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Large Shocks and Small Changes in the Marriage Market for Famine Born Cohorts in China

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Abstract

Between 1958 and 1961, China experienced one of its worst famines in history. Birth rates plummeted during these years, but recovered immediately afterwards. The famine-born cohorts were relatively scarce in the marriage and labor markets. The famine also adversely affected the health of these cohorts. This paper decomposes these two effects on the marital outcomes of the famine-born and adjacent cohorts in the rural areas of two hard hit provinces, Sichuan and Anhui. Individuals born pre and post-famine, who were in surplus relative to their customary spouses, were able to marry. Using the Choo Siow model of marriage matching, the paper shows that the famine substantially reduced the marital attractiveness of the famine born cohort. The modest decline in educational attainment of the famine born cohort does not explain the change in spousal quality of that cohort. Thus, the famine-born cohort, who were relatively scarce compared with their customary spouses, did not have significant above average marriage rates.

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1 Introduction

The "Great Leap Forward" was a national-level political and economic experiment carried out in China between 1958-1961.[1] Collectivization of farming, which began in the mid-fifties, increased in speed and scope. Rural labor was reallocated from agriculture towards industry: People were moved from villages to work in urban factories, while agricultural land and labor were directed towards steel production in "backyard furnaces". In many localities, strong political incentives contributed to official exaggeration of grain yields, which led to a reduction in sown area, and excessive state procurement and export based on these exaggerated reports. This was in addition to a state rationing system that already favored urban industrial workers to the detriment of the villages.

The Greap Leap Forward resulted in the most severe famine in China in the 20th century. Estimates of famine-related mortality range from 15 to 30 million deaths. Peng (1987) estimates that births lost or postponed resulted in about 25 million fewer births.[2] In general, the countryside was struck much harder than cities.[3] The economic experiment was abandoned by early 1962. The mortality rate quickly fell and the birth rate also quickly recovered.

While the drop in birth rates is widely recognized, much less is known about the effects on those who were born during the famine. The medical literature reports that there are severe deleterious long-run health effects for individuals suffering nutritional deprivation either in utero or in their infancy (See Barker, 1992). Recent research by Gorgens et. al. (2005), St. Clair et. al. (2005), and Luo, Mu and Zhang (2006) provide some direct confirmation for this in the case of China, focusing on such health-related outcomes as stunting, obesity, and schizophrenia.

Not all the effects of the famine on the famine-born cohorts were negative. Due to the drop in the birth rates, the famine-born cohorts were small relative to adjacent birth cohorts. This scarcity should increase their relative values in both the marriage and labor market. Their increased value in the labor market should also further add to their desirability in the marriage market.

The net effect of the famine on marital outcomes of famine-born cohorts is an aggregation of three effects: (1) a negative attractiveness effect due to adverse health outcomes that reduces demand for famine-born spouses; (2) a positive attractiveness (wage) effect due to relative scarcity of famine-born cohorts in the labor market that increases their demand as spouses; and (3) due to customary gender differences in ages of marriage, there is an increase in spousal demand for famine-born cohorts because of their relative scarcity in the marriage market.

[1] For an overview of the Great Leap Forward, see Lardy (1987).

[2] Ashton et. al. (1984) provide estimates at the national level of the magnitude of the demographic crisis. See Peng (1987) for a detailed analysis of the impact of the famine at the provincial level. Lin and Yang (2000) and Li and Yang (2006) examine causes of the famine. Becker (1997) provides a narrative account.

[3] The famine also extended beyond China's traditional famine belt region. For example, Sichuan province, in which mass famines were historically rare, was one of the hardest struck.

The objective of this paper is to study the effect of the famine on the marital outcomes of the famine-born and adjacent cohorts. We will decompose the observed changes in marital outcomes into those due to changes in relative scarcity versus those due to changes in attractiveness.

The change in marital attractiveness due to the famine is difficult to measure. In the censuses that we use, there are no wage measures that might capture attractiveness. Instead, we will use educational attainment as a proxy for attractiveness, but such proxies provide a noisy measure of the actual change in marital attractiveness.[4] To get around these difficulties, we will use a residual accounting approach to measure the unobserved changes in attractiveness where the differences in marital outcomes, after accounting for quantity changes, are attributed to changes in attractiveness.[5] To do so, we need a model of the marriage market that will provide an estimate of what a change in quantity, *ceteris paribus*, will do.[6] Our empirical model will be the CS marriage matching function (Choo and Siow 2006).[7] The main benefit of the CS marriage matching function is that it has substitution effects, a central focus of this paper.[8]

Sichuan and Anhui, two primarily agricultural provinces located in western and eastern China, respectively, were two of the most severely affected provinces by the famine.[9] Because the famine disproportionately affected rural rather than urban communities,[10] we will focus our analysis on the rural population in both provinces. Thus, all figures and statistics in this paper pertain to the rural population.

Figures 1 and 1a show the distributions of individuals by age in the 1990 Census for Sichuan and Anhui, respectively. Due to a high long-run birth rate and mortality rates that increase with age, population by age should be declining with age. As we can see in Figure 1 for Sichuan, there is a sharp drop in the population of the famine-born cohort, 29-31 year old men and women, or those

[4] Unobserved marital attractiveness is a standard concern. Akabayashi (2006) and Lee (2005), for example, show that individuals born in deterministic "unlucky" years in Japan and Korea respectively, have worse marriage market outcomes. These worse outcomes occur in spite of their relative scarcity in the marriage market as parents try to avoid those unlucky birth years.

[5] Residual accounting methods are common in economics. See, for example, Oxaca decompositions in labor economics and Solow residuals in growth accounting.

[6] Oxaca decompositions in labor economics use earnings regressions and Solow residuals in growth accounting use the Solow growth model.

[7] A marriage matching function is a production function for marriages (Pollard 1997, Pollack 1990). Inputs are population vectors of types of individuals. Output is a matrix of who marries whom, and who remains unmarried.

[8] The workhorse marriage matching function of demography, the harmonic mean marriage matching function, e.g. Schoen(1981), does not have substitution effects.

[9] In 1957, 86 and 92 percent of the labor force were in the primary (agriculture, fisheries and forestry) sector in Sichuan and Anhui, respectively. Between 65-70 percent of GDP originated in the primary sector. These data are taken from Xin Zhongguo wushi nian tongji ziliao huibian, 2005). Further details are in Peng (1987).

[10] Peng(1987) documents that excess mortality was more severe in rural than in urban areas. At the national level, the excess crude death rate for the urban population between 1958-1962 was 13.84 compared to 7.94 for the two preceding years. By comparison, the excess crude death rate for the rural population rose from 11.45 to 24.45 over the same period. See Peng (1987), p. 646.

born between 1959-1961. The panel also shows the quick recovery in fertility after the famine. Figure 1a plots population by age for Anhui, which was also heavily affected by the famine. Again, there is a sharp drop in the size of the famine-born cohort as well as a quick recovery in fertility after the famine.

Our empirical strategy is to compare the marital behavior of the famine-affected cohorts in 1990 to their same age counterparts in 1982. The famine-born cohort were between ages 29 to 31 in 1990. We consider the pre and post famine-born cohorts to be those between ages 32-34 and ages 26-28 in 1990, respectively. Thus we will compare the marital behavior of individuals between the ages of 26 to 34 in 1990 to their same age counterparts in 1982.

What Figures 1 and 1a cannot show are the quality effects of the famine on the famine-born cohort. Using national samples, Almond et. al.(2007) show that educational attainment fell for the famine-born cohort. In this paper, we will investigate the changes in educational attainment for the famine-affected cohorts as a proxy for the changes in marital attractiveness of those cohorts. We will also investigate the effects of the changes in educational attainment on changes in marital behavior.

Our results show that famine-affected women in 1990 had approximately the same long-run marriage rates as their same age non-famine-affected peers did in 1982. Pre famine-born men in 1990 had approximately the same marriage rates as their same age 1982 peers. Famine-born and post famine-born men had higher marriage rates than their same age 1982 peers. Taken as a whole, famine-affected individuals had weakly higher marriage rates than their non-famine affected peers. Given the large changes in customary sex ratios for the famine-affected cohorts, these individuals had to show substantial flexibility in their choices of spouses. For many of these individuals, marrying, albeit to a non-customary spouse, is substantially preferred to remaining unmarried.

We first consider a CS marriage matching function (MMF) where individuals are differentiated by gender and age. We estimate this model using the 1982 census for both provinces. Using these estimates, we predict what the marriage rates would have been in 1990 given the changes in population supplies affected by the famine. The predicted marriage rates are marginally higher than the actual marriage rates for famine-born women and marginally lower for pre-famine born women. The predicted marriage rates are significantly higher than the actual marriage rates for famine-born men and significantly lower for pre-famine born men. The large discrepancies between predicted and actual marriage rates of the famine-affected individuals imply that there was substantial decline in the marital attractiveness of the famine-born cohorts relative to their pre and post famine-born cohorts.

A natural question that arises is the extent to which the decline in marital attractiveness of the famine-born cohort can be captured by differences in educational attainment of the various cohorts. To answer this question, we re-estimate the CS model, allowing now for matching by both age and educational attainment. We show that the changes in educational attainment for the famine-born cohort are insufficient to explain changes in marital behavior of that cohort. Alternatively, the change in marital attractiveness of the famine-born

cohort is not well captured by the changes in their educational attainment.

Our paper is related to two literatures. First, it is related to the literature that studies the effects of the "Great Leap Forward" on social and economic outcomes (E.g. Almond, et. al. 2007; Chen 2007; Geogens, et. al. 2004; Porter 2007). Of these papers, Almond et. al. and Porter study the effects on the marriage market. We build on their work.

In addition to other outcomes, both of these two papers use a regression framework to study the causal effects of the famine on marital behavior of the affected cohorts. These include marriage rates, age at marriage, spousal age differences and other spousal characteristics. They concluded that the famine had modest effects on marriage rates, caused the affected cohorts to marry later, increased their spousal age gaps, and decreased their spousal education gaps. However, the two papers attribute the outcomes to different causal mechanisms. Almond et. al. emphasize the decline in marital attractiveness of the famine-born cohort whereas Porter emphasizes the relative scarcity of famine-born cohort in the marriage market. Almond et. al. use variations in provincial mortality rates of the famine-affected cohorts as a regressor and interpret its estimated effect as due to changes in marital attractiveness. Porter uses marital share weighted adult sex ratios of the famine-affected cohorts within and across provinces as a regressor and interprets its estimated effect as due to changes in sex ratios. Since the famine increased mortality and decreased birth rates (and therefore eventual population supplies to the marriage market), it is difficult to disentangle empirically the two effects in a regression framework. To relax the "either or" hypothesis, we use a structural model of marriage matching to decompose observed marital behavior to both of these mechanisms.

A famine effect on marital behavior is a general equilibrium effect. For example, the sum of all men of a particular type that different types of women marry must be less than or equal to the number of men of that type. A regression using individual level data of spousal characteristics on individual attributes ignores these general equilibrium constraints.[11] General equilibrium effects are potentially significant due to the large imbalances in customary sex ratios caused by the famine. These effects apply to both causal mechanisms discussed above. By construction, the CS model imposes all relevant general equilibrium constraints.

In general, our empirical results agree qualitatively with those found by Almond et. al. and Porter.[12] We also show that both relative scarcity and changes in marital attractiveness matter, and there are first-order general equilibrium effects. Ignoring these general equilibrium effects lead to inadmissible predicted marital behavior such as predicted marriage rates that are above one.

A caveat is in order. While there are deficiencies to the regression approach to study the effects of the famine on marital behavior, our approach is based on the untestable assumption that the CS model is the appropriate model of the

[11] The inability of the regression framework using individual level data to deal with general equilibrium effects are well known (E.g. Imbens and Woolridge 2008; Heckman, Lochner and Taber 1999). In the marriage context, see Choo and Siow.

[12] Finer comparisons are misleading because of the differences in samples and methodologies. We use rural Sichuan and Anhui samples and they use national samples.

marriage market. Such an assumption is standard to most residual accounting methods. Thus we view our paper as complimentary to the above two papers.

Our paper is also related to the literature which studies the effect of exogenous variations in the sex ratios on marital outcomes (Akabayashi, 2006; Bhrolchain 2001; Brainard 2006; Esteve i and Cabré 2004; Francis 2007). Many of the exogenous variations in sex ratios have both a quality and quantity dimension due to the effects of war (E.g. Brainard; Esteve i and Cabré; and Francis). Even the variations in sex ratios due to superstition about being born in "unlucky" years have a quality dimension (Akabayashi). Individuals born in these "unlucky" years suffer a social stigma which makes them less desirable in the marriage market. But they benefit from being relatively scarce in the labor and marriage market. Our framework can be applied to disentangle these two effects in these environments.

Methodology

In this paper, we will use three statistics to study marital behavior: marriage rates (which measure the gains to marrying versus not marrying), marriage shares (which measure who marries whom) and a marital accounting scheme, total gains to marriage (which combine the first two concerns).

Let t denote the year of the census, $t = \{1982, 1990)$. At each year, individuals are differentiated by their age and or education. Let j denote type j women and i denote type i men. $j = 1, .., J$ and $i = 1, ..I$. n_j^t is the number of women of type j in year t. n_i^t is the number of men of type i in year t. μ_j^t is the number of married women of type j year t. μ_i^t is the number of married men of type i year t. Let μ_{ij}^t be the number of type i men married to type j women. There are $I \times J$ types of marriages at time t.

The sex ratio between type i men and type j women, S_{ij}^t, is defined as:

$$S_{ij}^t = \frac{n_i^t}{n_j^t};\ i = 1, .., I;\ j = 1, ...J \tag{1}$$

In general, we expect adult sex ratios to be close to one.

The marriage rate is:

$$r_g^t = \frac{\mu_g^t}{n_g^t}; \qquad g = i, j;\ i = 1, .., I;\ j = 1, ...J \tag{2}$$

An equivalent measure to the marriage rate is the marriage odds ratio:

$$o_g^t = \frac{\mu_g^t}{(n_g^t - \mu_g^t)} = \frac{r_g^t}{(1 - r_g^t)}; \qquad g = i, j;\ i = 1, .., I;\ j = 1, ...J \tag{3}$$

The marriage rates or odds ratios are informative about the choice of whether to marry or not. They are equivalent univariate measures of marital behavior. The marriage rates or odds ratios are not informative about substitution patterns in marriage, i.e. who marries whom.

To study who marries whom, we first study spousal shares by types of husbands and wives:

$$s^t_{i|j} = \frac{\mu^t_{ij}}{\mu^t_i};\ i = 1, .., I;\ j = 1, ..J \tag{4}$$

$$s^t_{j|i} = \frac{\mu^t_{ij}}{\mu^t_j};\ i = 1, .., I;\ j = 1, ..J \tag{5}$$

$s^t_{i|j}$ is the share of type j spouses among type i's wives. $s^t_{j|i}$ is the share of type i spouses among type j's husbands. Shares are informative about spousal subsitution patterns, i.e. who to marry. By definition, the sum of the shares across different types of spouses for the same type of individual is one. Thus the shares are not informative about the choice of whether to marry or not. Nor are they informative about how shares will change if the sex ratio changes.

To investigate how substitution affects the decision to marry and vice versa, we need a statistic that will link the two effects. To that end, let π^t_{ij} be the total gains to a $\{i, j\}$ marriage relative to them not marrying:

$$\pi^t_{ij} = \ln \frac{\mu^t_{ij}}{\sqrt{(n^t_i - \mu^t_i)(n^t_j - \mu^t_j)}};\ i = 1, .., I; j = 1, ..J \tag{6}$$

The numerator is the number of $\{i, j\}$ marriages. The denominator is the geometric average of the number of unmarrieds. Total gains, π^t_{ij}, provides a complete (alternative to μ_{ij}) characterization of the marriage distribution.[13] Given π^t_{ij}, n^t_j, n^t_i, for all i and j, we can recover the marriage distribution, μ^t_{ij}. Thus π^t_{ij} is an accounting scheme for marriage distributions.

We can rewrite total gains as:

$$\pi^t_{ij} = \ln \sqrt{o^t_i o^t_j} \sqrt{s^t_{i|j} s^t_{j|i}};\ i = 1, .., I; j = 1, ..J \tag{7}$$

The total gains to $\{i, j\}$ marriages is the average of the log odds of marriages for i type men and j type men plus the average of the log shares. Thus total gains to marriage combines substitution patterns with marriage rates.

Consider a new time t' with different marital matches and population supplies, $\mu^{t'}_{ij}$, $n^{t'}_i$ and $n^{t'}_j$. We can estimate new total gains, $\pi^{t'}_{ij}$:

$$\pi^{t'}_{ij} = \ln \frac{\mu^{t'}_{ij}}{\sqrt{(n^{t'}_i - \mu^{t'}_i)(n^{t'}_j - \mu^{t'}_j)}};\ i = 1, .., I; j = 1, ..J \tag{8}$$

$\pi^{t'}_{ij}$ for all i and j is a complete description of the marriage distribution in time t'. So $\Delta\pi^{t't}_{ij} = \pi^{t'}_{ij} - \pi^t_{ij}$ for all i and j is a complete description of the

[13] It cannot deal with marital choices with zero observation. I.e. π^t_{ij} must be finite.

changes in the marriage distributions between the two periods.[14]

Tautologically, changes in total gains, $\Delta\pi_{ij}^{t't}$, are due to both changes in population supplies and changes in marital preferences. In order to disentangle observed changes in marital behavior between effects due to changes in marital preference and effects due to population supplies, we need a model of marital behavior. CS is such a model. It provides a behavioral derivation of π_{ij}^{t}. In their model, total gains measures the expected marital gain to a random $\{i,j\}$ pair marrying relative to them not marrying. The thought experiment is as follows. Consider a randomly chosen a type i male marrying a randomly chosen type j female. We compare the marital output of this random chosen couple to the geometric average of what they would have obtained if they had remain unmarried. So once the individuals are chosen, they could only compare whether to marry or forever remain unmarried. This measure of relative expected marital gain is unaffected by marriage market conditions because we are not choosing the couple based on relative scarcity, nor do we allow them to marry other individuals.

Thus in CS, π_{ij}^{t} are exogenous, independent of population vectors, n_i^t and n_j^t, or other determinants of marriage market conditions. If we have estimates of π_{ij}^{t} using μ_{ij}^{t}, n_i^t and n_j^t for all i and j using equations (6), we can predict what the new marriage distribution $\widehat{\mu}_{ij}^{t'}$ will be with new population vectors $n_i^{t'}$ and $n_j^{t'}$, and $\pi_{ij}^{t'} = \pi_{ij}^{t}$ for all i and j by solving:

$$\pi_{ij}^{t} = \ln \frac{\widehat{\mu}_{ij}^{t'}}{\sqrt{(n_i^{t'} - \widehat{\mu}_i^{t'})(n_j^{t'} - \widehat{\mu}_j^{t'})}};\ i = 1,..,I; j = 1,..J \tag{9}$$

In our context, let time t individuals be those whose marital behavior were unaffected by the famine. Let t' individuals be those who were affected by the famine. If the only effect of the famine was to change population supplies between t and t', then $\pi_{ij}^{t'} = \pi_{ij}^{t}$ and the marital distribution at time t' should be $\widehat{\mu}_{ij}^{t'}$ as in the system of equations (9).

So if the new actual marriage distribution, $\mu_{ij}^{t'}$, differs from the predicted marriage distribution, $\widehat{\mu}_{ij}^{t'}$, the total gains of marriage must have changed between the old and the new environments, i.e. $\pi_{ij}^{t'} \neq \pi_{ij}^{t}$ for at least some $\{i,j\}$. Because total gains completely describe the marriage distribution, the previous statement is always true. Without a model of marital behavior, we do not know how much of $\Delta\pi_{ij}^{t't}$ is due to changes in marital attractiveness and how much is due to changes in population supplies. The bite of CS is that it implies that $\Delta\pi_{ij}^{t't}$, the changes in total gains, only measure changes in marital attractiveness due to the famine.

In demography, CS is known as a MMF with substitution effects. The standard demographic MMF is the harmonic mean MMF (E.g. Schoen 1981) which

[14] CS has a proof of local uniqueness. Although there is no proof of global uniqueness, our experience with it using US (CS), Canadian (Choo and Siow 2006a) and Chinese data here do not suggest otherwise empirically.

excludes substitution effects,

$$\alpha_{ij} = \frac{\mu_{ij}}{n_i} + \frac{\mu_{ij}}{n_j} \tag{10}$$

The absence of substitution effects means that changes in $n_{i'}$ for $i \neq i'$ or $n_{j'}$ for $j \neq j'$ will not affect μ_{ij}. α_{ij} also describes the marriage distribution completely. But if CS is correct, α_{ij} is a function of marital preferences as well as population vectors. Using estimated α_{ij} to predict changes in the marriage distribution due to population changes will result in biased predictions. As will be discussed later, the harmonic mean MMF generates inadmissible predictions in our context.[15]

Summary Data and Sex Ratios

All the data presented here come from the one percent household sample of the 1982 Census of China and the one percent clustered sample of the 1990 Census of China. Wang (2000) and Mason and Lavely (2001) are useful resources on the details of the censuses and data samples. In our analysis, we only use those data pertaining to individuals who reside in rural counties. This can be rationalized on two grounds: first, the countryside was more affected by the famine than the cities,[16] and second, the rural marriage market was largely self-contained, and highly local in nature. There was some cross-provincial migration for marriage, but the numbers are relatively small. In the Data Appendix, we discuss how rural is defined, and several other data-related issues, including migration.

Tables 1 and 2 provide some summary statistics for rural counties in Anhui and Sichuan from the 1982 and 1990 censuses. The average spousal age differences in the two provinces ranged between two to four years. Any observed spousal age difference is an equilibrium outcome determined by marriage market conditions. Under average marriage market conditions existing in China at the times of the 1982 and 1990 censuses, the average spousal age difference was about three years. Because the censuses collect ages by years, we assume that the customary equilibrium spousal age difference is three years.

The first-order impact of the famine on the marital behavior of individuals would have been on the famine-born cohort and their customary spouses. For men who usually marry women three years younger, the customary spouses for the famine-born men were the post-famine-born women. For famine-born women, their customary spouses were the pre famine-born men. Thus, we consider individuals born between 1956 to 1964 to be the famine-affected cohorts. We observe the marital behavior of individuals in 1982 and 1990. For convenience, the ages of these individuals in 1990 are given below.

[15] The search for empirically tractable MMF with substitution effects is ongoing (Pollak 1990, Pollard 1997). CS provides a solution.

[16] See footnote 10.

	Pre famine	Famine	Post famine
Birth years	1956-1958	1959-1961	1962-1964
1982 ages	24-26	21-23	18-20
1990 ages	32-34	29-31	26-28

Our main interest is to examine the behavior of the famine on marital behavior in the 1990 census. The reason for focusing on the 1990 census is that by 1990, the post-famine cohort was 26-28 years old. Most women of that age category and older would have acquired their permanent marital status. Except for 26 and 27 year olds, most men of that age category and older would also have acquired their permanent marital status.

We will use individuals of the same age and characteristics in 1982 as controls for their counterparts in 1990. That is, the control group for post famine individuals are those who were 26-28 in 1982, the control group for famine-born cohort are those who were 29-31 in 1982, and the control group for the pre-famine cohort are those who were 32-34 in 1982. In general, as shown in the immediate table above, individuals in the control groups, of age 26 and older in 1982, were not affected at birth by the famine. There is one year of overlap. Individuals of age 26 in 1982, used as a control group for pre-famine 26 year olds in 1990, are also in the post-famine group in 1990. There was also no significant social or legal change to the labor and marriage markets between 1982 and 1990. Thus, it is reasonable to use individuals of the same age and characteristics in 1982 as controls for their counterparts in 1990.

2 Sichuan

Figure 1 shows the number of individuals by age in rural counties in Sichuan in 1990. The pre-famine cohort, 32-34, were affected by the famine. There were less of them than 35 or 36 year olds. Absent the famine, due to population growth and mortality risk, there should be less older individuals rather than more in a given census year. Thus the 32-34 year olds were adversely affected by the famine.

The famine-born cohort, 29-31, is substantially smaller than the adjacent cohorts, reflecting primarily the fall in the birth rates of that cohort. Recovery of the birth rates after the famine was very rapid. There is no visible impact of the famine on cohort sizes after 1964, ages 25 or younger in 1990.

Figure 1 also shows that there were less 35 and 36 year olds than 37 olds, which implies that these cohorts were also affected by the famine. We do not directly study their marital behavior because of our focus on the marital behavior of the famine-born cohort with their adjacent aged peers. The analysis of the famine-affected cohorts takes into account that they could and did marry these 35 year olds and older individuals in 1990.

2.1 Marriage rates

Figure 2 shows two sex ratios by age. The dashed line is the sex ratio of men to women for same age men and women. It shows that the famine had little to no impact on the sex ratio; there is no evidence that male children were favored over female children among the famine-affected cohorts. The solid line is the sex ratio by women's age where the men were three years older than the women. Here, the effect of the famine is very clear. The sex ratio was above 2.5 for famine-born women because there were relatively more pre-famine-born men. Also the sex ratio fell to 0.25 for post-famine-born women because there was a relative scarcity of famine-born men. If individuals valued the customary age of marriage, there should have been large marriage market effects on the famine-affected cohorts.

Figure 3 plots the marriages rates for men and women by age in 1990 and 1982. In both census years and at all ages, female marriage rates exceed 0.95 whereas male marriage rates are less than 0.9.

For women younger than age 40, marriage rates for women of the same age were essentially the same in 1990 and 1982. In other words, the famine-affected women in 1990 had the same marriage rates as their same age peers in 1982. Figure 2 earlier showed that the famine-born women were in relative scarcity and the post-famine women were in relative surplus when compared to their customary spouses. This strongly suggests that the famine-affected women also married non-customary spouses and that these substitutions to a first order left the marriage rates of famine-affected women unchanged.

In 1990, the marriage rates for famine-affected men were different from unaffected cohorts. The marriage rates of pre-famine-born men, 32-34, were lower than their adjacent older peers. They were also lower than that of the famine-born men, 29-31. Interestingly, post famine-born men had higher marriage rates than the famine-born men even though post famine-born men were not scarce relative to their customary spouses.

Compared with 1982 men of the same ages, the marriage rates of pre famine-born men in 1990 were not significantly different. Thus the lower marriage rates of pre famine-born men in 1990 compared to their adjacent older peers may have been a lifecycle effect rather than a famine-related effect.

Compared with 1982 men of the same ages, the marriage rates of famine and post famine-born men in 1990 were significantly higher. Thus, both within year comparisons in 1990 and across years comparisons suggest that the marriage rates of famine and post famine-born men were positively affected by the famine.

Based on marriage rates between 1990 and 1982, a tentative conclusion is that the marriage rates of famine-affected women in 1990 were unchanged. The marriage rates of pre famine-born men were unaffected whereas the marriage rates of famine-born and post famine-born men increased in 1990. These conclusions are summarized in Figure 4. The marriage rates of famine-born men increased by less than 5 percent compared to their 1982 peers. The marriage rates of post famine-born men increased by substantially more, 5 to 15 percent more than their 1982 peers. But famine-born men are scarce. It is therefore

surprising that their increased marriage rates were so modest.

Previous researchers who have studied marriage rates and large exogenous sex ratio changes in other contexts have also often found small effects of these changes on marriage rates, e.g. Bergstrom and Lam (1994) and Bhrolchain (2001). As we do in this paper, these researchers interpret these small effects as due to flexible spousal choices in the face of large changes in sex ratios. But there are anomalies in these common findings of small effects. If a large change in the sex ratio leads to a particular gender and age cohort being relatively scarce in the marriage market, that cohort should experience a substantial increase in its marriage rate. It is anomalous that the increased marriage rates of famine-born men in 1990 compared to their 1982 peers were significantly smaller than the post famine-born men. The behavior is less puzzling for famine-born women because marriage rates for women were already high. The marriage rate of famine-born women in 1990 could not have been significantly higher. On the other hand, it is anomalous that the marriage rate of post-famine women in 1990 was not significantly lower than their famine-born counterparts because the post-famine women were in relative surplus.

To get an appreciation of the quantitative discrepancies to be explained and the first order importance of accounting for general equilibrium considerations, we estimate the CS MMF using 1982 data where the type of an individual is their age.[17] With the same data, we also estimate the parameters of the harmonic mean MMF. Using the estimates from the two models and population supplies in 1990, we predict what the 1990 marriages rates would have been due to changes in population supplies alone.

Figures 4b and 4c show for Sichuan, the predicted male and female marriage rates from the two models respectively. For both genders, the predicted marriage rates from the harmonic mean MMF often exceed 1, an inadmissible prediction. These violations occurred because the harmonic mean MMF does not impose required general equilibrium accounting identities and the changes in sex ratios of customary spousal age differences were large. Thus as previous researchers have observed, the standard MMF used by demographers is a poor empirical MMF.

On the other hand, the predicted marriage rates from the CS MMF behave sensibly. In figures 4b and 4c, the predicted marriage rates are above average for the famine-born cohorts and below average for the adjacent aged birth cohorts. No accounting constraint is violated. Note that actual female marriage rates were over 0.95 for most ages. Even with large changes in sex ratios of the customary spousal age differences for the famine-born cohorts, their predicted marriage rates remained below 1. The predicted female marriage rates for famine-born cohorts were very similar to those predicted for adjacent aged cohorts. In other words, the CS MMF respects both the general equilibrium accounting constraints of MMFs and also captures the flexibility of individuals in their marital choices. These two attributes show the advantage of the CS MMF over the harmonic mean MMF.

[17] Details of the the estimation are in section 2.3.

In figure 4b, famine born males had lower marriage rates than predicted by CS and pre famine-born males had higher marriage rates than predicted by CS. So changes in relative scarcities of the different types of individuals caused by the famine cannot explain these discrepancies. The famine must have also changed marital attractiveness or total gains to marriage for these cohorts.

Figure 4c shows that the discrepancies between predicted and actual female marriage rates were small. CS is able to generate predicted male marriage rates that substantially responded to changes in population supplies and female marriage rates that marginally responded. It is clear that changes in population supplies alone cannot explain the observed changes in marriage rates. We also need to account for changes in marital attractiveness of the famine-affected cohorts.

2.2 Marriage shares

To set the stage, it is convenient to have an idea of what customary marital shares were. Figure 5 plots the distributions of husbands by spousal age differences for women who were 33, 30 and 27 in 1982. Because they were born substantially before the famine, the marital behavior of 1982 women of those ages should have been unaffected by the famine. We differentiate husbands by their age gaps over their wives, from -3 years to +6 years. Husbands within these 10 years ages interval account for 83-96% of all husbands. The figure shows that there is essentially no difference in the distributions of husbands by spousal age differences for these different aged women in 1982. The marital behavior of 1982 women of those ages was unaffected by the famine; and their spousal choices as represented by spousal age differences did not change with their age in 1982.

Turning to the effects of the famine, Figure 6 shows the marital partners of three age cohorts of women in 1990: 27 (post famine-born), 30 (famine-born) and 33 (pre famine-born). First consider 33 year old women who were born before the famine. Since women generally marry older men, Figure 2 tells us that the customary husbands of these women are not scarce. 90% of their husbands were in the 10 years age interval with the remainder primarily among older men. The largest share of husbands was two years older. For 33 year old women in 1990, the age distribution of their spouses looks the same as their same age peers in 1982 in Figure 5.

30 year old women were famine-born women. They are scarce relative to their customary husbands. Compared with the shares of 33 year old women, their marriage shares distribution shifted to the right. Although they could replicate the share distribution of the pre-famine women because they were scarce relative to older men, more of them chose to marry older husbands. One potential explanation is that they avoided competing with younger women.

27 year old women were born after the famine. They suffer a relative scarcity of customary husbands. As shown in the figure, their marriage share distribution is almost symmetric around age gap $[-2, 2]$. It flattens out between age gap 2 to 4 and then increases. Thus, post-famine women married a much larger

share of own age or younger men, and also significantly older men. The share of husbands in the age gap $[-2, 2]$ was 0.83. A larger share of these women married significantly older men than the other cohorts of women. Figure 6 shows that in 1990, the distributions of husbands by spousal age differences were significantly different between pre famine-born, famine-born and post famine-born women.

Using the behavior of women in 1982 as control groups, Figure 7 plots the ratio of 1990 husbands' shares to 1982 shares for 27, 30 and 33 year old women. If there is no difference in shares between 1982 and 1990 for the same age women, then the ratio should be 1. Consider the case of 33 year old women. The ratio of shares are slightly above 1 for age gap between [0,4]. In both 1982 and 1990, most of the husbands of these 33 year old women fell in the age gap between [0,4] years. The ratio of shares are lower than 1 outside [0,4]. This says that in the [0,4] range, and to a first approximation, pre famine-born women in 1990 had the same relative distribution of husbands by spousal age differences as their 1982 counterparts. But pre-famine women in 1990 had substantially less younger or older husbands outside the range. Less younger husbands can be explained by the relative scarcity of famine-born men. Why older men outside the range was lower in 1990 will be discussed later.

Famine-born women in 1990, age 30, behaved very differently from their 1982 counterparts. They were far more likely to marry older men and far less likely to marry men of the same age or younger. Since these women are relatively scarce, they could have married their customary partners. But they did not do so.

Post-famine women in 1990, age 27, also behaved very differently from their 1982 counterparts. They were far more likely to marry same age or younger men, also pre famine-born men, and far less likely to marry famine-born men. So here, post-famine women avoided the scarce famine-born men. What is interesting is that their increased demand for substantially older, pre famine-born men. Both 27 and 30 year old women in 1990 had relatively more demand for significantly older men, which may partially explain why 33 year old women in 1990 had relatively lower demand for husbands older than 4 years.

Taken as a whole, Figure 7 shows that different cohorts of famine-affected women responded differently in their spousal choices. This finding is anticipated by the observation that female marriage rates did not differ much across different cohorts of famine-affected women.

2.3 Total gains

To preview what we will find, recall that marriages rates of famine-born women were the same as their pre and post famine-born peers. The marriage rates of famine-born men were lower than their post famine-born peers. But famine-born men and women are relatively scarce in the marriage market. Let j denote the cohort of famine-born women and i denote their customary spouses. To a first order, o_j^t did not change and j type women are scarce relative to type i men. $s_{j|i}^t$ must fall and by equation (7), π_{ij}^t must fall. Under the CS interpretation, the expected gains to marriage for a random $\{i, j\}$ pair relative to them not

marrying must have fallen.

Another way to see that total gains must have changed, we estimate total gains π_{ij}^{1982} for every $\{i, j\}$ match where a type is defined by the individual's age. Then we use the estimated total gains, π_{ij}^{1982}, to predict what the marriage distribution in 1990 would be if the only change in 1990 were changes in the population vectors, $\widehat{\mu}_{ij}^{1990}$.[18]

Figure 8 plots the ratio of own gender predicted marriage rate in 1990, $\widehat{r}_g^{1990}$, to r_g^{1990}, the actual marriage rate in 1990 by age, $\widehat{r}_g^{1990}(r_g^{1990})^{-1}$. The ratio for women is marginally above one for the famine-born cohort, age 29-31, and the pre famine-born cohort, age 32-34. It is significantly lower than one for the post famine-born cohort, age 26-28. This behavior implies that total gains to marriage must have changed between the two periods. The change in total gains is more apparent in the male ratio. Here, the ratio is less than one for both pre and post famine-born males, and it is sigificantly larger than one for famine-born males. In other words, if total gains did not change for the famine-born cohort, their predicted marriages rates would have been significantly higher than what was observed. Instead, their adjacent birth cohorts benefited in the marriage market.

To investigate the change in total gains for famine-affected cohorts, we first consider total gains of individuals who were born before the famine. Figure 9 shows total gains for 27, 30 and 33 year old women and their spouses from -3 years to +6 years older in 1982. Total gains for 30 and 33 year old women and their spouses were similar in 1982. Total gains for 27 year old women, while similar in shape, were slightly lower than the other two age cohorts.

Figure 10 plots total gains of three age cohorts of women in 1990, 27 (post famine-born), 30 (famine-born) and 33 (pre famine-born) and their husbands. Starting with pre famine-born 33 year old women and their spouses, total gains is a smooth concave function in husband's age gap. Total gains from [0,4] were relatively similar. Total gains of post famine-born 27 year old women and their spouses were in general similar to the pre famine women. Where they differ, and total gains were lower for post-famine women, were with husbands between 1 to 3 years older. For post famine-born women, these husbands were famine-born men. Thus, marrying famine-born men resulted in lower total gains to marriage relative to the pre-famine women with spouses 1 to 3 years older.

Total gains for famine-born women, age 30, and their spouses were significantly lower than that of pre and post famine-born women. This means that the gains to marrying for famine-born women and their spouses were generally lower than for their pre and post-famine counterparts. The way to understand this finding is as follows. Figure 3 shows that the marriage rates of famine-born women were similar to pre and post-famine women. There are some small differences in the marriage rates of the husbands (measured by age gaps) of famine-born and other famine-affected women. But there were large differences

[18] As an alternative to CS, we also estimated the Schoen's harmonic mean mating rule parameters using the 1982 data. We then used the estimates and the 1990 population vectors to generate marriage rates for 1990. This model generated predicted marriage rates for females in excess of 100% which is inadmissible.

in the customary marriage sex ratios as shown in Figure 2. These large differences in the customary marriage sex ratios should have resulted in significantly different marriage rates for famine-born and other famine affected women. But because the marriage rates for all the famine-affected women were roughly the same in spite of large differences in customary marital sex ratios, total gains for the famine-born women had to be lower than the other famine-affected women. This interpretation was anticipated by the lower total gains that post famine-born women obtained from marrying famine-born men relative pre famine-born women marrying men with the same age gap.

As we discussed in the introduction, the lower total gains for famine-born women and men in marriage is highly suggestive of the lower "quality" of these individuals as spouses. Thus we may tentatively conclude that famine-born men and women were damaged by the famine.

Figure 11 presents the difference in total gains between 1990 and 1982 for the same age women and their spouses. The differences in total gains were negative for the famine-born women, age 30, for all spousal ages. The gains were particularly low in marriages with same age or younger men. So for famine-born women, their benefit in the marriage market from relative scarcity was completely erased by their drop in quality as spouses.

The difference in total gains for 33 year old women between the two censuses was roughly zero. Excluding the level effect, the difference in total gains for 27 year old women was high for same age, younger and significantly older men, and significantly lower for slightly older men. Using the CS interpretation of total gains, post-famine women "preferred" to marry same age, younger or much older men, rather than their customary spouses, famine-born men.

2.4 Education effects

Since the famine had a negative impact on the health and human capital endowments of famine-born individuals (see Almond et. al. (2007), Gorgens et. al. (2005), St. Clair et. al. (2005), Luo, Mu and Zhang (2006)), their educational attainment may have been affected. This may enable us to use the change in educational attainment of that cohort to proxy for their drop in marital attractiveness, thereby explaining their drop in total gains to marriage.

Figure 12 shows the fraction of women who had less than a primary school education by age. Not surprising, in both the 1990 and 1982 censuses, the fraction grew with the age of the women. It is difficult to see the change in educational attainment at the levels for the famine-born cohort. This implies that it is unlikely that the change in educational attainment of the famine-born cohort will be able to explain the changes in total gains to marriage of that cohort.

Figure 13 shows the log difference (growth rate) of the fraction of women who had less than a primary school education by age. In the 1982 census, the growth rate fell rapidly by age for women below age 35. Such a decline in the growth rate should be expected if women increased their educational attainment over time. In the 1990 census, the growth rate also fell by age for women above

age 32. For women between age 28 and 32, the growth rate of the fraction of women with less than a primary school eduction formed a valley with a bottom at age 30. Based on deviations from trend growth, the famine-affected cohorts had less education than they would otherwise have. Although we do not present the results here, the results for male educational attainment are similar. Figure 13 raises the possibility that changes in the growth rate of education of the famine-affected cohorts may be able to explain some of the fall in total gains to marriage of those cohorts.

Denote individuals with more than a primary education as high education and those with a primary education or less as low education. Figure 14 shows the ratio of 1990 to 1982 female marriage rates by age and education. High education women were less likely to marry in 1990 than in 1982 compared with their low education peers. For high educated famine-born women (age 30), the ratio is slightly higher than their adjacent aged peers. For low educated famine-born women, the ratio is slightly lower than their adjacent aged peers. These small differences in marriage rates suggest that high educated famine-born women may have fared better than their low education counterparts.

To evaluate the overall effects of the changes in educational attainment on marital behavior, we estimate total gains π_{ij}^{1982} for every $\{i, j\}$ match where a type is defined by the individual's age and education (high versus low). We then use the estimated total gains, π_{ij}^{1982}, to predict the marriage distribution in 1990, $\widehat{\mu}_{ij}^{1990}$, due to changes in population vectors alone. Figure 15 plots the ratio of the own predicted gender marriage rates in 1990 to the actual marriage rates in 1990 by age, $\widehat{r}_g^t(r_g^t)^{-1}$, $g = i, j$.

Figure 15, where predictions depend on age and education, looks remarkably similar to Figure 8 where the predictions only depend on age. In other words, the change in educational attainment of the famine-born cohort did not have a first order impact on predicted marriage rates.

To examine this more closely, Figure 16 plots 1990-1982 total gains for marriages with two high educated spouses. Total gains for post-famine women were higher than their 1982 peers. But note that relative total gains for post-famine women married fell as the age of their husbands increased from own age to famine-born husbands. So famine-born men also had lower total gains. Total gains for famine-born and pre-famine women were slightly lower than their 1982 peers. Figure 17 plots total gains for marriages with two low educated spouses. Total gains for pre and post-famine women were higher than their 1982 peers. On the other hand, total gains for famine-born women were substantially lower than their 1982 peers. Figures 16 and 17 suggest that among famine-born women, low educated women suffered a larger drop in total gains than high educated women.

3 Anhui

In general, the effects of the famine on the marital behavior of the famine-affected cohorts in Anhui were about the same as for Sichuan.

Figure 1a and 2a present the number of individuals by age in 1990 in Anhui, and the same age sex ratio as well as the sex ratio for men three years older by female age. These two figures are similar to what we saw for Sichuan. In particular, the timing of the effects of the famine on birth rates in both provinces were the same.

Figure 3a shows the male and female marriage rates in 1982 and 1990. As the figure shows, female marriage rates between 1982 and 1990 were very similar. Across most ages, male marriage rates were lower in 1982. One potential explanation for the higher male marriage rates in 1990 is that relatively more unmarried men left the province in 1990 than in 1982. At this point, we are unble to compute how many individuals left the province in 1990 and 1982. This explanation bears further investigation.

To see the effects of the famine more clearly, Figure 4a shows the ratio of 1990 to 1982 marriage rates by gender and age. There is a small dip in the marriage rate of famine-born females relative to pre and post famine-born cohorts. This dip is more visible for males. Quantitatively, the effects are not large, within 2-3% difference. These dips are different from their Sichuan counterparts.

Note however that because famine-born individuals are relatively scarce, these dips in marriage rates should be reflected in significant drops in total gains for famine-born individuals.

Figure 5a shows that in 1982, Anhui women at ages 27, 30 and 33 had very similar shares of husbands by spousal age differences. Figure 6a shows that in 1990, Anhui women at ages 27, 30 and 33 had different shares of husbands by spousal age differences.

Figure 7a shows the 1990 shares divided by the 1982 shares. For 1990 33 years old wives (pre-famine-born females), their shares of same age or older husbands were roughly the same as for the 1982 wives. On the other hand, the 1990 share of younger husbands (famine-born males) were lower than their 1982 peers.

For 1990 30 years old (famine-born) wives, their shares of own age husbands were lower than older or younger husbands compared with their 1982 peers. Finally, 1990 27 years old (post-famine) wives, their shares of own age spouses were significantly higher than famine-born spouses, but comparable to pre famine-born spouses when compared with their 1982 peers. That is, post famine-born wives were more likely to have own age or pre famine-born spouses.

The behavior of 33 years old (pre-famine) and 27 years old (post-famine) wives with respect to their choices of husbands were similar to that of Sichuan women. However famine-born Anhui wives were more likely to marry own aged spouses compared with their Sichuan counterparts.

Figure 8a shows the ratio of 1990 predicted marriage rates by age to actual marriage rates using π_{ij}^{82} where the type of an individual is defined by their age. The model underpredicts the number of marriages for post famine-born women. It substantially over predicts the number of married famine-born men, and under predicts the marriage rates of pre- and post- famine-born men. Thus we know that total gains must have changed between 1982 and 1990 for the same age groups.

Figure 9a shows the total gains for 27, 30 and 33 years old women in 1982. Although the shape of the three curves are similar, total gains for 27 years old women were lower than for 30 and 33 years old women. Figure 10a shows the total gains for 27, 30 and 33 years old women in 1990. Total gains for 30 years old women were significantly lower than for 33 years old and roughly comparable to 27 year olds. Total gains for own age spouses for 30 year old women were lower than those for pre and post-famine women.

Figure 11a shows 1990 total gains minus 1982 total gains. The most stark feature is that the difference in total gains for 30 year old women were lower than that for 27 and 33 year old women at all spousal age differences. In other words, famine-born women were less desirable as spouses compared to their same age counterparts in 1982.

For 33 year old women (i.e the pre-famine cohort and their same age counterparts), the difference in total gains were above zero with own age and older husbands. It was lower than zero for younger (famine-born) husbands. Finally, total gains for 27 year old (post famine-born) women were higher than their 1982 peers for own age and younger men, but lower than their 1982 peers for older (famine-born) men. Thus Figure 11a unambiguously show that famine-born individuals had lower total gains to marriage compared with 1982 same age peers or with pre and post famine-born individuals.

Figures 12a and 13a show the fraction of women with primary or lower education and the growth in that fraction by age in 1990 and 1982 respectively. As in Sichuan, educational attainment declined with age. In Figure 13a, there is a sharp jump in the growth rate of low education famine-born, age 30, women which shows that the famine-born generation had less educational attainment than expected. But as shown in Figure 12a, the level effect is small.

Figure 14a shows the ratio of 1990 to 1982 female marriage rates. For women with low education, the marriage rates of the famine-born cohort were slightly lower than pre and post famine-born women. For women with high education, famine-born women suffer a larger dip in their marriage rates relative to pre and post famine-born women.

Figure 15a shows the ratio of predicted marriage rates by age to actual marriage rates using π_{ij}^{82} where the type of an individual is defined by their age and education. The Figure is almost identical to Figure 8a where the type of an individual is defined by age alone. What this means is that accounting for the changes in educational attainment between same age 1982 and 1990 indviduals did not account for the changes in marital quality of the famine-born individuals.

Figure 16a shows 1990 minus 1982 total gains for high educated women with high educated men. famine-born high educated women (age 30) had weakly lower total gains compared with their 1982 peers. Total gains for pre famine-born high educated women were roughly the same as their 1982 peers. Post famine-born educated women had higher total gains than their 1982 peers, although there was a small relative dip with older (famine-born) men.

Figure 17a shows 1990 minus 1982 total gains for low educated women with low educated men. famine-born low educated women (age 30) had significantly

lower total gains compared with their 1982 peers. Total gains were relatively higher with same age males. Total gains for pre famine-born high educated women were roughly the same as their 1982 peers for own age and older men. They were lower with younger (famine-born) men. Post famine-born educated women had the same total gains than their 1982 peers with own age or pre famine-born men. They had lower gains with famine-born men.

Comparing figures 16a and 17a, high educated famine-born individuals suffered a smaller loss in total gains to marriage than their low educated counterparts. This finding is comparable to that for Sichuan.

4 Conclusion

From our analysis of marital behavior in rural Sichuan and Anhui, our conclusion is that, at a first approximation, famine-born individuals suffered a significant drop in marital quality with non-famine-born potential spouses. To compensate for their drop in marital quality with non-famine-born potential spouses, famine-born individuals tended to marry own age spouses, and thus avoid marrying their customary aged spouses. In other words, the variations in customary sex ratios caused by the famine had a small effect on marriage rates because famine-born individuals were more likely to marry their own, and non-famine-born individuals married other non-famine-born individuals rather than their customary famine-born potential spouses.

Comparing our findings with previous work on the effects of demographic shocks on marital outcomes, we agree with their finding that individuals show substantial flexibility in their choices of spouses. In other words, for most individuals, marrying, albeit to a non-customary spouse, is substantially preferable to remaining unmarried. However, when there is large non-unitary sex ratios at customary marriage age differences, an unaffected marriage rate for affected individual imply that those individuals suffered a strong loss in marital attractiveness. This was the fate of famine-born individuals in China.

Data Appendix

All data are either from the 1% household sample of the 1982 Census of China, or the 1% clustered sample of the 1990 Census of China. Our samples are individuals in rural counties of Sichuan and Anhui, over the age of 18. There are issues common to both censuses, as well as differences between them, that required attention for the analysis in this paper. This appendix describes the most important of those issues.

Sampling. The microdata sample for 1982 was sampled at the household level, while the 1990 "clustered" sample was sampled at the level of the *administrative unit*. Lavely and Mason (2006) discusses the geographic coverage of the 1990 sample and compares summary statistics from the sample to tabulations from the complete census. They concludes that, aside from a few discrepencies,

the sample "reproduces the geographic distribution of population and major population components quite well." We would not expect the different sampling methods to bias our results. The marriage markets we investigate are *de facto* defined as the subset of rural counties in each province. While the two census samples will contain exactly the same counties, they ought to both have a representative sample of rural households in each province.

Defining rural areas. Our analysis covers rural counties in Sichuan and Anhui. There has been much research and debate about the best definitions of rural and urban populations for various purposes (see Chan (1994), Martin (1992) and Shen (1995). The "official" definitions in fact changed between the 1985 and 1990 censuses. Our intention, in analyzing only rural areas, is to look at those areas most severely affected by the famine, and avoid conflating the very different effects suffered by cities and villages. Also, since the 1982 and 1990 use different classifications for the smaller geographic units, we wanted to select geographic areas on criteria which could be consistently applied in both censuses.

Both censuses define the largest three levels of geographic units according to a six digit *goubiao* (GB) code. The first two digits define the province (or municipalities like Beijing and Tianjin, which report directly to the central government). The second two digits define a prefecture within the province, and the last two label the counties within the prefecture. See Chan (1994) for a diagram of these levels in the two censuses. Within Sichuan and Anhui, we select those counties whose last two digits indicate they are *xian* (as opposed to *shi* or *shixiaqu*, which refer to urban areas). This definition will generally not capture the same households as those included in the official definition.[19]

Migration. Fan and Huang (1998) document substantial marriage-related migration between certain provinces from 1985 to 1990. They find that in Sichuan, particularly, a large number of women migrated out of the province for marriage-related reasons. Of our sample of over 433 thousand married women in Sichuan in 1990 —only the 1990 census contains migration data— about 0.93% moved to their current county from another county or province for marriage. Of those who migrated from other provinces, they largely came from Guizhou and Yunnan. Out of over 240 thousand married women in our 1990 Anhui sample, about 0.8% moved to their current county from another county or province for marriage; Sichuan, Henan, and Jiangsu were the main sources of inter-provincial marriage migrants. There are about 3,057 women in the 1990 sample who migrated for marriage from Sichuan to another province between 1985 and 1990, while 410 women did so from Anhui to another province during that time. Jiangsu—a coastal province experiencing rapid economic growth—was the most frequent destination for marriage migrants from both Anhui and Sichuan.

Though marriage migration is an important and interesting response to the famine-caused imbalance in sex ratios, our analysis requires no special accounting for migration. Any impact of migration prior to 1990 will be accounted for

[19] In earlier versions of the analyses, we also used a definition based on the share of individuals working in rural sectors. This definition resulted in a similar sample of counties.

in the 1990 sex ratios, which are the inputs to the MMFs.

Defining married couples within households. Except for household heads and their spouses, the census does not provide any definite way to determine who is married to whom within the household. Also, it provides no way to identify a person's spouse if that spouse does not live in the same household. For example, a male and female household member whose marital statuses are both "Married" and are identified "Children of the household head" may be married to each other (and one is a son-in-law or daughter-in-law). Or it is possible that they are both biological children of the household head who are married to spouses living outside the household.

Assuming that the first possibility is the more likely, we determine the married couples within households according to the following rules. First, we identify all "potential" married couples within each households as those who are of the opposite sex and have consistent relationships to the household head (both children of the head, or parents of the head, etc.). For children of household heads, we also required that potential couples be within five years of age.[20] If each person in the household has only one potential spouse, we define them to be married. If a person has multiple potential spouses, we assign married couples through positive assortive matching by age, e.g., the oldest married male child is married to the oldest married female child within five years his age.

Determining spouses was by far most problematic for children of household Heads, simply because there were more of these than parents, grandparents, grandchildren, etc. Fortunately, in the majority of households, there was only one potential married couple amongst the children.[21] In Sichuan, amongst households where there was at least one potential married child couple, 93.3% had only one potential couple, while 99.6% had two potential combinations or less. In Anhui, household sizes were slightly larger, as only 83% of households with at least one potential child couple had only one potential couple, while 93.6% had no more than two potential combinations.

Imputing missing spouses. For some individuals, there were no potential spouses in their household; for example, there were households where the household head was married, but no spouse was present; or there were households with an odd number of married children. We imputed the age and education of these individuals' spouses by assigning values randomly from the distribution of spouse age and eduction for those of the same sex and age in that province with non-missing spouses.

[20] We performed tests of these rules by relaxing the age assumption, and comparing marriage age distributions of the full sample with the restricted sample of household heads and their spouses.

[21] We calculate the potential married couple combinations amongst children in a household to be $P(I, J)$ if $J < I$, or $P(J, I)$ otherwise, where I is the number of married male children in the household, J is the number of married female children in the household and $P(\cdot, \cdot)$ is the permutation operator. For example, a household with one married female child and two married male children has two potential child couple combinations. One with three female children and two male children (or vice versa) has six potential combinations.

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Figure 1: Sichuan number of individuals by age, 1990

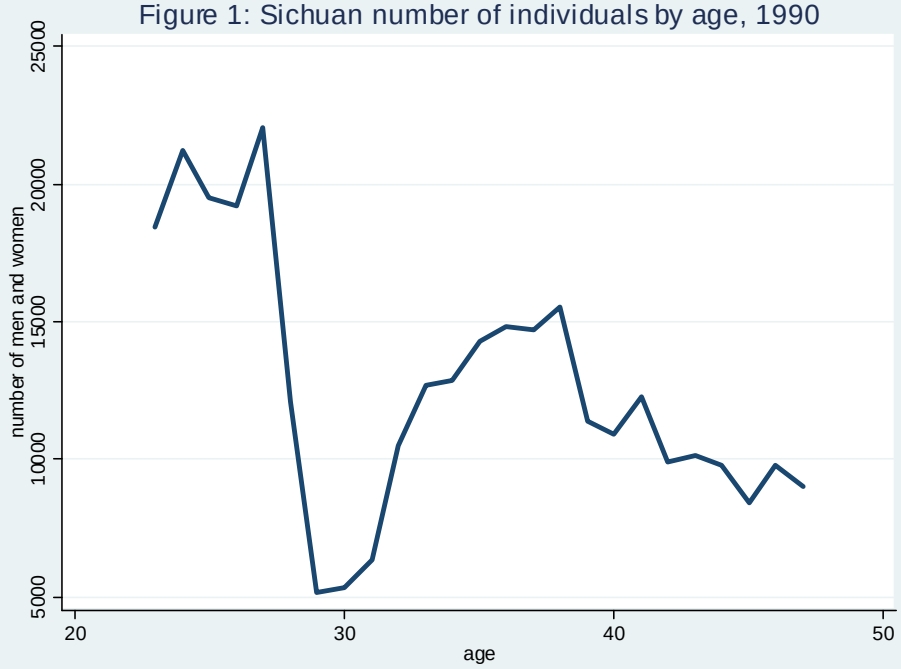

Figure 1a: Anhui number of individuals by age, 1990

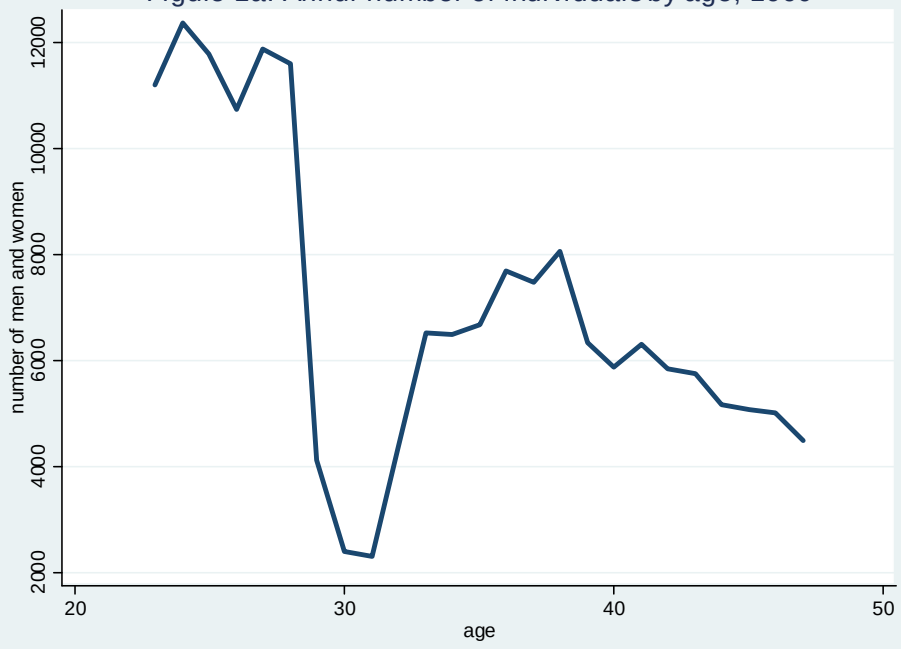

Figure 2: Sichuan sex ratios by female age, 1990

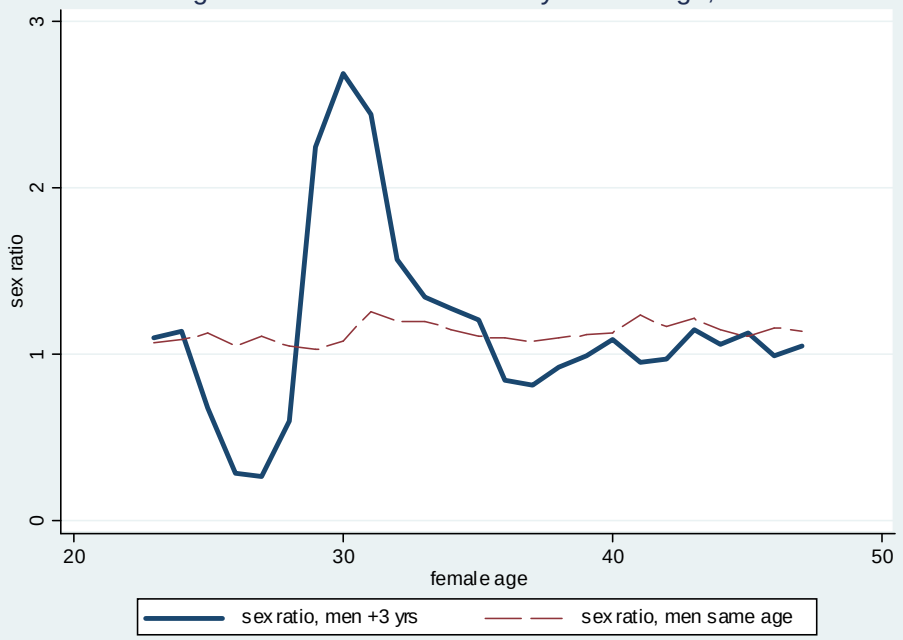

Figure 2a: Anhui sex ratios by female age, 1990

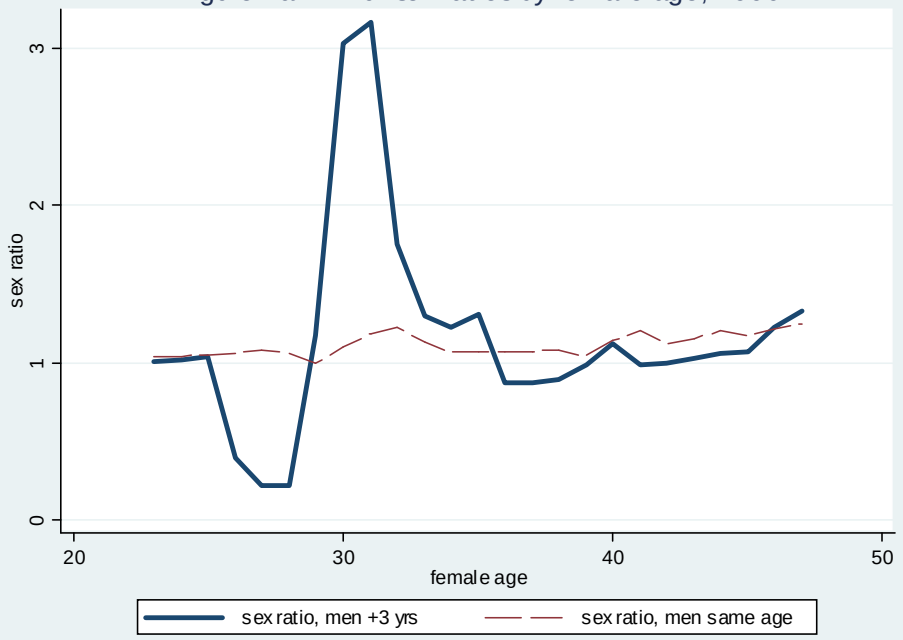

Figure 3: Sichuan marriage rates, 1990, 1982

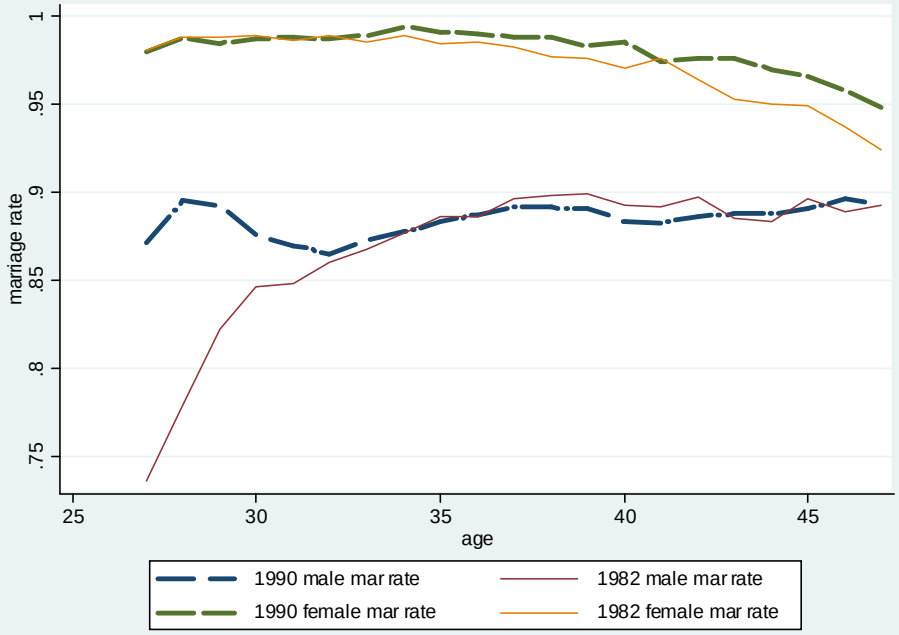

Figure 3a: Anhui marriage rates, 1990, 1982

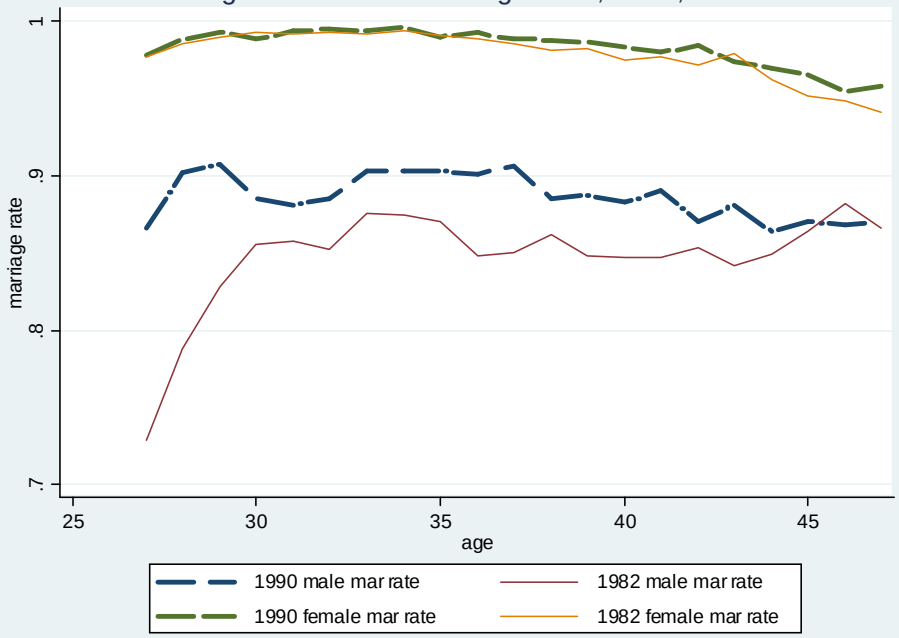

Figure 4: Sichuan 1990/1982 marriage rates

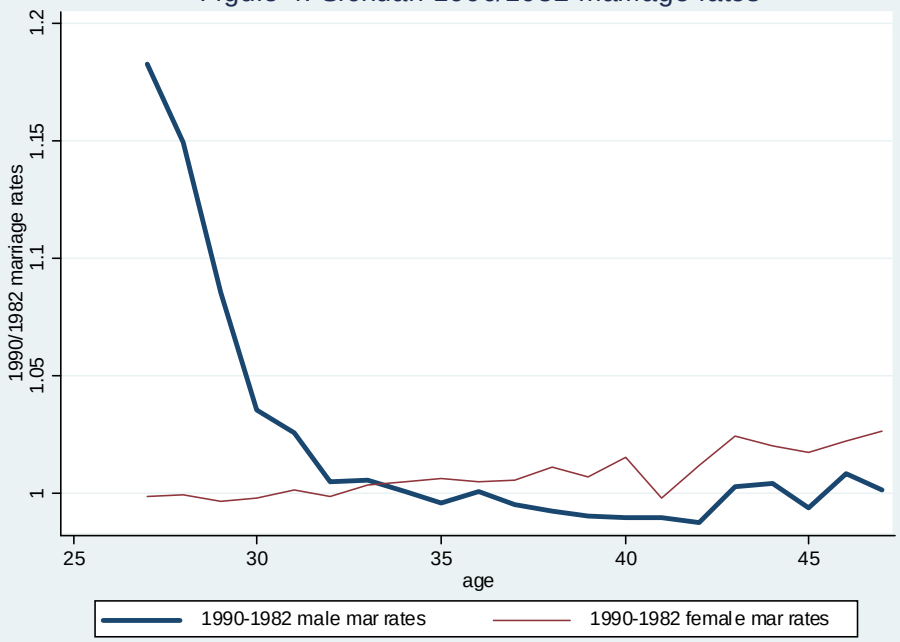

Figure 4a: Anhui 1990/1982 marriage rates

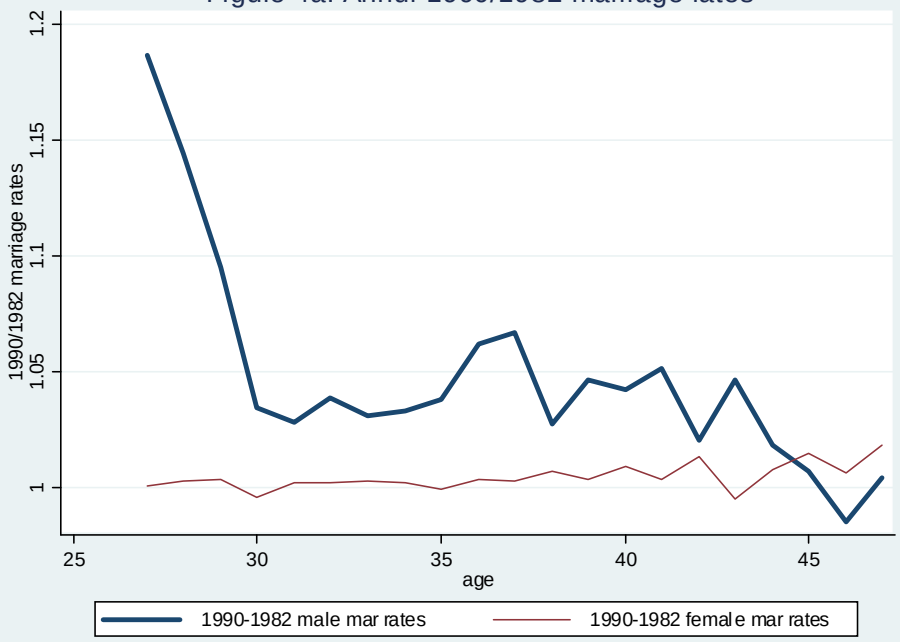

Figure 4b: 1990 predicted and actual Sichuan male marriage rates

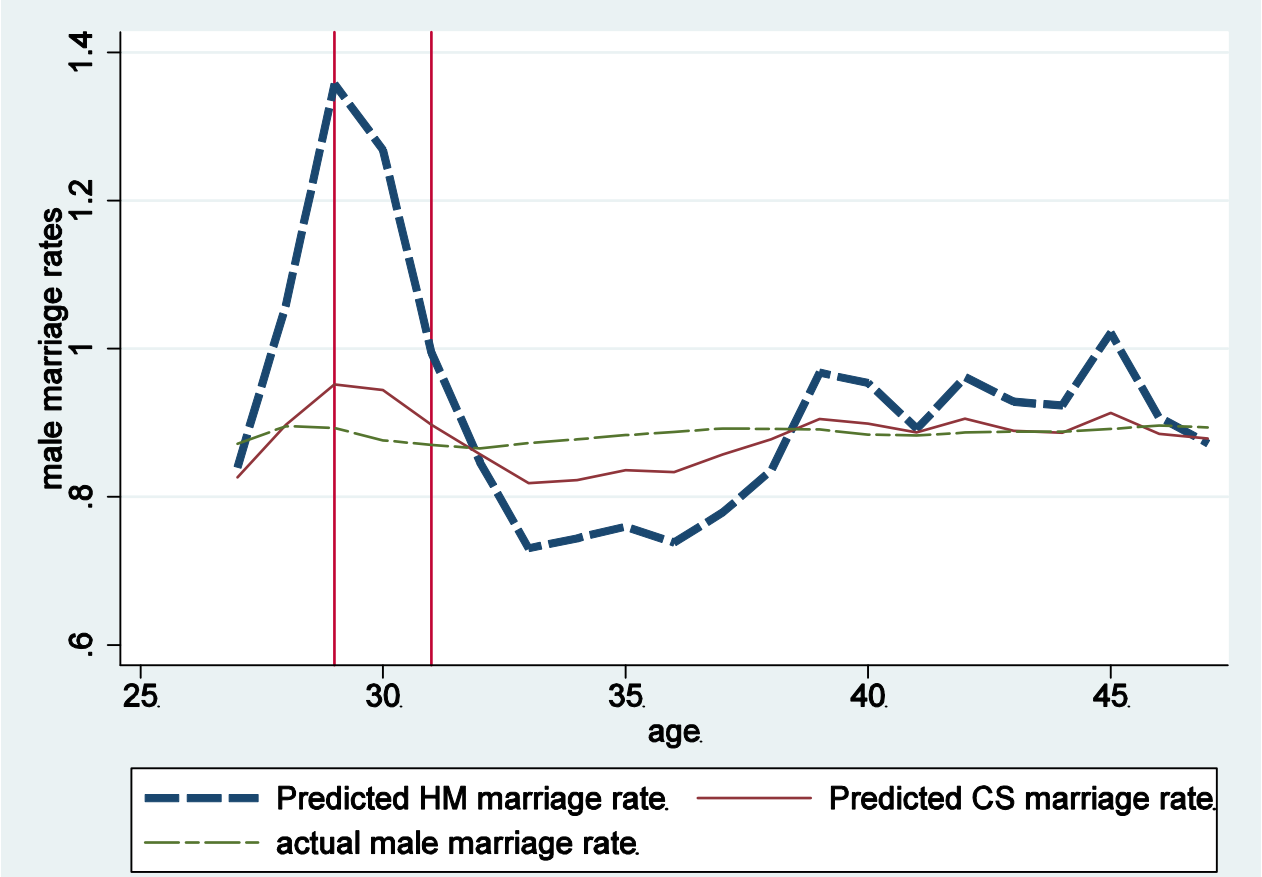

Figure 4c: 1990 predicted and actual Sichuan female marriage rates

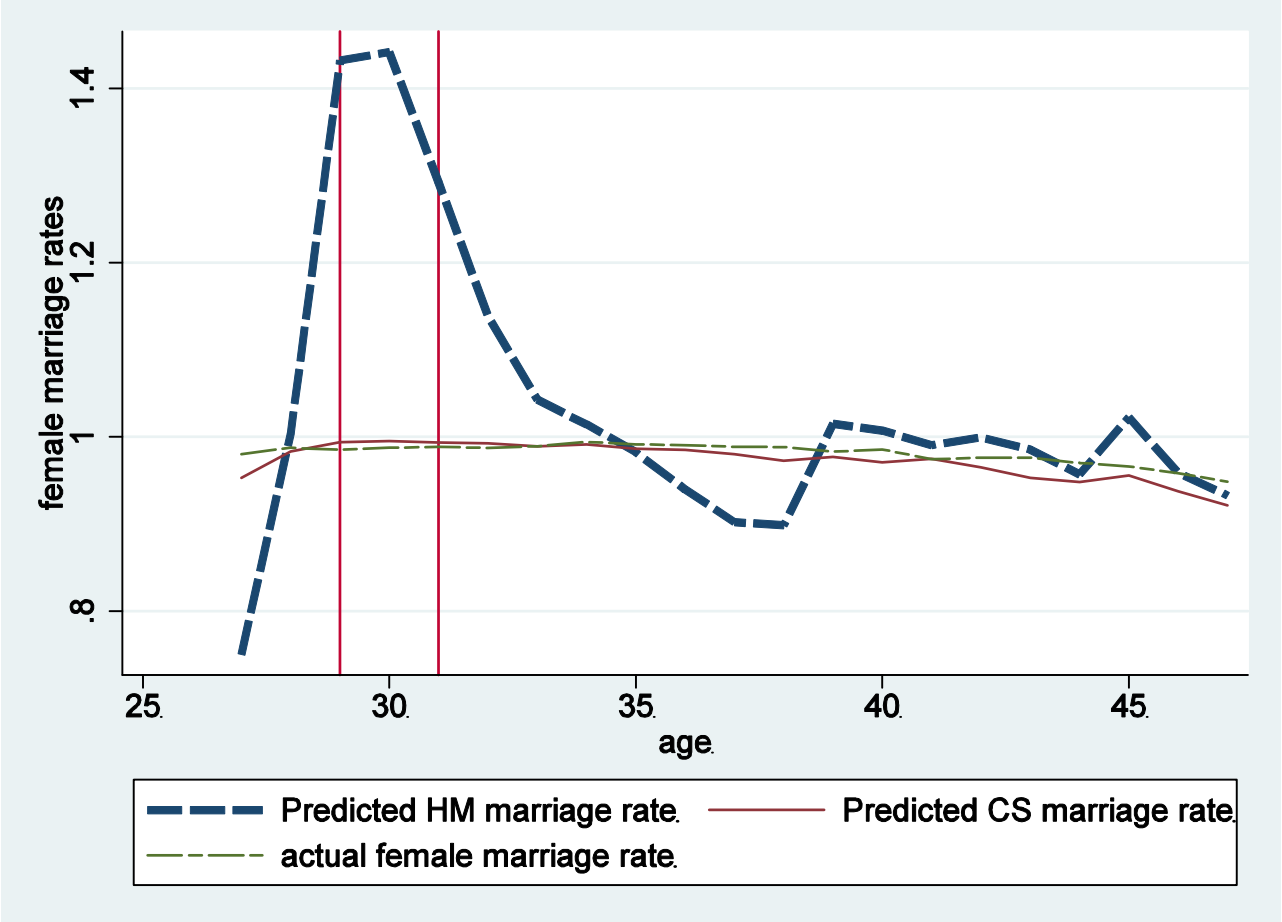

Figure 5: Sichuan share of husband by his age gap, 1982

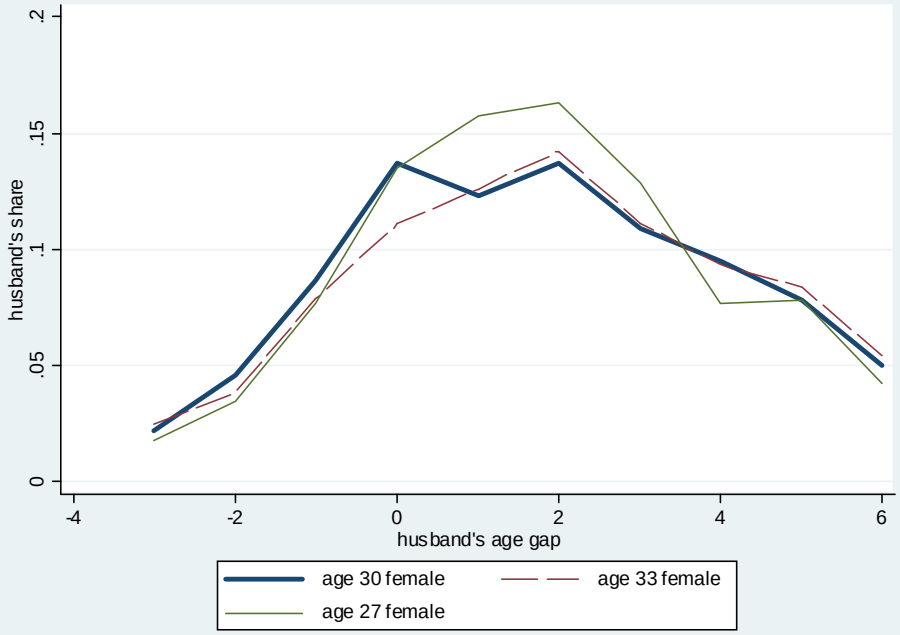

Figure 5a: Anhui share of husband by his age gap, 1982

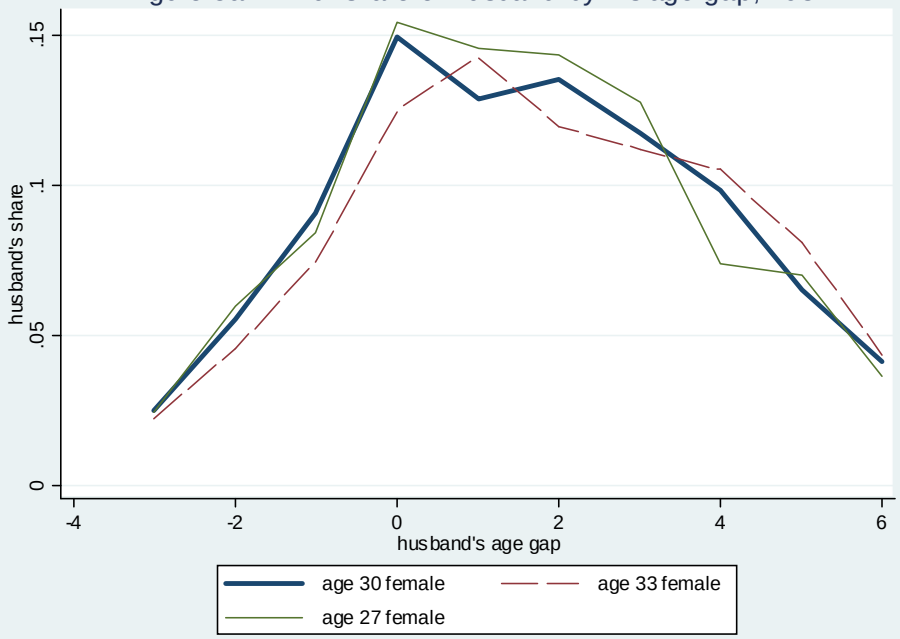

Figure 6: Sichuan share of husband by his age gap, 1990

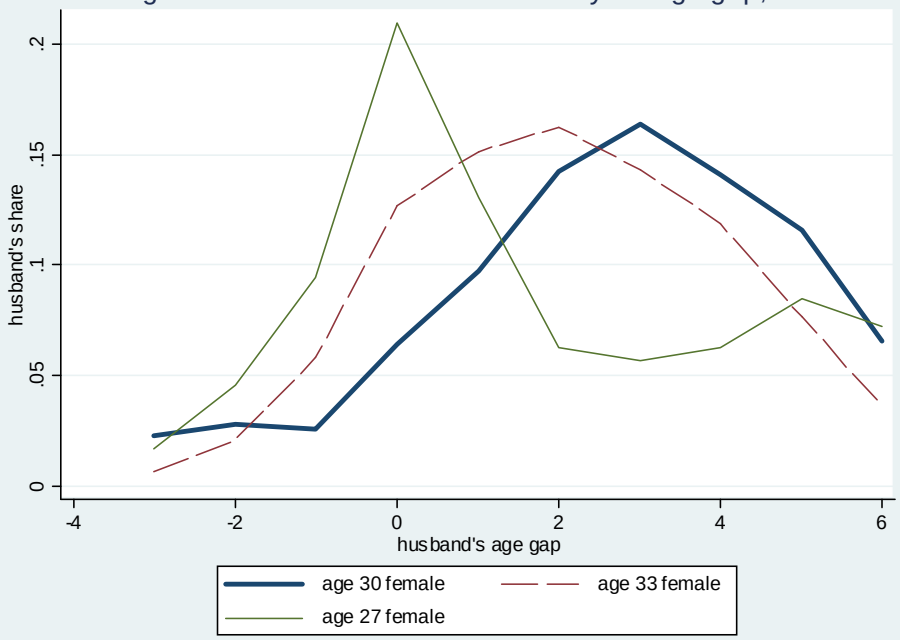

Figure 6a: Anhui share of husband by his age gap, 1990

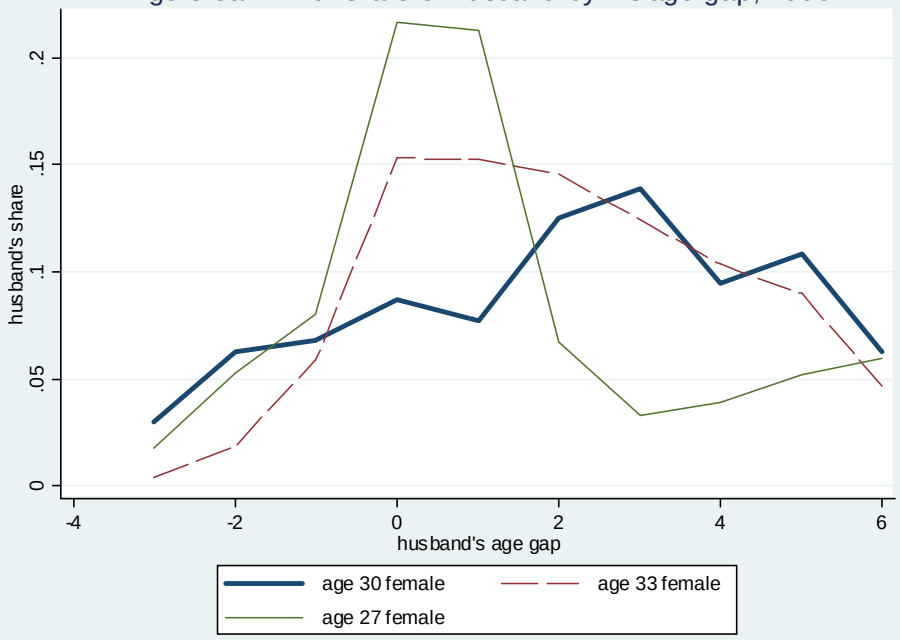

Figure 7: Sichuan 1990/1982 share of husband by his age gap

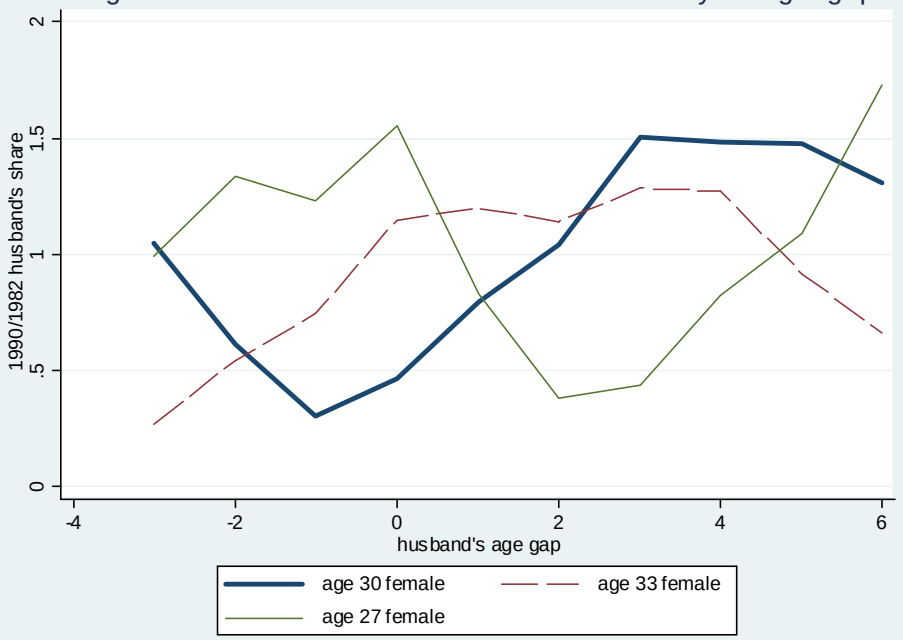

Figure 7a: Anhui 1990/1982 share of husband by his age gap

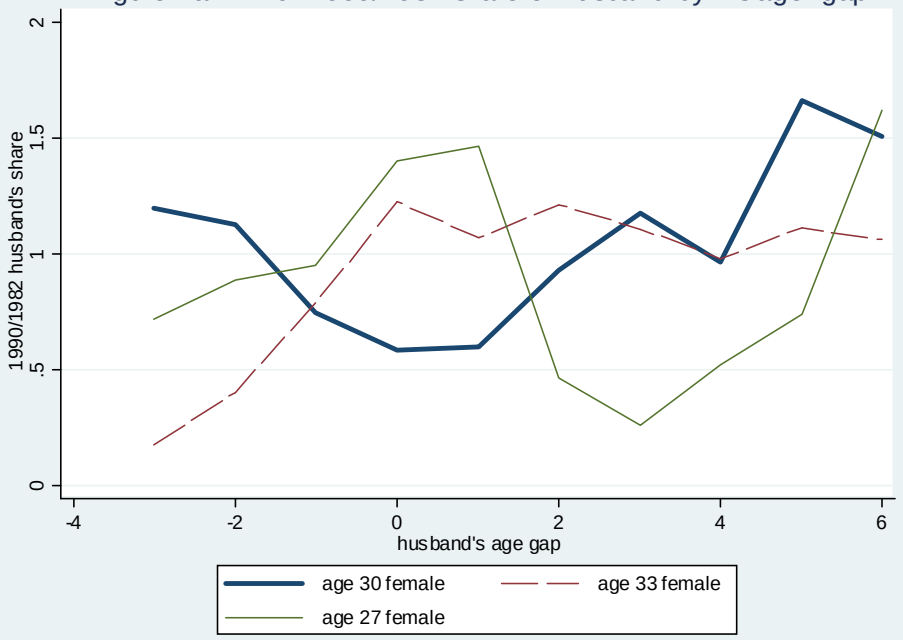

Figure 8: Sichaun predicted, by age, over actual marriage rates, 1990

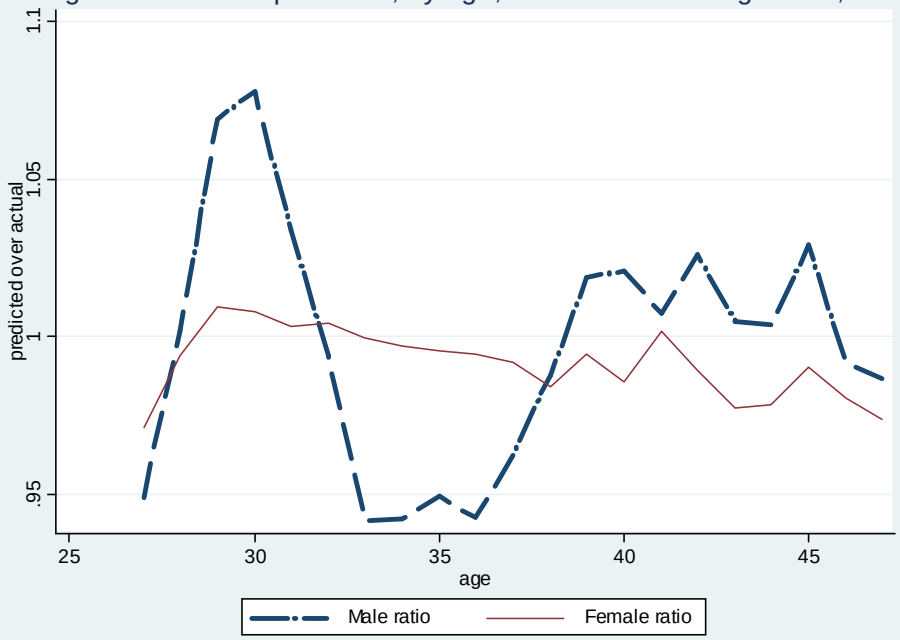

Figure 8a: Anhui predicted, by age, over actual marriage rates, 1990

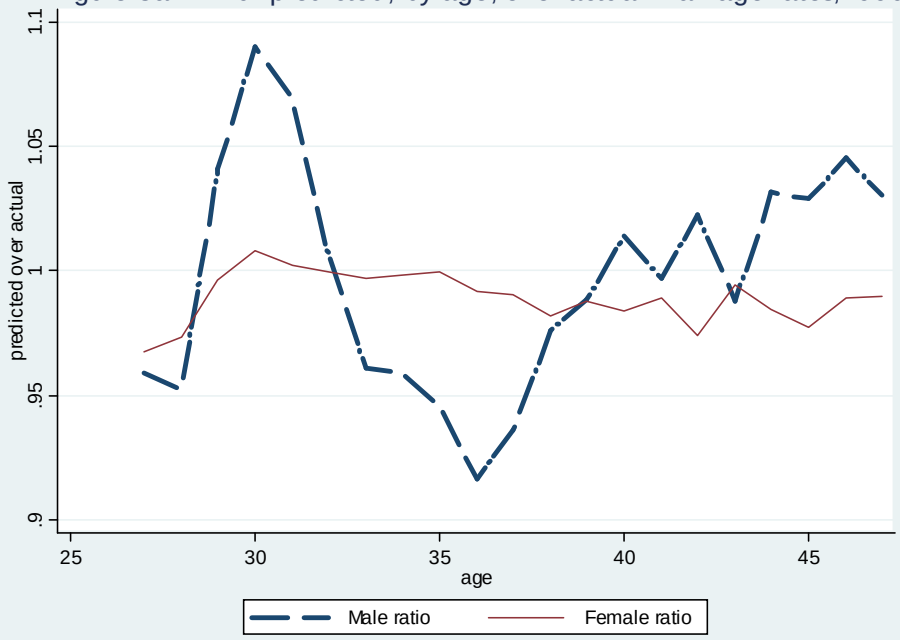

Figure 9: Sichuan total gains by husband's age gap, 1982

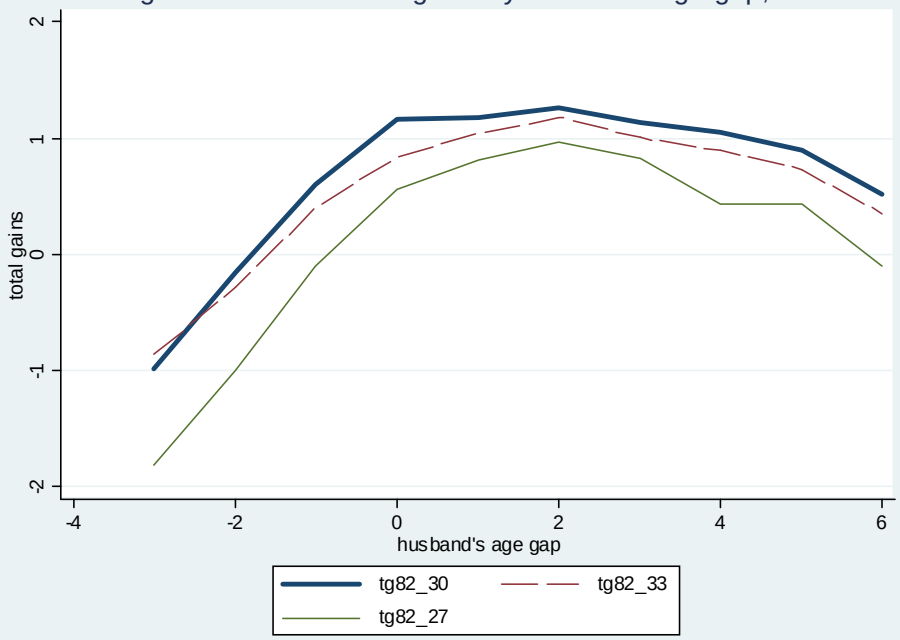

Figure 9a: Anhui total gains by husband's age gap, 1982

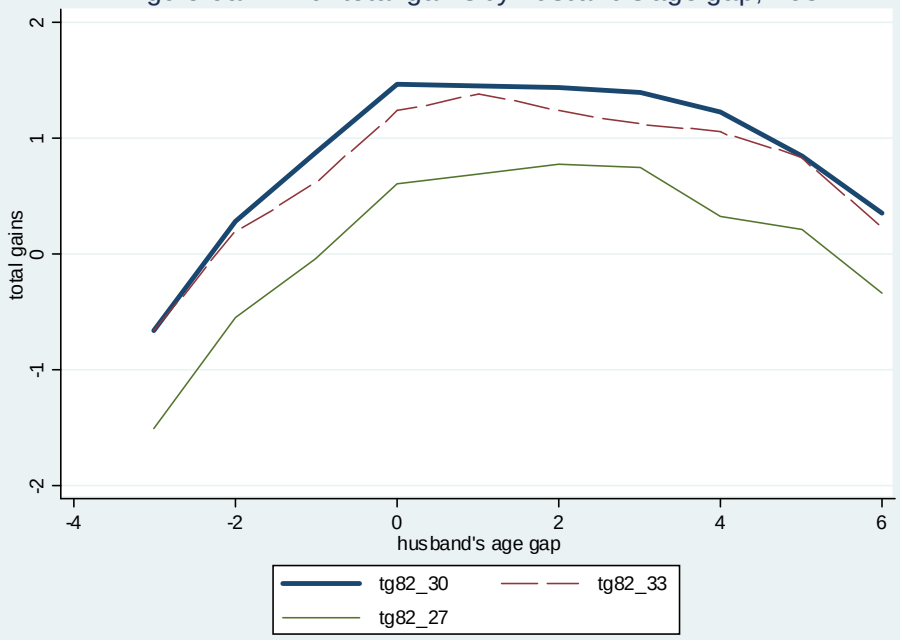

Figure 10: Sichuan total gains by husband's age gap, 1990

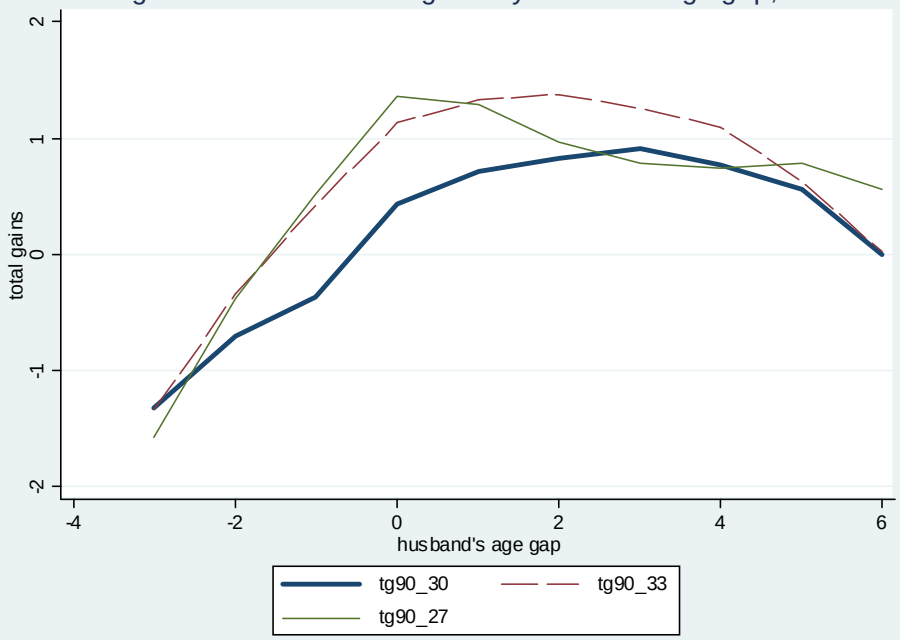

Figure 10a: Anhui total gains by husband's age gap, 1990

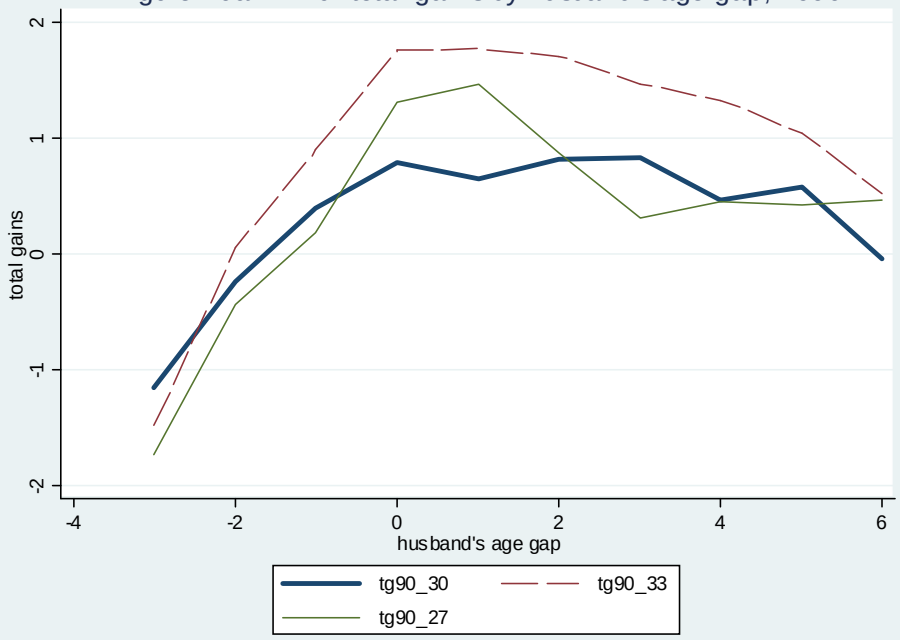

Figure 11: Sichuan 1990-1982 total gains by husband's age gap

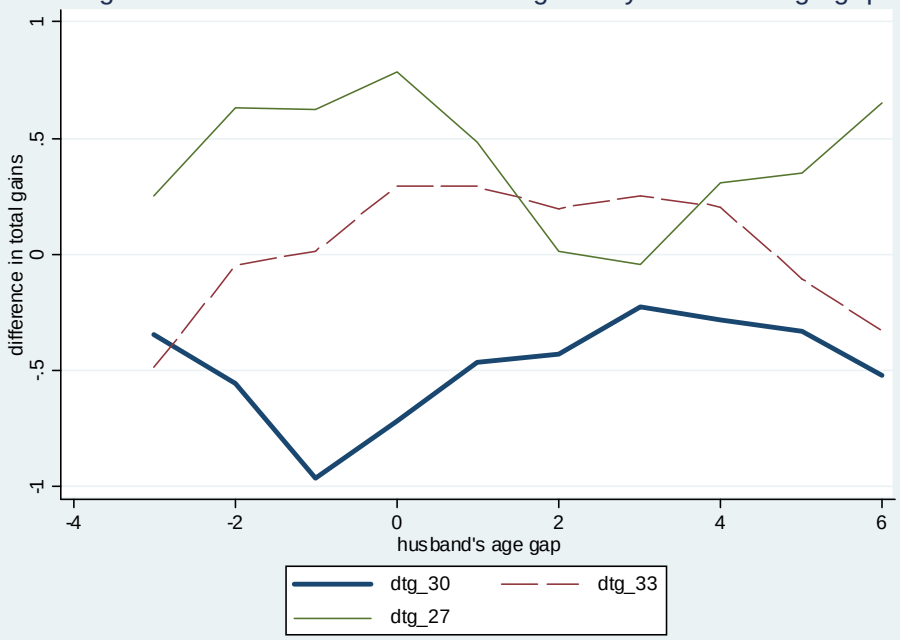

Figure 11a: Anhui 1990-1982 total gains by husband's age gap

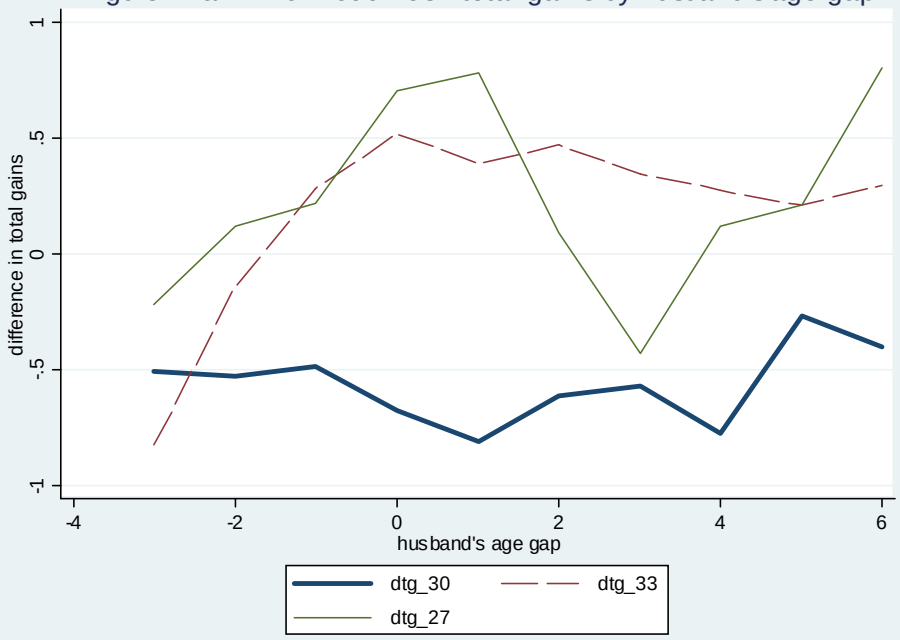

Figure 12: Sichuan 1990, 1982 fraction low education female

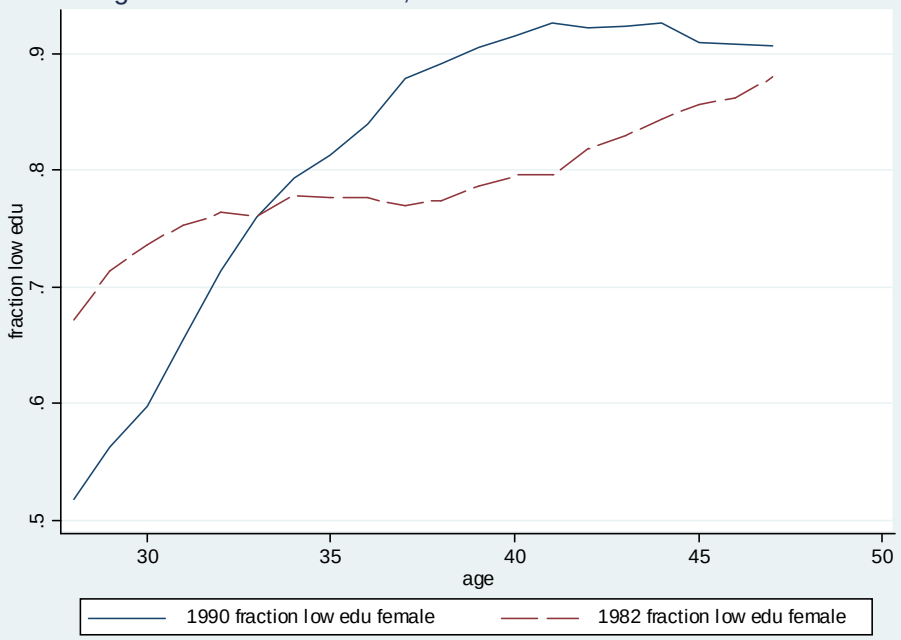

Figure 12a: Anhui 1990, 1982 fraction low education female

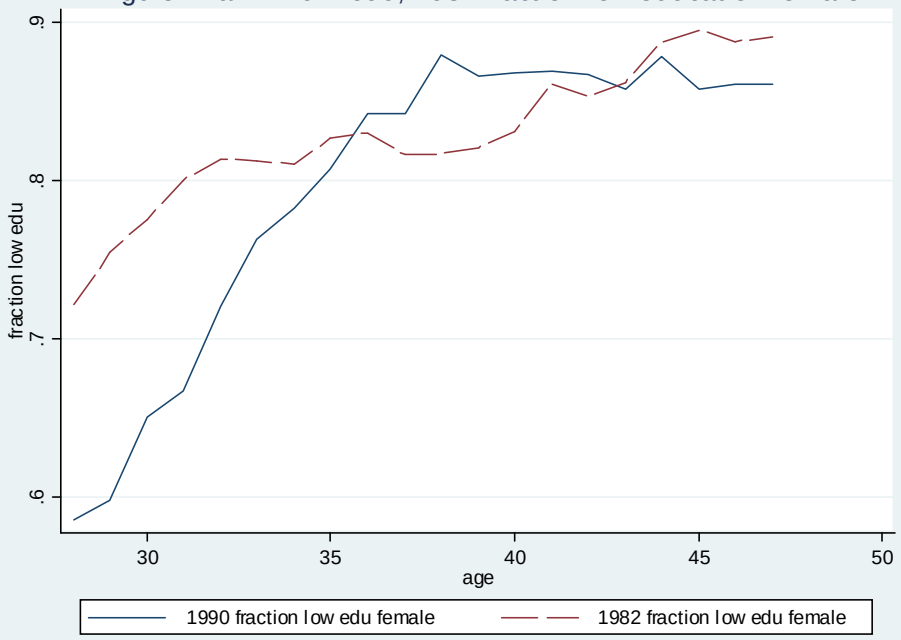

Figure 13: Sichuan 1990, 1982 growth fraction low education female

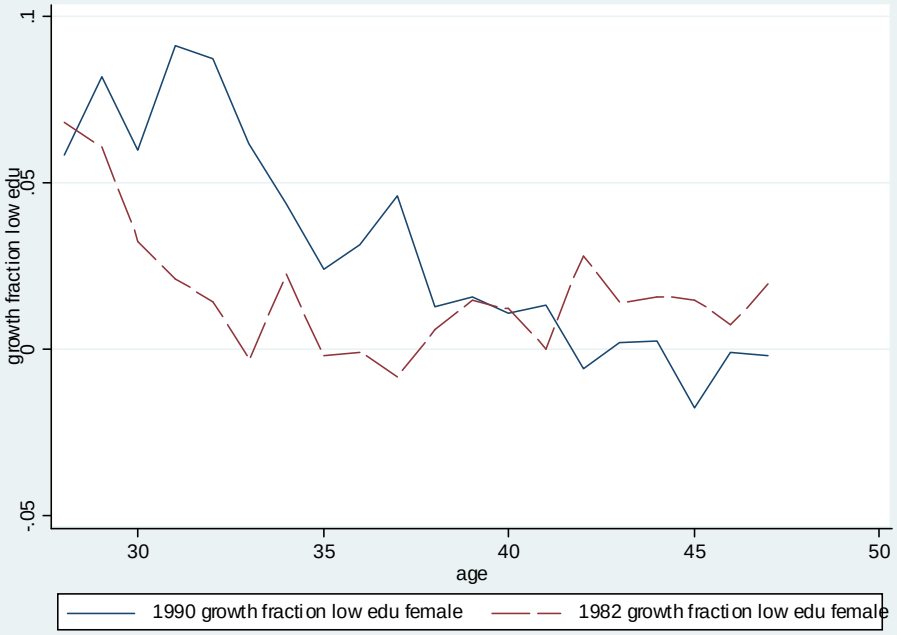

Figure 13a: Anhui 1990, 1982 growth fraction low education female

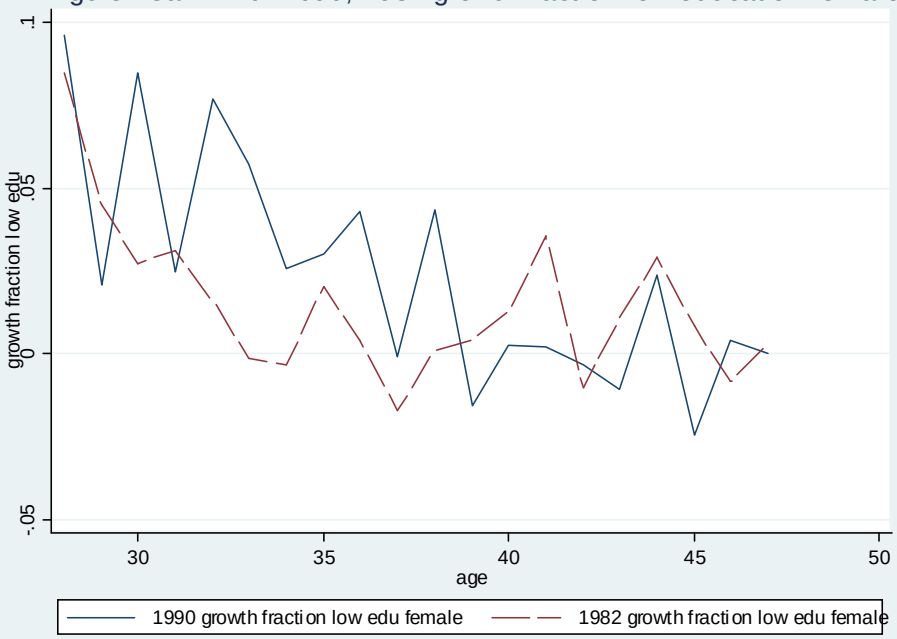

Figure 14: Sichuan 1990/1982 female marriage rates by education

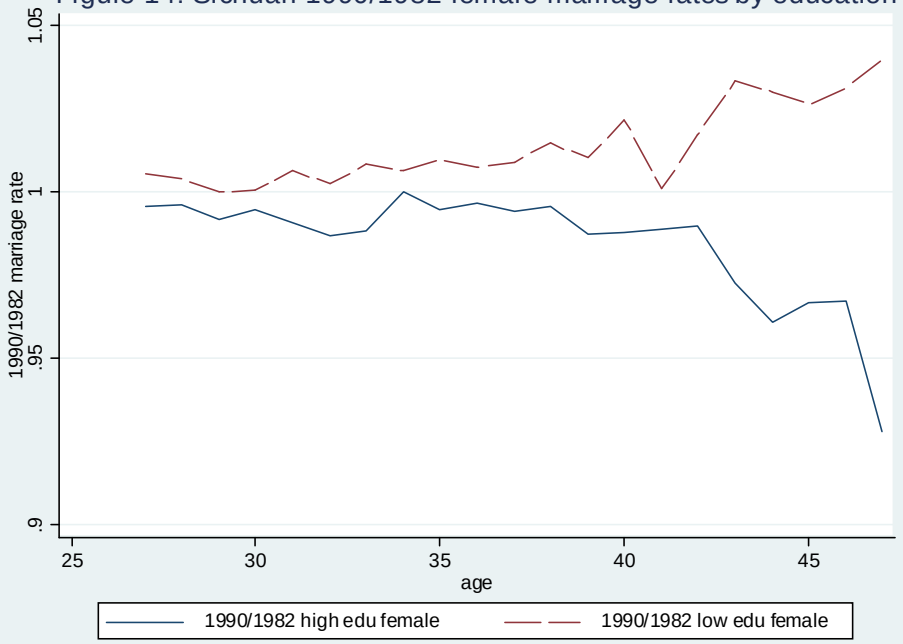

Figure 14a: Anhui 1990/1982 female marriage rates by education

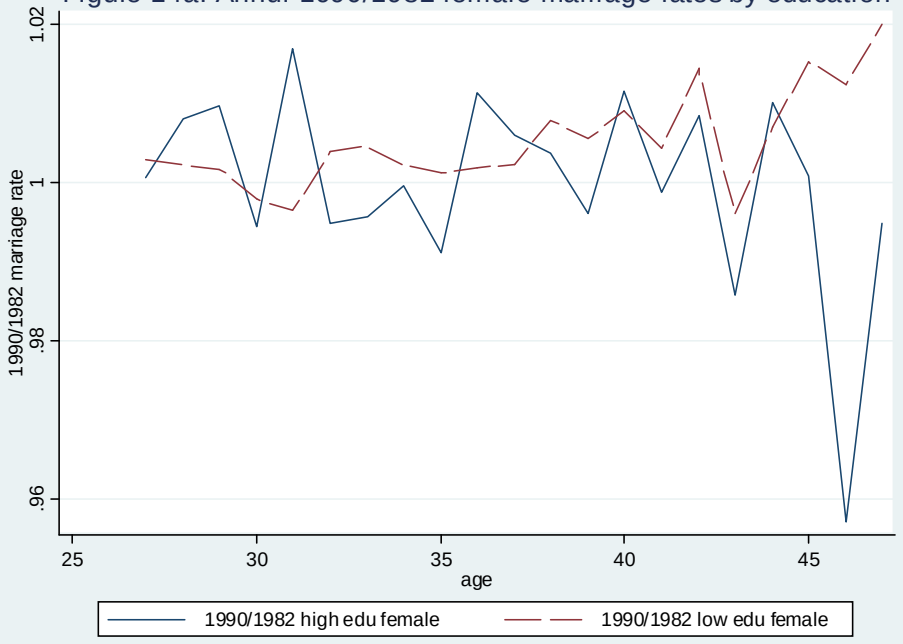

Figure 15: Sichuan predicted, by age & edu, over actual marriage rates,199

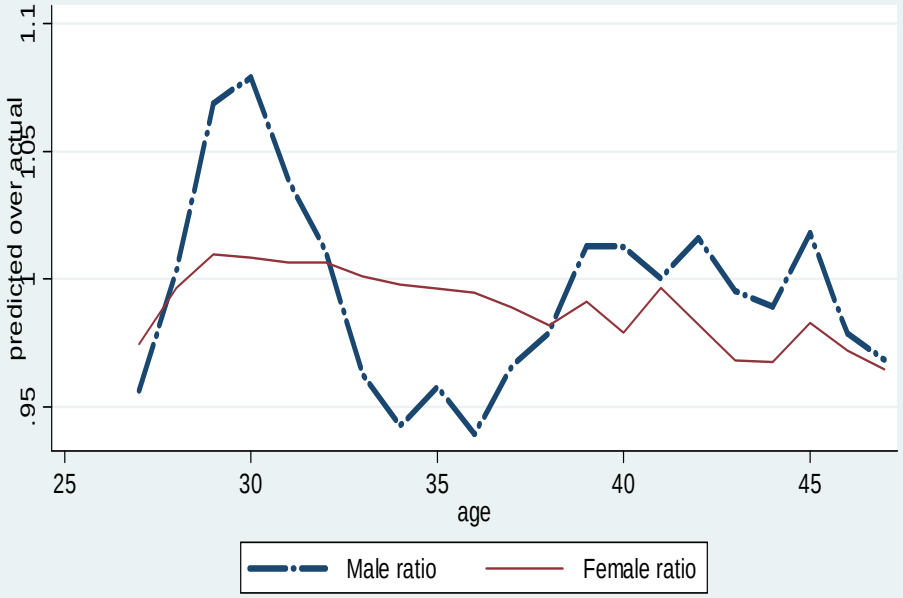

Figure 15a: Anhui predicted, by age & edu, over actual marriage rates,199

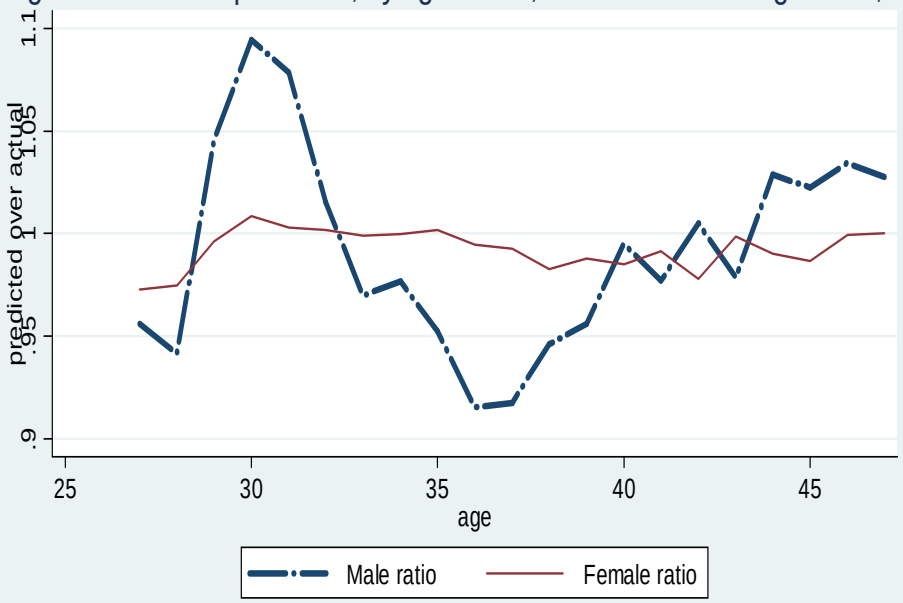

Figure 16: Sichuan HH 1990-1982 total gains by husband's age gap

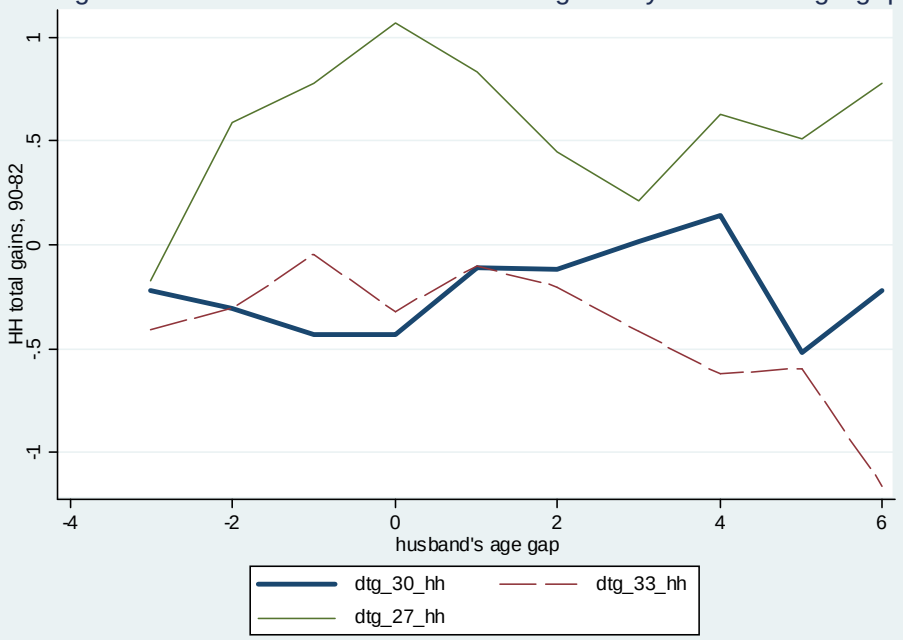

Figure 16a: Anhui HH 1990-1982 total gains by husband's age gap

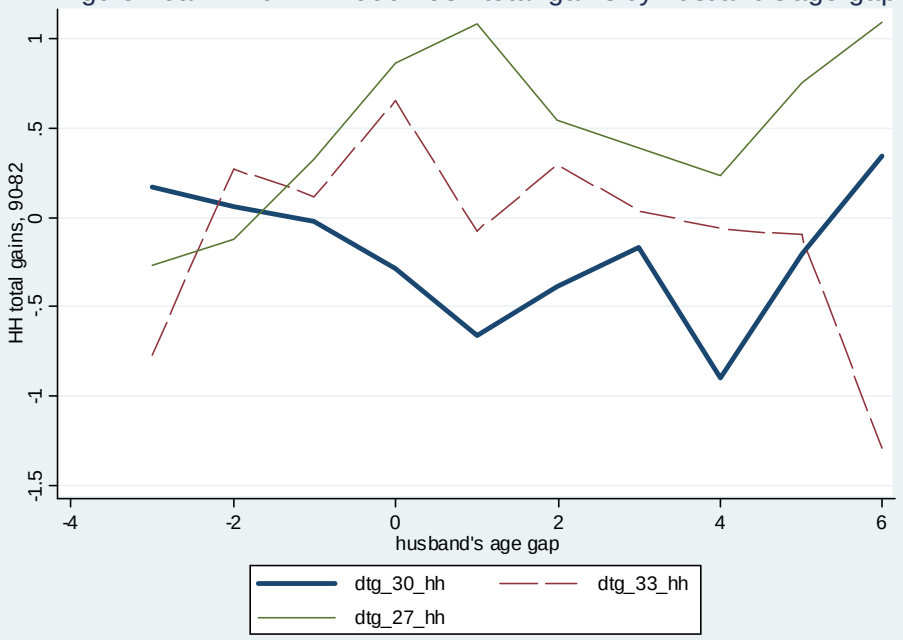

Figure 17: Sichuan LL 1990-1982 total gains by husband's age gap

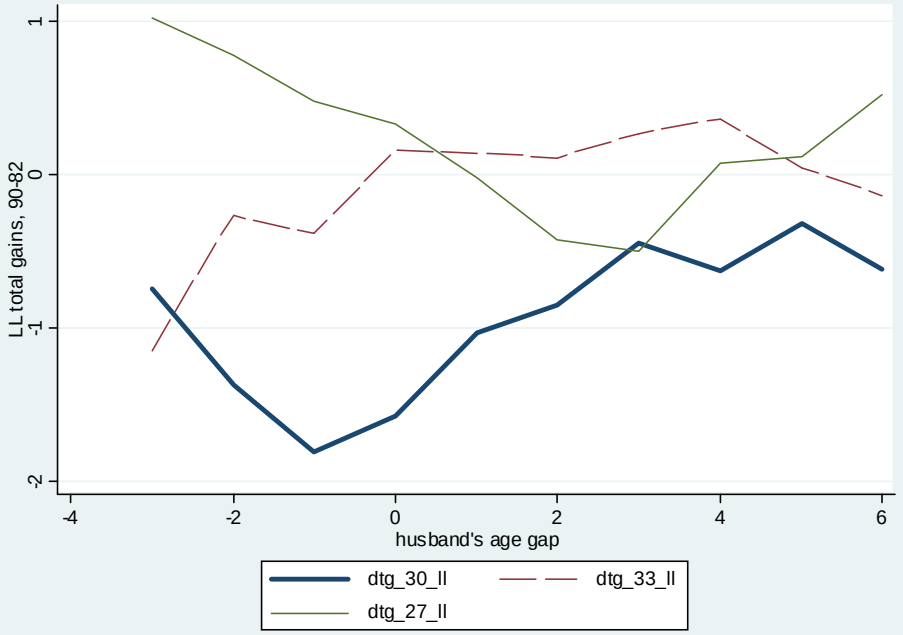

Figure 17a: Anhui LL 1990-1982 total gains by husband's age gap