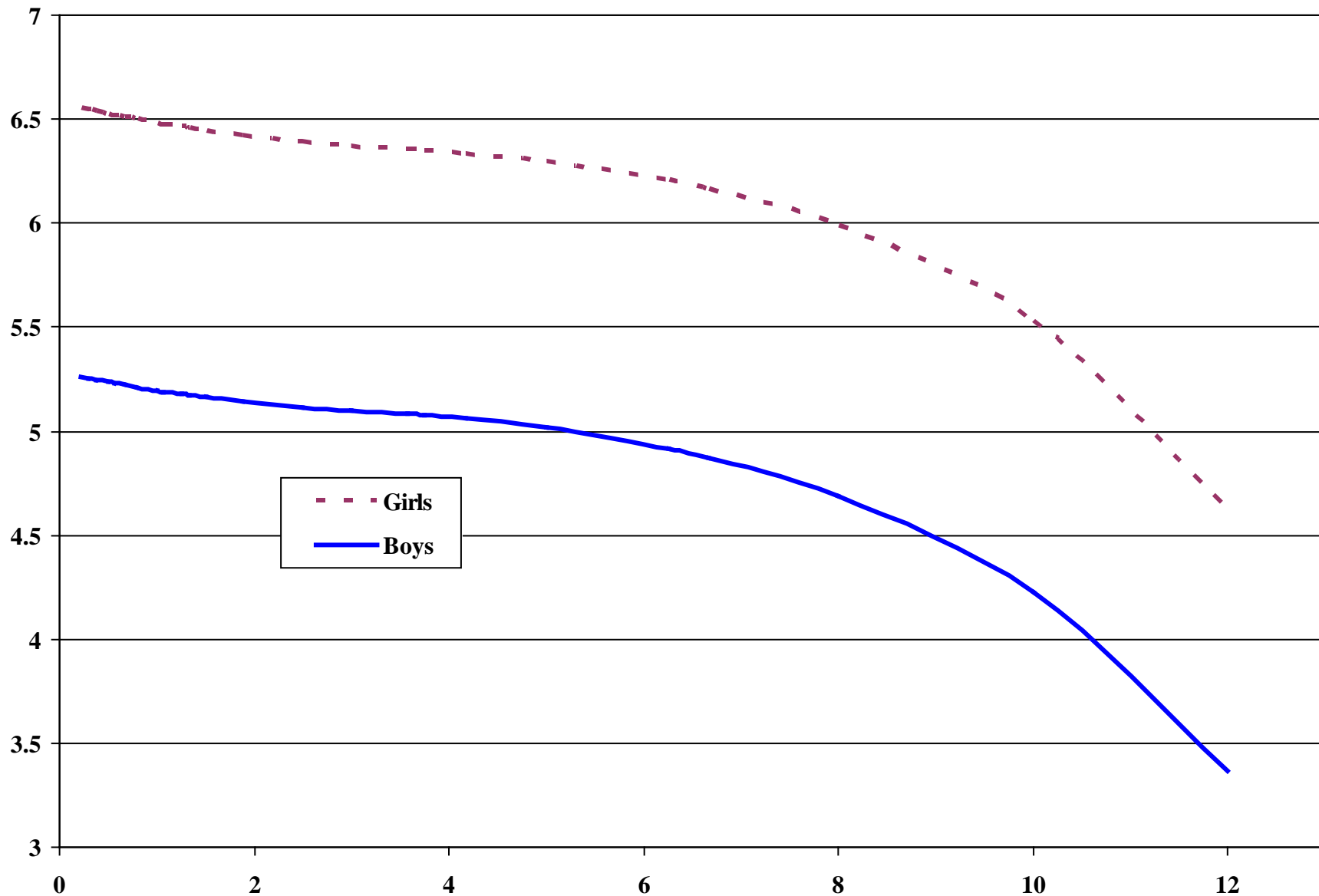**Figure 8. Locally-weighted Within-Twin Estimated Effects of Birthweight on Weight for Height , by Gender and Per-capita Family Income (Rural Sample)**
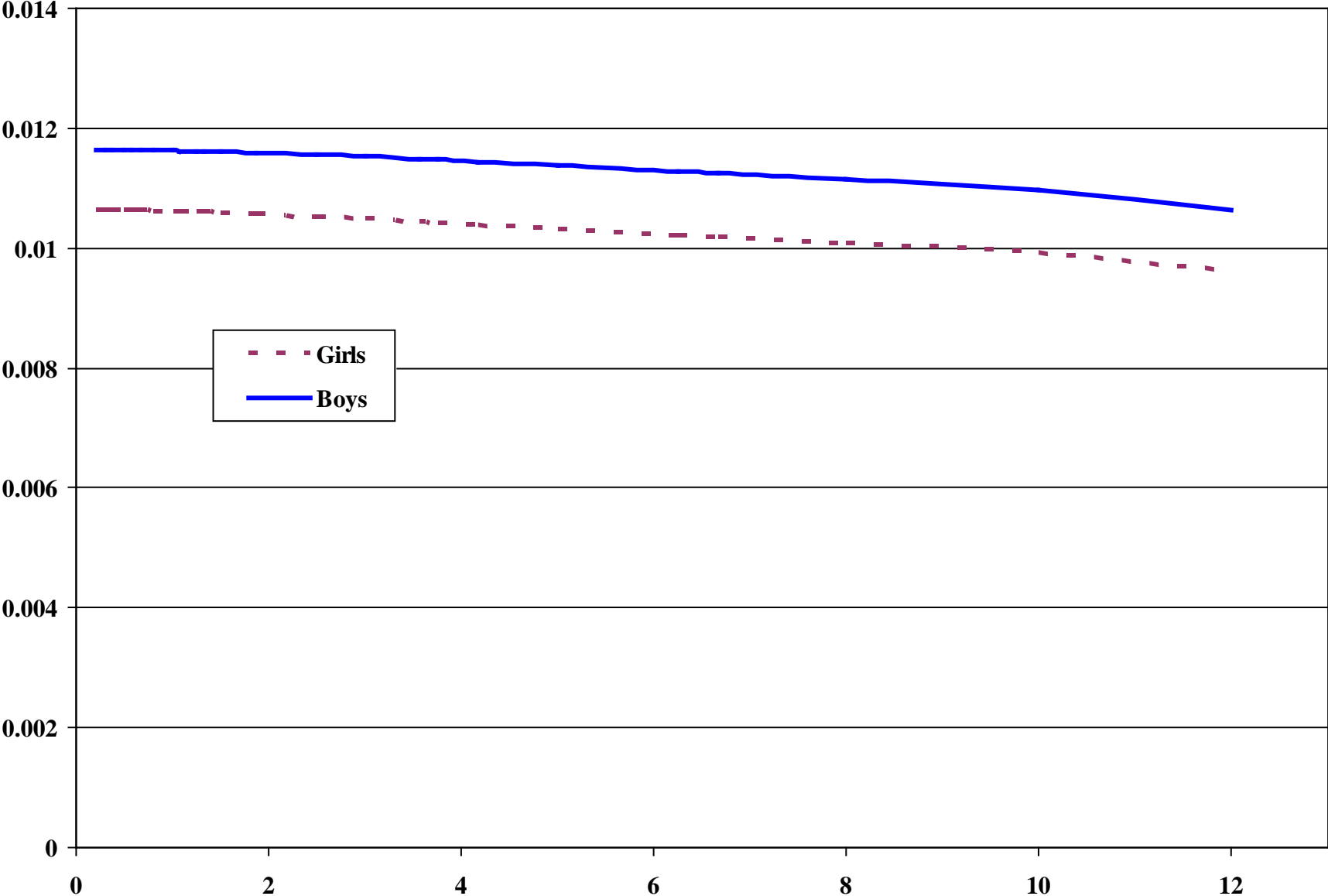
Figure A: Average BMI at Ages 17-19 in Urban Areas, by Gender
(Source: National Nutrition Survey 1992 and 2002, *China Health Statistical Yearbook 2009*)
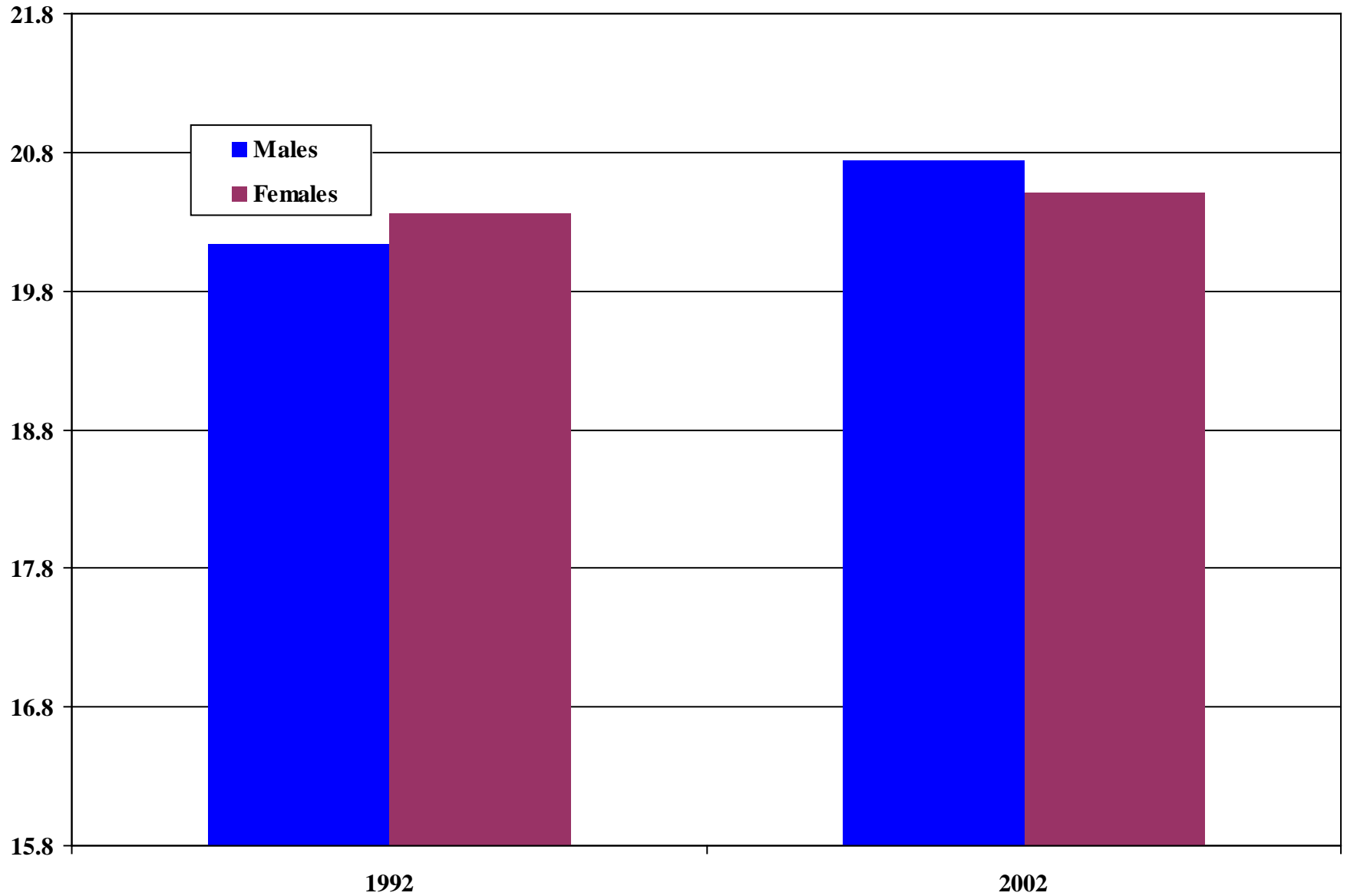
Figure B: Average BMI at Ages 17-19 in Rural Areas, by Gender
(Source: National Nutrition Survey 1992 and 2002, *China Health Statistical Yearbook 2009*)
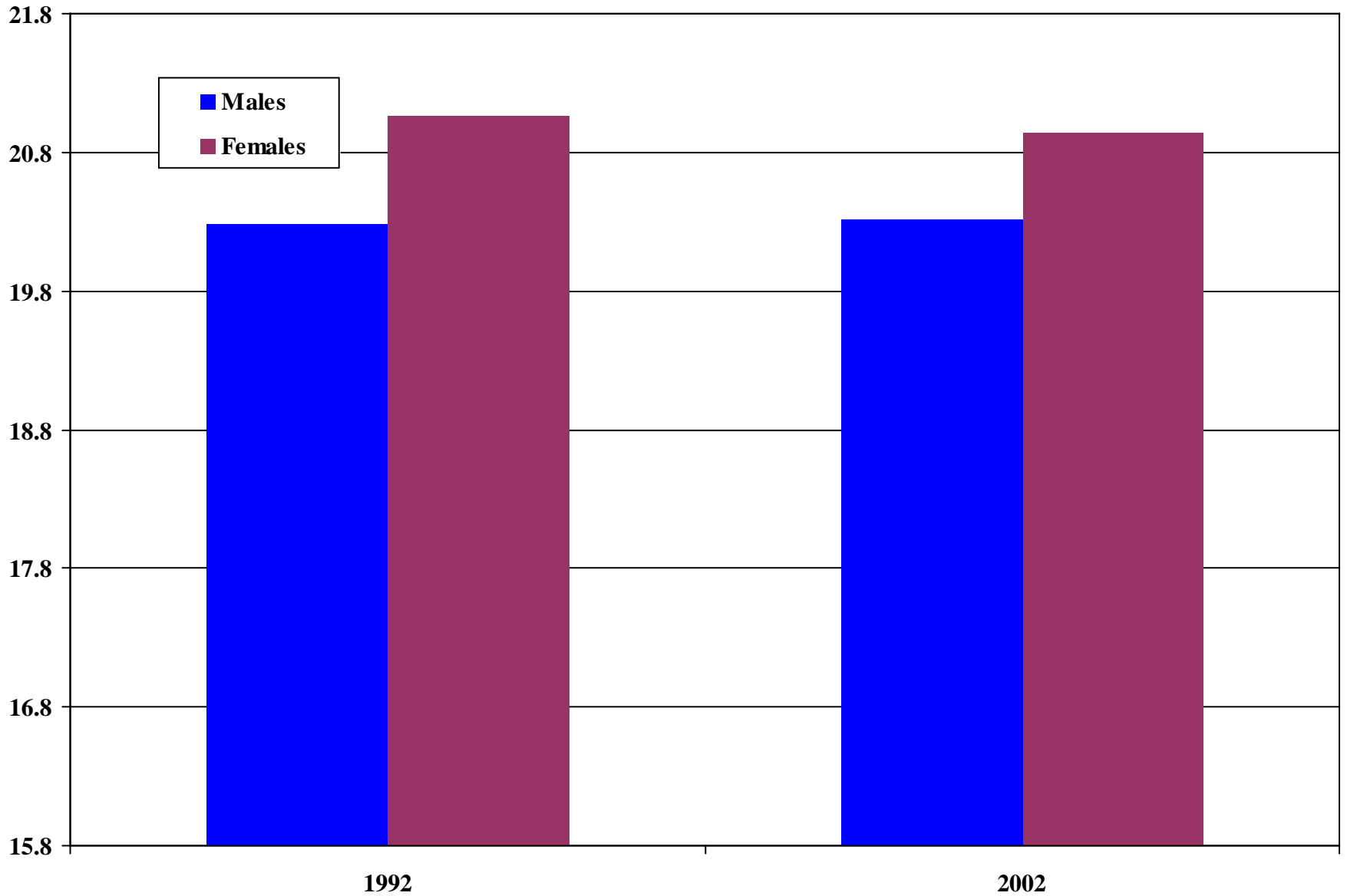
Table 1
Descriptive Statistics: Adult Twins Aged 18-29 in Five Cities

	Males	Females
Mean age	24.7 (2.96)	24.7 (3.11)
Mean birthweight	2.54* (.602)	2.43* (.576)
Mean years of schooling attained	12.2* (2.68)	12.7* (3.07)
Log monthly wage	6.60* (.548)	6.49* (.503)
Mean weight for height	.364* (.053)	.321* (.042)
Number of twins	611	326

*Statistically significant gender difference (.05 level).

Table 2
Descriptive Statistics: Child Twins Aged 12-15 in Kunming

| | Rural | | Urban | |
	Boys	Girls	Boys	Girls
Mean age	13.5	13.3	13.4	13.5
	(1.13)	(1.11)	(1.17)	(1.08)
Mean birthweight	2.52	2.45	2.51*	2.35*
	(.486)	(.446)	(.557)	(.484)
Mean of math and language grades (percent)	75.0*	78.7*	79.6	79.8
	(17.1)	(14.3)	(14.4)	(18.9)
Mean number of honors per year of school	.0667*	.144*	.128	.178
	(.157)	(.300)	(.283)	(.337)
Mean weight for height	.275*	.264*	.272	.274
	(.0436)	(.0431)	(.0408)	(.0419)
Parental expected years of school completed	12.7	13.1	14.4*	14.9*
	(2.53)	(2.55)	(2.17)	(2.13)
Parent expects child will attend college	.160	.180	.371*	.502*
	(.367)	(.385)	(.484)	(.501)
Parent expects child will have good health	.799	.829	.784	.825
	(.402)	(.378)	(.412)	(.381)
Mean homework time (minutes per school day)	43.9	46.6	63.0*	73.7*
	(25.2)	(32.9)	(51.2)	(50.4)
Parent provides homework assistance	.716	.676	.873	.858
	(.452)	(.469)	(.334)	(.350)
Mean child medical expenditures	157.8	135.4	241.8	348.1
	(445.1)	(362.5)	(673.7)	(1802)
Number of twins	194	222	205	211

*Statistically significant gender difference (.05 level).

Table 3

Table 3
Occupational Distribution, by Gender, Location, Birthplace and Migration Status : Respondents Aged 25-34
(Source: 2005 China Census Survey)

Population Group	Rural Native Nonmigrants		Rural City Migrants		City Natives	
Gender	Females	Males	Females	Males	Females	Males
Employed workers						
1. Heads of organizations and enterprises	4.1	4.0	3.9	3.4	27.5	17.8
2. Professional, technical specialists	0.3	0.8	1.3	3.2	2.8	5.0
3. Clerks and managers	0.8	1.4	3.0	5.4	11.6	13.4
4. Commerce	4.7	4.2	23.3	16.9	18.2	13.0
5. Services	3.3	4.1	19.1	12.6	9.9	8.9
6. Farming, fishery	73.8	63.6	2.8	1.6	10.8	9.7
7. Production, transportation	13.0	22.0	46.7	57.1	19.3	32.2
Nonbrawn occupation (1-5)	13.2	14.4	50.5	41.3	69.9	57.9
Not employed	16.2	3.9	29.3	3.2	26.1	12.2

Table 4

Within-twin Estimates of Birthweight Effects on Schooling Attainment, Wages, and Weight-for-Height in Urban China, by Gender:
Twins Aged 18-29
(Source: Chinese Adult Twins Survey, 2002)

	Schooling Attainment (Years)		Log Monthly Wage		Weight for Height	
	(1)	(2)	(3)	(4)	(5)	(6)
Birthweight	.276 (1.08)	-	.111 (1.62)	-	.0093 (1.95)	-
Birthweight - female	-	.867 (2.17)	-	.0543 (0.52)	-	.00134 (0.18)
Birthweight - male	-	-.0275 (0.09)	-	.195 (2.46)	-	.0133 (2.37)
t-statistic: difference (male - female) [p]	-	-1.92 [.052]	-	2.08 [.038]	-	1.36 [.175]
Number of twins	936	936	744	744	936	936

Asymptotic t-ratios in parentheses.

Table 5

Within-twin Estimates of Birthweight on Educational and Health Outcomes, by Gender and Rural-Urban Location: Twins Aged 12-15
(Source: Chinese Child Twins Survey, 2002)

	Mean Language and Math Grade (Percent)			Number of Student Honors per Year of Schooling			Weight for Height		
	All	Rural	Urban	All	Rural	Urban	All	Rural	Urban
Birthweight - female	5.55	6.44	4.63	.0526	.0988	.00679	.00973	.00752	.0113
	(2.88)	(2.23)	(1.79)	(1.57)	(2.31)	(0.13)	(2.66)	(1.31)	(2.44)
Birthweight - male	3.69	4.88	2.28	.0187	.0705	-.0376	.0108	.00977	.0107
	(2.00)	(1.79)	(0.91)	(0.58)	(1.75)	(0.74)	(3.08)	(1.80)	(2.39)
t-statistic: difference (male - female) [p]	-3.77	-1.92	-3.22	-3.94	-2.80	-3.03	1.12	1.66	0.40
	[.000]	[.057]	[.002]	[.000]	[.006]	[.003]	[.264]	[.099]	[.686]
F(2, 414): urban = rural [p]	-	0.570 [.566]		-	1.88 [.154]		-	1.09 [.338]	
Number of twins	830	414	416	832	416	416	832	416	416

Asymptotic t-ratios in parentheses.

Table 6
Within-twin Estimates of Birthweight on Parental Education and Health Expectations, by Gender and Rural-Urban Location:
Twins Aged 12-15
(Source: Chinese Child Twins Survey, 2002)

	Expected Years of Schooling Completed			Expect Attend College			Expect Good health		
	All	Rural	Urban	All	Rural	Urban	All	Rural	Urban
Birthweight - female	.400	.504	.318	.103	.112	.107	.116	.140	.0933
	(2.16)	(1.83)	(1.26)	(2.63)	(2.19)	(1.83)	(2.79)	(2.06)	(1.87)
Birthweight - male	.294	.385	.223	.078	.0886	.0787	.106	.133	.0769
	(1.65)	(1.48)	(0.91)	(2.09)	(1.84)	(1.38)	(2.66)	(2.08)	(1.58)
t-statistic: difference (male - female) [p]	-2.23 [.026]	-1.81 [.071]	-1.33 [.185]	-2.45 [.015]	-1.91 [.057]	-1.71 [.089]	-0.95 [.340]	-0.42 [.674]	-1.17 [.245]
$F_{(2, 414)}$: urban = rural [p]	-	0.15 [.858]		-	0.07 [.968]		-	0.36 [.696]	
Number of twins	830	414	416	832	416	416	832	416	416

Asymptotic t-ratios in parentheses.

Table 7

Within-twin Estimates of Birthweight on Child and Parental Schooling Inputs and Parental Child Health Expenditures, by Gender and Rural-Urban Location: Twins Aged 12-15 (Source: Chinese Child Twins Survey, 2002)

	Homework (Minutes per School Day)			Any Parental Homework Assistance			Child Health Expenditures		
	All	Rural	Urban	All	Rural	Urban	All	Rural	Urban
Birthweight - female	4.18	13.4	-4.06	.0740	.108	.0451	-61.9	163.7	-281.7
	(0.80)	(2.52)	(0.46)	(2.33)	(2.33)	(1.03)	(0.31)	(1.57)	(0.72)
Birthweight - male	2.98	10.96	-4.12	.0582	.798	.0454	-64.8	156.3	-289.9
	(0.59)	(2.18)	(0.48)	(1.91)	(1.82)	[1.06]	(0.34)	(1.59)	(0.77)
t-statistic: difference (male - female) [p]	-0.89	-1.92	0.02	-1.93	-2.58	0.02	-0.06	-0.30	-0.08
	[.376]	[.057]	[.983]	[.054]	[.011]	[.981]	[.955]	[.766]	[.940]
F(2, 414): urban = rural [p]	-	1.43 [.241]		-	1.64 [.195]		-	0.65 [.522]	
Number of twins	832	416	416	832	416	416	832	416	416

Asymptotic t-ratios in parentheses.