



# Educational assortative mating and couples' linked occupational trajectories in China

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## ABSTRACT

Educational assortative mating profoundly influences couples' division of labor; however, we know little about how it shapes couples' paired occupational trajectories. We employed multi-channel sequence analysis to discern types of couples' linked occupational trajectories based on the couple-level data from China Labor-force Dynamics Survey (CLDS), and multinomial logistic models to examine how educational assortative mating is associated with couples' occupational trajectories. For most occupational types, husbands had more advantaged or at least similar occupational trajectories than their wives. Couples in educational hypergamy were likely to have occupational trajectory types with husbands having some advantages; couples in educational hypogamy were likely to have occupational trajectory types with wives having some advantages. The specialization and resource bargaining perspectives provide more powerful explanations than the "doing gender" perspective. Chinese couples tend to choose the occupational arrangement that maximizes the family's economic interests rather than the one that best conforms to gender norms and expectations.

## 1. Introduction

The past few decades have observed declining gender differences in educational attainment in many societies and even a reversal of this gender gap such that more women have attained college degrees than men in some societies (Esteve et al., 2016). This gender gap reversal in education has reshaped educational assortative mating, contributing to an increase in educational homogamy (wives equally educated as their husbands) and hypogamy (wives more educated than their husbands), and a decrease in educational hypergamy (wives less educated than their husbands) (Esteve et al., 2016; Van Bavel et al., 2018). This shift in educational assortative mating has profound consequences for families in terms of household specialization and gender-economic well-being (Van Bavel et al., 2018). A growing body of literature focuses on couples' individual earning trajectories (Qian, 2017a, 2017b, 2018) and, in a recent study, family wealth trajectories (Cheng and Zhou, 2022); however, studies have paid little attention to couples' linked occupational trajectories (for exceptions, please see [Langner, 2015; Visser and Fasang, 2018]). Occupation is a central concern of stratification research, bridging educational attainment and income (Blau and Duncan, 1967), and all three indicators are used to capture one's socio-economic status. The institution of occupation is itself gender segregated, and this segregation has profound influences on economic inequality both within and between heterosexual couples (Busch, 2020; England, 2010; Petersen and Morgan, 1995). To address the research gap, this study examines how educational assortative mating shapes couples' linked occupational trajectories and

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makes two potential contributions to the literature.

Firstly, by examining how educational assortative mating shapes couples' linked occupational trajectories, this current study contributes to a better understanding of gender economic inequality within families. Prior studies on couples' economic well-being within marriage focus exclusively on income patterns (e.g., Qian, 2017a, 2017b, 2018). Though evidence on driving reasons is still mixed, research consistently reveals a "marriage premium" for men's wages (e.g., Cheng, 2016; Killewald and Gough, 2013; Light, 2004) and a "motherhood penalty" for women's wages (e.g., Budig and England, 2001; Gonalons-Pons et al., 2021). In terms of the influences of educational assortative mating, a recent study finds that wives in educational hypogamy exhibit a more positive change in income over the marital course, as compared to those in educational homogamy and hypergamy (Qian, 2017b, 2018). However, little is known about how couples' educational attainment is translated into differing household divisions of paid work and then labor market performance. Compared to income patterns, occupational trajectories can more accurately reflect the division and arrangement of paid work within couples and directly present the essence of the major theoretical perspectives for gendered division of labor within households—specialization, resource bargaining, and doing gender perspectives. For instance, Schneider (2012) argues that occupation is a more salient, stable, and visible marker of gender deviance than income because work is a key way in which men and women perform their masculinity and femininity. Moreover, investigating the different combinations of couples' occupational trajectories by educational assortative mating could potentially reveal the extent to which changes in gender equality in public arenas such as education has translated into changes in gender relations and power dynamics among heterosexual couples.

Secondly, by taking a life course perspective, this study examines how couples' occupations evolve across the marital course and interact with each other. Educational assortative mating can influence couples' initial division of labor and set the stage for their later division of labor due to both a comparative advantage in the labor market and perceived gender ideologies (Verbakel et al., 2008). A few studies reveal an interdependence in couples' employment status, working hours, and retirement decisions (e.g., Bertogg et al., 2021; Miller, 2020; Visser and Fasang, 2018). Nevertheless, studies rarely focus on couples' linked transitions between occupations and changes within occupations. The study fills this gap by taking a dynamic and dyadic perspective on couples' linked occupational trajectories.

We situate our study in contemporary China, which provides an interesting setting for addressing our research questions. In the past few decades, China has experienced a significant educational expansion, especially among women, leading to an increase in hypogamy, homogamy, and a decrease in hypergamy (Dong and Xie, 2023; Han, 2010). However, the narrowing gender gap in education has been accompanied with an increased occupational segregation in the wake of market transition, leading to a persistent and even widening gender gap in income (Wu, 2019). This current study may contribute to uncovering the reasons behind this mismatch of gender equity progress in education and occupation institutions from the perspective of household specialization. Specifically, we investigate how couples' occupational trajectories jointly and interdependently evolve under different educational assortative mating.

Using data from the China Labor-force Dynamic Survey (CLDS), we employed multi-channel sequence analysis and multinomial logit models to address the following two research questions. What are the major types of paired couples' occupational trajectories in contemporary China? How is educational assortative mating associated with types of couples' occupational trajectories?

## 2. Theoretical background

In the following sections, we introduce the theoretical reasons motivating our research hypotheses. We first elaborate on how educational assortative mating is linked to couples' division of labor through specialization, resource-bargaining, and "doing gender" perspectives. We then introduce and apply the life course perspective on building analytic models for occupational trajectories. Next, we explain the uniqueness of the Chinese social setting and proposed our hypotheses.

### 2.1. Educational assortative mating and couples' division of labor

There are three prominent theoretical perspectives in explaining the link between educational assortative mating and couples' division of labor. Specialization proposed by Becker (1991) assumes that couples maximize their family utility through a gender-specific division of labor. The partner who has a comparative advantage in the labor market specializes in paid work, while the other specializes in unpaid work (Becker, 1991). The resource-bargaining perspective assumes that couples consistently leverage their comparative resources and re-negotiate with each other to maximize individual utility. The partner who has higher educational attainment may have higher bargaining power within a relationship and tends to focus more on paid work and reduce time spent on unpaid work, which may lead to the spouse's transitions into non-standard or part-time jobs or even withdrawal from the labor market. In a gender-equitable labor market, both the specialization and resource-bargaining perspectives predict that the one who has an educational advantage over the spouse because of its associated higher earnings potential is more likely to specialize in the labor market and thus has a more promising occupational trajectory. Empirical evidence, to some extent, lends some support for these perspectives. For instance, prior studies find that women married to men less educated than themselves are more likely to be primary earners and exhibit more positive changes in income than women married to men equally or more educated than themselves (Qian, 2017a, 2017b). Prior studies also reveal that men in hypogamous marriages spent more time in childcare than men in homogamous and hypergamous marriages (Miller, 2020).

In addition, the division of labor within couples is profoundly influenced by major life events such as a transition into parenthood. Prior studies show strong evidence of the motherhood penalty (Budig and England, 2001; England, 2016) and the fatherhood premium (Glauber, 2008; Hodges and Budig, 2010; Killewald and Gough, 2013). Employing a couple-based perspective, Killewald and García-Manglano (2016) identify tradeoffs between spouses on paid work adjustments to parenthood (e.g., wives who experience large

decreases in paid work time following parenthood will tend to have husbands with the smallest decreases in paid work time), and also highlight complementarity in adjustments to housework hours, occupation traits, and wages (e.g., wives who experience large increases in housework time following parenthood tend to have husbands who increase their housework time more than most husbands in other cases). Given the joint influential impact of parenthood on couple's division of labor, it is essential to control for parenthood status when investigating the associations between educational assortative mating and couple's occupational trajectories over the marital course.

In contrast to perspectives of specialization and resource-bargaining, "doing gender" perspective provides an explanation from a symbolic interaction viewpoint (West and Zimmerman, 1987). Unlike hypergamy, which has long been a dominant assortative mating pattern, hypogamy has been viewed as a deviance from traditional gender roles and expectations. To reconcile inner conflicts arising from this deviance and to construct suitable gender identities that align with conventional gender expectations, women with higher educational attainment than their husbands may refrain from out-earning them by reducing their labor force participation or offset higher earnings by increasing domestic responsibilities or yielding to their husbands' authority in decision-making (Bertrand et al., 2015; Tichenor, 2005). Therefore, the "doing gender" perspective predicts that, regardless of educational assortative mating, husbands may have a more favorable occupational trajectory than their wives. Empirical evidence testing the "doing gender" perspective is quite mixed. For instance, Gupta (2007) finds that women's absolute income is a better predictor of housework time than their relative income compared to their husbands, suggesting that economic autonomy rather than "doing gender" a more appropriate explanation. However, Aassve et al. (2014), using cross-national data, reveal that beliefs about gender roles influence housework sharing within couples. Using the American Time Use Study (ATUS), Schneider (2011) uncovers a quadratic relationship between women's share of earnings and housework time that remains robust to absolute income and the exclusion of outliers.

## 2.2. Life course perspective

This study draws on the life course perspective (Elder et al., 2003; Elder and Rockwell, 1979) to get a better understanding of how educational assortative mating is associated with couples' unfolding occupational trajectories across the marital course.

The life course principle of life-span development recognizes the importance of individual life histories over the life course. Late-life career status is connected to individuals' occupational trajectory in the formative years of their lives. Educational assortative mating affects couples' initial division of labor and sets the stage for their later division of paid and unpaid work (Verbakel et al., 2008; Visser and Fasang, 2018). For instance, recent studies find that wives in educational hypogamy exhibit a more positive change in income over the marital course and have a continuously high probability of being primary earners, as compared to those in educational homogamy and hypergamy (Qian, 2017b, 2018). Admittedly, the associations between educational assortative mating and couples' occupational trajectories may be confounded by occupational assortative mating. According to the life course perspective, couples' subsequent occupational trajectories are likely to be influenced by their relative occupational positions at the beginning of their marriages. Several empirical studies also reveal significant associations between occupational and educational assortative mating. Research in the United States and Sweden find a positive association, revealing that women in hypogamous unions tend to have better occupations than their partners (Chudnovskaya, 2019; Schwartz et al., 2021) however, a study in China indicates an exchange between education and occupation, showing that women in hypogamous unions tend to have lower occupational scores than their partners (Xu, 2022). To mitigate this confounding effect, we should consider occupational assortative mating when examining the associations between educational assortative mating and couples' occupational trajectories.<sup>1</sup>

The life course principle of linked lives acknowledges the interdependence of an individual's lives with others in shared relationships. Husbands' and wives' occupational trajectories are influenced by their socioeconomic status per se and also their socioeconomic status relative to each other. Different types of educational assortative mating may indicate a varied division of labor within marriages. For instance, performing a dual trajectory analysis of working hours across decades of couples' lives, Langner (2015) finds that highly educated women are not only less likely to permanently specialize in unpaid work but also more likely to try working full-time. Based on 20 years of linked couples' employment trajectories, another quantitative study reveals that educational assortative mating earlier in life is associated with a polarization into resource-rich high-status dual-earners and resource-poor low-status male breadwinner couples later in life (Visser and Fasang, 2018). In addition, a recent study finds that an individual's timing of retirement is influenced by earnings relative to his or her partner (Bertogg et al., 2021).

## 2.3. The Chinese context and hypotheses

China provides a unique social context for examining how educational assortative mating shapes couples' occupational trajectories. China has experienced an unprecedented educational expansion since 1999 driven by a drastic policy shift aiming at expanding higher

<sup>1</sup> To alleviate the confounding influences of occupational assortative mating, we have attempted to control for occupational assortative mating upon their first marriage in the model presented in Appendix Table A-1. The main results remain consistent. However, some standard errors could not be estimated due to insufficient cases in several cells; therefore, we utilized the types of enterprises prior to first marriage in the main tables and figures.

education. Higher education has transitioned from elite to universal education with a college gross enrollment rate increasing from 26.5% in 2010 to 59.6% in 2022.<sup>2</sup> The expanding opportunities in higher education are increasingly taken by female students from urban areas (Wu and Zhang, 2010). This narrowing gender gap in educational attainment has changed the pattern of educational assortative mating, resulting in an increase in homogamy and hypogamy and a decrease in hypergamy, although homogamy and hypergamy are still the mainstream educational assortative mating patterns in contemporary China (Dong and Xie, 2023; Han, 2010). Given the changes in educational assortative mating, we may expect that couple's linked occupational trajectories are more similar in younger cohorts (i.e., born after 1970) than in older cohorts (i.e., born before 1970). Moreover, types of couples' linked occupational trajectories may vary with their employment status, occupation types, and career growth pace; we thus may also expect to observe different types of couples' linked occupational trajectories contingent upon these factors.

In the meantime, we have observed a persistent gender inequality in earnings despite the declining gender gap in educational attainment. Marketization has long been seen as the dominant force shaping gender inequality (He and Wu, 2018; Shu and Bian, 2003). Wu summarizes three specific arguments to explain the unchanged even widening gender earnings inequality (Wu, 2019). The first argument points out that marketization with an emphasis on profits, productivity, and efficiency over social justice has led to a rise in employers' discrimination against women (He and Wu, 2018; Honig and Hershatter, 1988). This is because gender essentialism appeals to a free market logic that emphasizes biological difference and regards women as inferior laborers (Ji et al., 2017). The second argument emphasizes rising gender occupational segregation following the market transition. Prior studies reveal that gender segregation by ownership sector (i.e., public and private sectors) has declined over time under the process of marketization, but gender segregation among industries has increased, meaning that men tend to fill jobs with better pay and women tend to be left with the lower-paying ones (Shu, 2005). The third argument focuses on the transformation in gender relations within families along with marketization. Women after the market transition are facing more issues of work-life balance than women before the market transition (Ji et al., 2017). This is partially because the social responsibilities of working units (i.e., *danwei*), such as childcare and social services, have been shifted back to private families as the wanes of the public sector (Ji et al., 2017; Zuo and Bian, 2001). The marketization launched in 1992 was deepened in the 1990s, a little earlier than educational expansion; however, these two important historical events were interwoven with each other, contributing to a significant transition in educational assortative mating and gender division of labor within and outside of the family. In summary, these three arguments reflect women's disadvantaged positions in the labor market compared to men's due to increasing employers' discrimination against women, rising gender occupational segregation, and increasing family responsibilities.

Against the Chinese context, employing the competing perspectives (i.e., specialization/resource-bargaining versus "doing gender") to analyze how educational assortative mating sets up the stages of couples' division of labor and applying the life course approach to evaluate how couples' occupational trajectories evolve across the marital course, to some extent, contribute to understanding the gender economic inequity in China. Next, we will introduce our proposed hypotheses according to the three theoretical perspectives—specialization, resource-bargaining, and "doing gender"—in combination with the life course approach.

The life-span development and linked-lives principles predict that the division of paid work within couples, established earlier in life according to their comparative advantages in educational attainment, can evolve over the marital course in major four ways: persistence, convergence, divergence, or cross-over. Persistence refers to that couples' occupational trajectories maintain a relatively stable difference over the marital course. Convergence indicates that the gap in couples' occupational trajectories narrows over the marital course, while divergence suggests the opposite. Cross-over refers to the difference in couples' occupational trajectories flips over the marital course.

As mentioned before, in a gender-equitable labor market, both specialization and resource-bargaining perspectives predict that the one who has an educational advantage because of its associated higher earnings potential over his/her partner specializes in the labor market and thus has a more promising occupational trajectory. However, in reality, increased discrimination against women by employers, worsening gender segregation in the industry, and the increase in women's family responsibilities have favored men's career advancement over that of women. Therefore, we expect a divergence of occupational trajectories between men and women in educational hypergamy or homogamy due to women's cumulative disadvantages in the labor market over the marital course. As for couples in educational hypogamy, women may take a lead in the earlier stages of occupational trajectories; however, the gender discriminated and segregated labor market may gradually erode or even reverse women's lead; therefore, we may observe a convergence (even a cross-over) of occupational trajectories of couples in educational hypogamy. We thus propose the following two hypotheses.

**Hypothesis 1a.** Compared to couples in educational homogamy, couples in educational hypergamy are more likely to exhibit a pattern of occupational trajectories where husbands have more advantaged occupational trajectories than wives, and this gender gap is widening over the marital course.

**Hypothesis 1b.** Compared to couples in educational homogamy, couples in educational hypogamy are more likely to exhibit a pattern of occupational trajectories where wives have more advantaged occupational trajectories than husbands, but this gender gap is stable or narrowing over the marital course.

<sup>2</sup> The data source is from Department of Development Planning, Ministry of Education, 2010 and 2022. The information can be access via the following websties. [http://www.moe.gov.cn/srcsite/A03/s180/moe\\_633/201203/t20120321\\_132634.html](http://www.moe.gov.cn/srcsite/A03/s180/moe_633/201203/t20120321_132634.html); [http://www.moe.gov.cn/fbh/live/2023/55167/sfcl/202303/t20230323\\_1052203.html](http://www.moe.gov.cn/fbh/live/2023/55167/sfcl/202303/t20230323_1052203.html).

Additionally, given the high heterogeneity among homogamous couples, we may observe differing couple's paired occupational patterns between those with higher education and those with lower education. This is because the former may be more likely to occupy better job positions and embrace more egalitarian gender roles than the latter (Boehnke, 2011; Chatard and Selimbegovic, 2007). We, therefore, need to consider the potential variations between homogamous couples with higher education and those with lower education.

In contrast, the "doing gender" perspective predicts that, regardless of educational assortative mating, husbands may consistently have more advantaged occupational trajectories than their wives after marriage. This occurs because, in hypogamous marriages, wives may compensate for their deviation from gender expectations by taking more housework or deliberately limiting their efforts or time in the labor market. In the Chinese context, women may change to more family-friendly and stable jobs with limited occupational advancement after marriage, especially after becoming parents. Furthermore, increased discrimination against women and gender segregation in industries may contribute to such compensatory behaviors. We thus propose the following competing hypothesis, as compared to the first set of hypotheses.

**Hypothesis 2.** Despite educational assortative mating, couples are more likely to exhibit a pattern of occupational trajectories where husbands have more advantaged occupational trajectories than wives, and this gender gap is widening over the marital course.

### 3. Data and methods

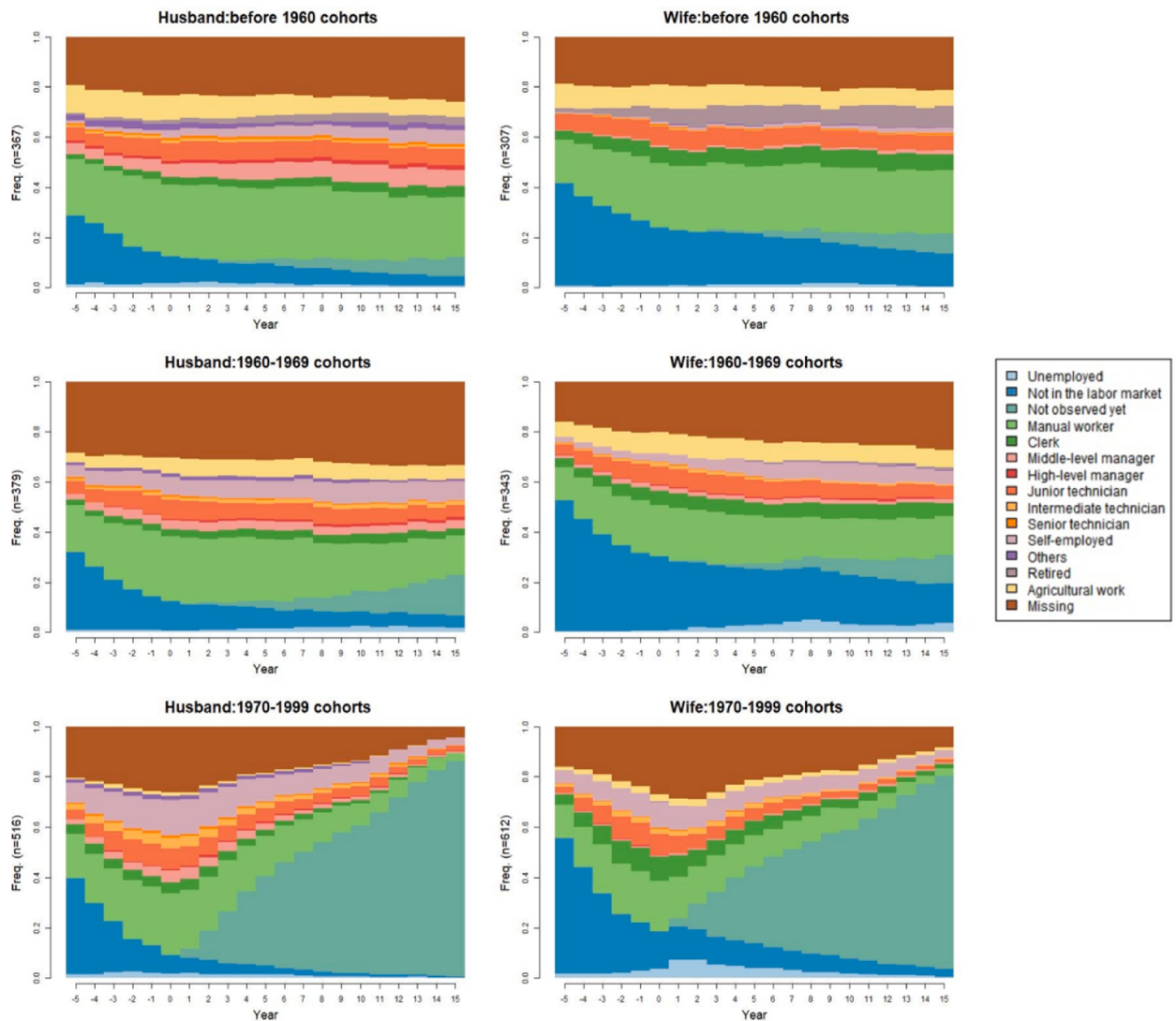
#### 3.1. Data

We used data from the 2012 wave of the China Labor-force Dynamics Survey (CLDS). The CLDS, launched by Sun Yat-Sen University, is the first national longitudinal social survey targeted at the labor force in China. Initiated in 2012, this survey has been conducted every two years since then and has accumulated four waves of data till now (2012, 2014, 2016, and 2018). This survey was conducted using probability-proportional-to-size sampling (PPS), with population size, administrative units, and socioeconomic status (SES) as the main stratification variables, covering 29 provinces or their administrative equivalents (municipalities and autonomous regions) in China excluding Hong Kong, Macao, Taiwan, Tibet autonomous region, and Hainan province. The CLDS designed a set of multi-level questionnaires around the labor force, including individual-, household-, and community-level surveys. The household-level surveys tracked relationships among family members, and within each household, interviewing individuals aged 15–64 and those aged 65 or older who were employed. Drawing on the information on relationships among family members, we could match individuals with their spouses and create couple-dyadic data.

We used the 2012 wave of the CLDS because only it retrospectively collected the respondents' complete work history of the first ten jobs up to the survey year, including the start and end dates, industry sector types, enterprise types, work locations, and position levels at each job. A total of 16,253 individuals and corresponding 10,612 households were interviewed in 2012, and 96.51% (15,686) of individuals aged 15–64 and those aged 65 or older who were employed. Those who had only agriculture work experiences were excluded because only those who were living in urban areas and ever had non-agricultural work experiences completed the questions about work history, yielding a sample of 6805. Among them, 4196 individuals were in their first heterosexual marriage during the 2012 survey and could be matched with their corresponding household information. After successfully matching with their spouses within households, 1315 couples both reporting complete non-agricultural work history have been identified. After excluding individuals with missing values in the measures of our interest (64 couples dropped), we got our final analytic sample of 1251 couples (2502 persons).

#### 3.2. Measures

**Job states and trajectories.** The CLDS used the national occupational classification in the Fifth China Population Census. This national occupational classification grouped occupations into seven types: (1) managers of state organs, the party and mass organizations, enterprises and institutions, (2) professionals, (3) clerical support and related workers, (4) business and service workers, (5) agriculture, forestry, stock raising, and fishery workers, (6) production, transportation equipment operators and related workers, (7) and others. Based on this occupational classification, we constructed occupational trajectories with 15 types of job states combining information on employment status and available position levels of each job. The employment status included employed in enterprises, self-employed, working in agriculture, not employed and others. We classified those who were not employed into four subgroups to distinguish individuals at their different employment statuses including those not in the labor market, not observed yet, unemployed, and retired. We classified those who were employed by enterprises into three major groups: blue collars (i.e., type 4 and type 6 in the national occupational classification), technician-oriented white collars (i.e., type 2 in the national occupational classification), and management-oriented white collars (i.e., type 1 and type 3 in the national occupational classification). Blue collars refer to technician manual workers, non-technician manual workers, business staff, and service staff. For technician-oriented white collars, we considered their different position levels and classified them from low to high levels into junior technicians, intermediate technicians, and senior



**Fig. 1.** Sequence distribution plot of occupational trajectories by gender and birth cohorts for couples.

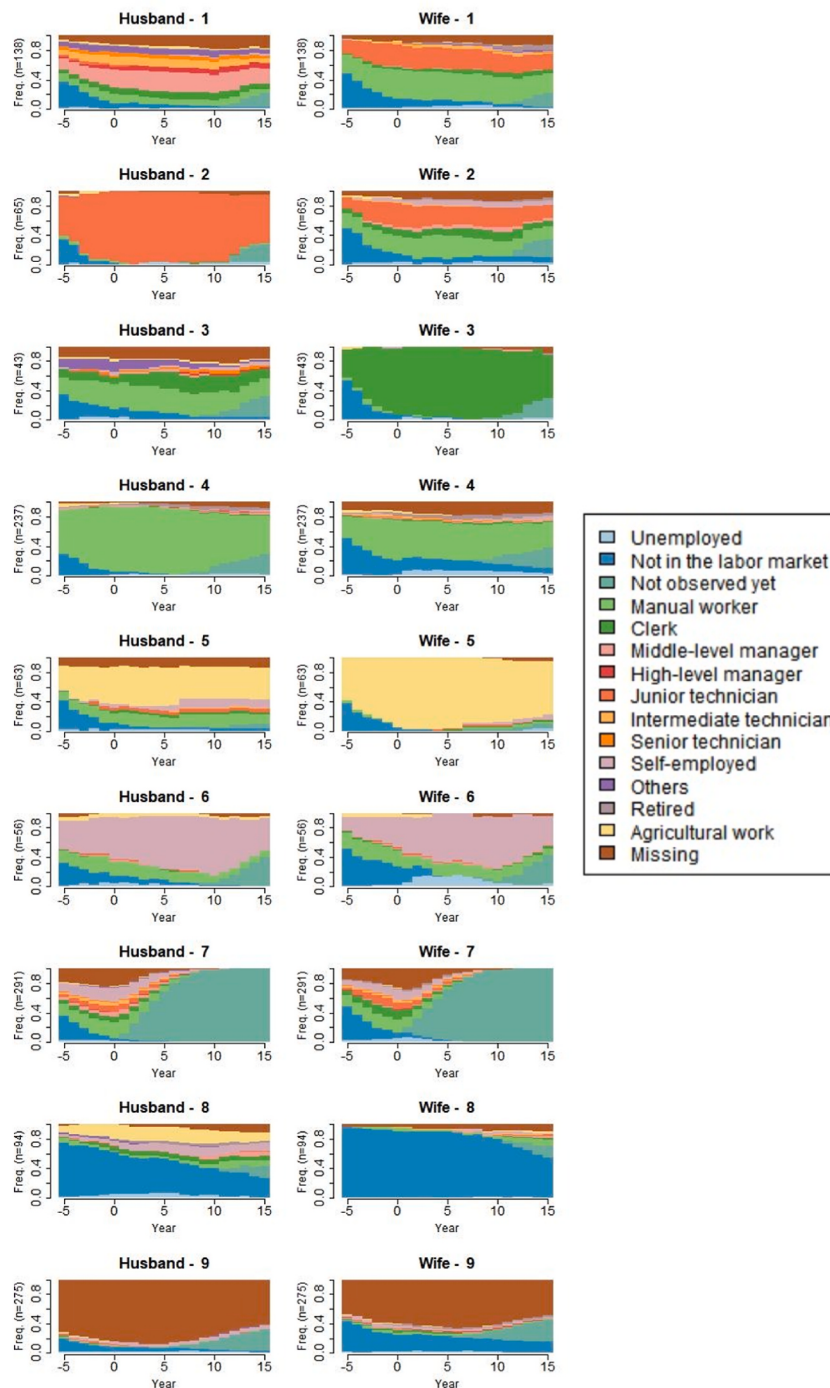
**Notes:** The x-axis shows five years before and 15 years after the first marriage; “zero” represents the year of first marriage. The y-axis shows the frequency of job states.

technicians. For management-oriented white collars, we classified them into clerks, middle-level managers, and high-level managers. Moreover, missingness was treated as a unique and separate type of job state because sequence analysis has an advantage in recognizing “missingness” as a unique state and a potential to extract information from it.<sup>3</sup>

In China, types of enterprises (i.e., *danwei*; state-owned vs. non-state-owned) play important roles in determining employee welfare and job stability. We did not incorporate enterprise types into the classification of job states for two reasons. One is that incorporating it would dramatically increase the number of job states and the difficulty in identifying the typology of occupational trajectories. The other is that this study focuses more on occupational trajectory over the marital course, specifically on the changes of position levels. To control for the heterogeneity resulting from different enterprise types, we included types of couple’s enterprise before the first marriage as a covariate in the multivariate models.

Combining the beginning and end dates of the first ten jobs and the year of the first marriage, we constructed couple-dyadic data of occupational trajectories five years before and 15 years after the year of first marriage. We initially aimed to illustrate changes in

<sup>3</sup> We conducted a robustness check by excluding the trajectory type of “dual missingness” from the model of multinomial logistic regression and re-estimated the marginal predicted probability of eight types of couple’s occupational trajectories by couple’s educational assortative mating (please see Figure A-1). The main results remain unchanged.



**Fig. 2.** Sequence distribution plot for the types of occupational trajectories of couples.

**Notes:** Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Entry-level female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness.

occupational trajectories around the time of first marriage in Figs. 1 and 2 by incorporating couples' occupational trajectories five years prior to the marriage. This approach is partly based on previous studies indicating that women are more likely to take non-standard or part-time jobs or to exit the labor market entirely upon their first marriage (Piotrowski et al., 2015; Zhang et al., 2008).<sup>4</sup> Employing a multi-channel sequence analysis, we developed a typology of couples' occupational trajectories identifying nine different types: high-level male breadwinner, entry-level male breadwinner, entry-level female breadwinner, dual manual workers, dual farmers, dual self-employed, young dual-earners, dual joblessness/instability, and dual missingness.

**Educational assortative mating.** After matching husbands' and wives' educational attainment, we created a measure of educational assortative mating with four categories: low-level homogamy (neither had a high school degree), high-level homogamy (both had a high school degree), female hypergamy (the husband had a high school degree and the wife had no high school degree) and female hypogamy (the wife had a high school degree and the husband had no high school degree).<sup>5</sup> Considering the changing marginal distribution of education across birth cohorts and the changing social values placed on educational degrees due to educational expansion (Feng, 2022; Uchikoshi, 2022), especially the college expansion since 1999, we conducted a robustness check using various cutoffs by birth cohorts.<sup>6</sup> We also performed a robustness check by directly comparing the educational attainment of paired husbands and wives without employing cutoffs.<sup>7</sup> The main results remain consistent across the two types of educational assortative mating (please see Appendix Figures A-4 and A-5 for more details).

**Covariates.** We included couple-level demographic and socio-economic covariates that are associated with both educational assortative mating and couples' occupational trajectories. A categorical measure of couples' age assortative mating was constructed by subtracting wives' age from husbands' age at first marriage (less than or within 3 years [reference group], and older than 3 years). Only 15 couples had wives who were more than 3 years older than their husbands (1.29%); they thus were combined with those whose age difference was within 3 years. We also constructed ethnicity (at least one was non-Han [reference group] and both were Han), *hukou* status (at least one had a rural *hukou* [reference group] and neither had a rural *hukou*), and party membership (neither was a communist party member [reference group] and at least one was a communist party member) of couples combining husbands' and wives' information. *Hukou* is a system of household registration used in mainland China. Different benefits (e.g., education, medical care, and social security) are attached to a specific *hukou* type with non-rural *hukou* at a higher social status than rural *hukou*. Couples' occupation type before the first marriage (at least one in state-owned [reference group] and neither in state-owned) was included to control for the heterogeneity resulting from working in different types of enterprises and potential occupational assortative mating. The birth cohort (<1960 [reference group], 1960–1969, and 1970–1999) and the age at first marriage of husbands were also considered. To avoid the issue of multicollinearity, we did not include the birth cohort and age at the first marriage of husbands simultaneously. We controlled for the parenthood status of couples (had no children [reference group], one child, and two or more children) because it significantly influenced occupational trajectories, especially for women (Huang and Sverke, 2007; Killewald and Zhuo, 2019). Additionally, we included the measure of the region (East [reference group], Middle, and West) to control for spatial heterogeneity.<sup>8</sup>

### 3.3. Analytic strategy

To identify couples' linked occupational trajectories over the marital course, we applied multi-channel sequence analysis (MCSA)

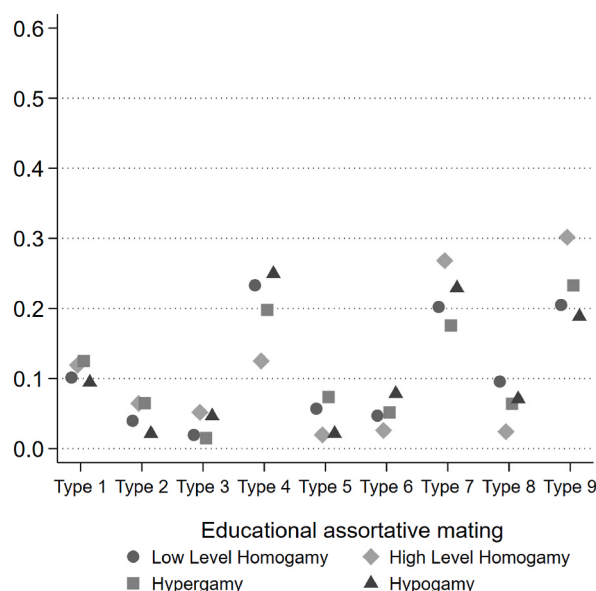
<sup>4</sup> To alleviate the confounding influences of occupational assortative mating, we controlled for the types of enterprises where the husband and wife worked prior to their first marriage in the model presented in Table 3. Moreover, for a robustness check, we adjusted the starting point for the occupational trajectories to the year of first marriage and replicated the results in Figs. 2 and 3 (please see Figures A-2 and A-3 for more details). Comparing results in Fig. 2 and Figure A-9, only Type 3 exhibits some difference. The husband was stable as a manual worker, while the wife was either a clerk or technician; we, therefore, labeled Type 3 as “female breadwinner” instead of “entry-level female breadwinner” in Figure A-9. Comparing results in Fig. 3 and Figure A-10, we found that within Type 3 (female breadwinner), couples were most likely to be hypogamy, as compared to other types, in Figure A-10. Despite this difference, the main conclusion remains unchanged.

<sup>5</sup> We chose a high school degree instead of a college degree as a cutoff. This is because the gross college enrollment rate was below 50% in China before 2019, and most adults did not go to college; therefore, only 20.80% of men and 15.91% of women had at least a college degree in our analytic sample, leading to a highly unbalanced distribution of four categories of educational assortative mating. Furthermore, the possible adoption of the full combination of educational assortative mating (homogamy, hypergamy, and hypogamy) and levels of educational attainment (middle school and below, high school, and college and above) will generate a large number of different types (i.e., nine types), which may lead to a high degree of uncertainty for the estimated probabilities of occupational trajectories of couples belonging to different types.

<sup>6</sup> We used a high school degree as the cutoff for birth cohorts prior to 1960 and for those born between 1960 and 1969, while a college degree served as a cutoff for the 1970–1999 birth cohorts. The measure of educational assortative mating was categorized into four groups: low-level homogamy (neither had the cutoff degree), high-level homogamy (both had the cutoff degree), female hypergamy (the husband had the cutoff degree while the wife did not), and female hypogamy (the wife had the cutoff degree while the husband did not).

<sup>7</sup> The constructed measure of educational assortative mating comprises four categories: low-level homogamy (the husband and the wife had the same level of educational attainment but neither had a high school degree), high-level homogamy (the husband and the wife had the same level of educational attainment and both had a high school degree), female hypergamy (the husband had a higher level of educational attainment than the wife), and female hypogamy (the wife had a higher level of educational attainment than the husband).

<sup>8</sup> The eastern region includes Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Guangxi provinces. West region includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Shanxi, Henan, Hubei, and Hunan provinces. Middle region includes Chongqing, Sichuan, Guizhou, Yunnan, Shanxi, Gansu, Ningxia, Qinghai, and Xinjiang provinces.



**Fig. 3.** The predicted probability of nine types of couple's occupational trajectories by couple's educational assortative mating.

*Notes:* Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Entry-level female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness.

to reveal clusters of couples' occupational trajectories (Gauthier et al., 2010). As a special type of social sequence analysis, MCSA enables us to analyze longitudinal (or retrospective) occupational trajectories of both husbands and wives simultaneously and offers a systematic view of how their linked occupational trajectories develop over time.

Social sequence analysis operationalizes individual job history as a sequence of states, treating events and experiences such as promotions, demotions and unemployment as embedded within the context of trajectories that unfold over time. Social sequence analysis maintains the integrity of occupational trajectories and accounts for their inherent complexity such as the ordering of states, the length of time spent in each state, the timing of promotions or demotions, and the number of promotions or demotions. Therefore, the whole occupational trajectories, rather than individual statuses, are treated as the unit of analysis.

Retaining the advantages of social sequence analysis, multi-channel sequence analysis provides a systematic approach for dealing with the multi-dimensionality of trajectories such as couples' linked occupational trajectories. Husbands' and wives' occupational trajectories each constitute one "channel" of the dyadic couple trajectories. Multi-channel sequence analysis also accounts simultaneously for local interdependencies between husbands' and wives' job states present at each point of the alignment process for all channels. Moreover, it offers a powerful visualization of the parallel channels evolving over time.

Multi-channel sequence analysis relies on the computation of "distances" between the two paired occupational trajectories of couples. We used an optimal matching analysis to determine how much each paired trajectories differ from the others (for more technical details, please see Gauthier et al., 2010) and generated a distance matrix. The optimal matching considers "substitution" costs (changing one element of a sequence into another), and "insertion" and "deletion" costs (inserting and removing elements from parts of the sequence). Substitution costs were estimated based on the observed transition probabilities in the trajectory—the lower the probability of transitioning into another state, the higher the cost will be. Insertion and deletion costs were set to half of that of the substitution costs, which is the default setting of the optimal matching procedure. Moreover, the substitution costs were estimated for each channel based on their transition rates of states. As robustness checks, we also used the dynamic hamming distance method, hamming distance method, and longest common suffix method as alternatives to the optimal matching method. Compared to the optimal matching, only the type of entry-level female breadwinner changed in these alternative methods, partially because this is the least frequent type (please see Figure A-6 in the appendix), while the other types have remained unchanged. We also replicated the findings in Fig. 3 with the method of dynamic hamming distance; the corresponding results are presented in Figure A-7. The main findings have remained consistent.

Hierarchical clustering using Ward's linkage was then applied to the distance matrix to reveal clusters of paired occupational trajectories. The algorithm of Ward's linkage clustering seeks to reduce the residual sum of squares by fusing clusters. By doing so, it groups the paired trajectories that are most alike into clusters. The final choice for the number of clusters was by obtaining the solution with the widest average silhouette width ( $ASW = 0.27$ ) and the highest Pearson's Gamma value ( $PG = 0.64$ ). The clustering algorithm revealed that the nine-cluster solution was most preferable based on these criteria.

Finally, multinomial regression analyses were used to examine how educational assortative mating is associated with membership in each cluster. For ease of interpretation, marginal predicted probabilities of belonging to each cluster (at observed values of predictors and covariates) were calculated. The probability of belonging to each cluster by different types of educational assortative

**Table 1**

Nine types of couples' occupational trajectories found from multi-channel sequence analysis (N = 1251).

| Type | Name                           | Sample size | Description                                                                                                                                     |
|------|--------------------------------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| 1    | High-level male breadwinner    | 137         | The husband had a clear career advancement trajectory from entry-level to senior positions, while the wife remained in an entry-level position. |
| 2    | Entry-level male breadwinner   | 64          | The husband was stable in a junior technician position, while the occupational trajectory of the wife was unstable and at a lower level.        |
| 3    | Entry-level female breadwinner | 43          | The wife was stable in an entry-level position, while the occupational trajectory of the husband was unstable and at a lower level.             |
| 4    | Dual manual workers            | 232         | Both the husband and wife were stable in manual worker positions with husband having a higher rate of labor participation.                      |
| 5    | Dual farmers                   | 63          | A large portion of couple's job states was at agricultural work, and the husband had some episodes of self-employed and manual worker states.   |
| 6    | Dual self-employed             | 56          | The husband and wife were both self-employed, and the wife entered the labor market later than the husband.                                     |
| 7    | Young dual earners             | 288         | The husband and wife were both at their early career stages and had similar career trajectories.                                                |
| 8    | Dual joblessness/instability   | 94          | A large portion of couple's job states was not in the labor market, and the husband had some episodes of volatile and low status job states.    |
| 9    | Dual missingness               | 274         | A large portion of couple's job states was missing, and a small portion of the job states was not in the labor market.                          |

mating could be directly compared. All social sequence analyses were performed in R 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria), and multinomial regression analyses were performed in Stata 16 (StataCorp, College Station, TX).

#### 4. Results

##### 4.1. The pattern of couples' paired occupational trajectories

To clarify the distribution of husbands' and wives' occupational trajectories, we presented a sequence distribution plot of occupational trajectories by gender and birth cohorts in Fig. 1 (sequence index plot present in Figure A-8). The x-axis shows five years before and 15 years after the first marriage; "zero" represents the year of first marriage. The y-axis shows the frequency of job states. Comparing husbands' and wives' occupational trajectories, we found that husbands were more likely to join the labor market earlier (the portion of "not in the labor market" decreased earlier among husbands), to stay in the labor market for a longer period (the portion of "not in the labor market" was smaller across the marital course among husbands), and to have more advantaged occupational trajectories (the portions of higher-level occupation were larger among husbands), as compared to their wives.<sup>9</sup> Specifically, husbands had a larger portion of occupational trajectories as middle-level and high-level managers and intermediate and senior technicians, as compared to their wives. Regarding the gender differences before first marriage across cohorts (five years prior to the first marriage), the occupational trajectories of wives were more likely to resemble those of husbands among the younger birth cohorts (i.e., 1970–1999 birth cohorts), as compared to their older counterparts (i.e., <1960 and 1960–1969 birth cohorts).

We then demonstrated the pattern of the couples' paired occupational trajectories based on the results of multi-channel sequence analyses in Fig. 2 (sequence index plot in Figure A-9). Multi-channel sequence analyses identified nine types of couples' paired occupational trajectories and labeled them as high-level male breadwinner (Type 1), entry-level male breadwinner (Type 2), entry-level female breadwinner (Type 3), dual manual workers (Type 4), dual farmers (Type 5), dual self-employed (Type 6), young dual-earners (Type 7), dual joblessness/instability (Type 8), and dual missingness (Type 9). A detailed description of the nine types of couples' occupational trajectories was presented in Table 1.

For couples who belong to Type 1 (high-level male breadwinner), husbands had a relatively clear occupational advancement trajectory from entry-level to senior positions, while wives remained in an entry-level position; the gender gap was diverging over the marital course. For couples who belong to Type 2 (entry-level male breadwinner) and Type 3 (entry-level female breadwinner), either husbands or wives were stable in an entry-level position, while the other had an unstable and lower-level career trajectory; the gender gap was relatively stable over the marital course. Couples who belong to Type 4 (dual manual workers), Type 5 (dual farmers), Type 6 (dual self-employed), Type 7 (young dual earners) and Type 8 (dual joblessness/instability) had a similar occupational trajectory. For couples who belong to Type 4 (dual manual workers), both husbands and wives were stable manual workers. For couples who belong to Type 5 (dual farmers), a large portion of job states was at agricultural work, and husbands had some episodes of self-employed and manual worker states. For couples who belong to Type 6 (dual self-employed), husbands and wives were both self-employed, and wives entered the labor market later than husbands. For couples who belong to Type 7 (young dual earners), husbands and wives were both at their early career stages and had similar occupational trajectories. For couples who belong to Type 8 (dual joblessness/instability), a large portion of couple's job states was not in the labor market, and husbands had some episodes of volatile and low status job states. For couples who belong to Type 9 (dual missingness), both husbands' and wives' job states were majorly missing, but wives had a

<sup>9</sup> The average age at first employment is 21.04 years for husbands and 21.07 years for wives; the average working hours per week is 51.09 for husbands and 49.53 for wives.

**Table 2**

Descriptive statistics for the types of occupational trajectories of couples.

| Measures                                         |                                           | Type 1 | Type 2 | Type 3 | Type 4 | Type 5 | Type 6 | Type 7 | Type 8 | Type 9 | Total |
|--------------------------------------------------|-------------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| Educational assortative mating (%)               | Low-level homogamy                        | 27.74  | 20.31  | 16.28  | 43.10  | 66.67  | 53.57  | 28.47  | 73.40  | 57.30  | 43.01 |
|                                                  | High-level homogamy                       | 44.53  | 54.69  | 62.79  | 24.14  | 6.35   | 14.29  | 47.57  | 5.32   | 20.44  | 31.10 |
|                                                  | Hypergamy                                 | 18.98  | 20.31  | 6.98   | 17.24  | 23.81  | 17.86  | 12.50  | 13.83  | 15.69  | 15.91 |
|                                                  | Hypogamy                                  | 8.76   | 4.69   | 13.95  | 15.52  | 3.17   | 14.29  | 11.46  | 7.45   | 6.57   | 9.99  |
| Husband-wife age gap categories (%) <sup>a</sup> | [-3, 3]                                   | 75.91  | 68.75  | 76.74  | 70.26  | 76.19  | 73.21  | 71.18  | 72.34  | 72.26  | 72.26 |
|                                                  | (3,20]                                    | 24.09  | 31.25  | 23.26  | 29.74  | 23.81  | 26.79  | 28.82  | 27.66  | 27.74  | 27.74 |
| Ethnicity of couple (%)                          | At least one was non-Han                  | 7.30   | 10.94  | 4.65   | 9.91   | 4.76   | 5.36   | 9.03   | 4.26   | 8.76   | 8.15  |
|                                                  | Both were Han                             | 92.70  | 89.06  | 95.35  | 90.09  | 95.24  | 94.64  | 90.97  | 95.74  | 91.24  | 91.85 |
| Hukou status of couple (%)                       | At least one had a rural hukou            | 10.95  | 7.81   | 4.65   | 21.55  | 49.21  | 57.14  | 54.17  | 46.81  | 56.20  | 39.09 |
|                                                  | Neither had a rural hukou                 | 89.05  | 92.19  | 95.35  | 78.45  | 50.79  | 42.86  | 45.83  | 53.19  | 43.80  | 60.91 |
| Party membership of couple (%)                   | Neither was a communist party member      | 49.64  | 53.13  | 39.53  | 81.47  | 73.02  | 89.29  | 77.43  | 85.11  | 82.12  | 74.50 |
|                                                  | At least one was a community party member | 50.36  | 46.88  | 60.47  | 18.53  | 26.98  | 10.71  | 22.57  | 14.89  | 17.88  | 25.50 |
| Types of enterprises before first marriage (%)   | Neither in state-owned                    | 24.82  | 10.94  | 23.26  | 28.45  | 84.13  | 80.36  | 73.96  | 92.55  | 94.16  | 61.79 |
|                                                  | At least one in state-owned               | 75.18  | 89.06  | 76.74  | 71.55  | 15.87  | 19.64  | 26.04  | 7.45   | 5.84   | 38.21 |
| Birth cohort of husband (%)                      | <1960                                     | 44.53  | 35.94  | 44.19  | 40.95  | 44.44  | 14.29  | 3.47   | 43.62  | 28.10  | 28.94 |
|                                                  | 1960–1969                                 | 37.23  | 34.38  | 30.23  | 30.60  | 46.03  | 42.86  | 6.94   | 36.17  | 41.24  | 30.14 |
|                                                  | 1970–1979                                 | 18.25  | 29.69  | 23.26  | 27.16  | 9.52   | 41.07  | 30.21  | 19.15  | 28.10  | 26.22 |
|                                                  | 1980–1999                                 | 0.00   | 0.00   | 2.33   | 1.29   | 0.00   | 1.79   | 59.38  | 1.06   | 2.55   | 14.71 |
| Age at first marriage of husband                 | Mean                                      | 27.10  | 27.47  | 27.23  | 27.96  | 24.89  | 26.98  | 29.35  | 25.69  | 26.54  | 27.45 |
|                                                  | SD                                        | 4.38   | 4.56   | 3.85   | 6.40   | 4.46   | 4.65   | 7.45   | 5.24   | 5.46   | 6.01  |
| Parenthood status (%)                            | Had no children                           | 19.71  | 10.94  | 18.60  | 17.24  | 15.87  | 5.36   | 32.29  | 18.09  | 13.34  | 19.26 |
|                                                  | Had one child                             | 62.04  | 64.06  | 67.44  | 57.76  | 30.16  | 58.93  | 55.90  | 37.23  | 45.26  | 52.84 |
|                                                  | Had at least two children                 | 18.25  | 25.00  | 13.95  | 25.00  | 53.97  | 35.71  | 11.81  | 44.68  | 41.61  | 27.90 |
| Region (%)                                       | West                                      | 35.04  | 29.69  | 23.26  | 23.28  | 22.22  | 19.64  | 18.75  | 31.91  | 19.34  | 23.42 |
|                                                  | Middle                                    | 24.82  | 21.88  | 23.26  | 28.02  | 41.27  | 26.79  | 25.00  | 18.09  | 22.99  | 25.26 |
|                                                  | East                                      | 40.15  | 48.44  | 53.49  | 48.71  | 36.51  | 53.57  | 56.25  | 50.00  | 57.66  | 51.32 |
| N                                                |                                           | 137    | 64     | 43     | 232    | 63     | 56     | 288    | 94     | 274    | 1251  |

**Notes:**

Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Entry-level female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness.

<sup>a</sup> Only 15 couples had wives who were more than 3 years older than their husbands (1.29%); they thus were combined with those whose age difference was within 3 years.

larger portion of job states being not in the labor market. For couples with similar occupational trajectories such as Type 4 (dual manual workers), Type 5 (dual farmers), Type 6 (dual self-employed), and Type 8 (dual joblessness/instability), it can be somewhat challenging to determine who had a more advantaged occupational trajectory, as these occupations lack a standardized promotion process. Nevertheless, husbands still maintained a slight advantage over their wives in the job market for those types.

Table 2 showed descriptive statistics for couples in the nine clusters. In general, most couples' marriages were low-level homogamy (neither had a high school degree; 43.01%), followed by high-level homogamy (both had a high school degree; 31.10%), hypergamy (only husband had a high school degree; 15.91%), and hypogamy (only wife had a high school degree; 9.99%). For couples who belong to Type 1 (high-level male breadwinner), Type 2 (entry-level male breadwinner) and Type 3 (entry-level female breadwinner), most marriages were high-level homogamy. Within each type, approximately 70% of couples had husband-wife age gap within 3 years old, and around 90% of couples were both Han ethnicity. For Type 1 (high-level male breadwinner), Type 2 (entry-level male breadwinner), and Type 3 (entry-level female breadwinner), couples tended to have a higher socioeconomic status than couples of other types featured by higher percentages of urban hukou, communist party membership, and occupation in state-owned enterprises. Most Type 7 (young dual earners) couples were born after 1970, especially between 1980 and 1989. Type 5 (dual farmers) and Type 8 (dual joblessness/instability) couples transitioned into first marriage earlier than other types of couple. Type 5 (dual farmers), Type 8 (dual joblessness/instability), and Type 9 (dual missingness) couples were most likely to have more than one child, while Type 7 (young dual earners) were least likely to have children. Type 5 couples (dual farmers) were mostly from the middle region of China, while couples of other types were mostly from the east region of China.

#### 4.2. Educational assortative mating and couples' paired occupational trajectories

Table 3 presented the associations between educational assortative mating and types of couples' paired occupational trajectories with high-level homogamy as reference. In Table 3, the relative risks (low-level homogamy relative to high-level homogamy) of couples in Type 1 (high-level male breadwinner), Type 2 (entry-level male breadwinner), Type 3 (entry-level female breadwinner),

**Table 3**

Estimates from multinomial logit models for the associations between educational assortative mating and the types of couple's occupational trajectories.

| Ref. = Type 4                                                              | Type 1              | Type 2              | Type 3               | Type 5               | Type 6               | Type 7              | Type 8              | Type 9              |
|----------------------------------------------------------------------------|---------------------|---------------------|----------------------|----------------------|----------------------|---------------------|---------------------|---------------------|
|                                                                            | RRR                 | RRR                 | RRR                  | RRR                  | RRR                  | RRR                 | RRR                 | RRR                 |
| Educational assortative mating (ref. = High level homogamy)                |                     |                     |                      |                      |                      |                     |                     |                     |
| Low level homogamy                                                         | 0.45<br>(0.23–0.86) | 0.33<br>(0.14–0.77) | 0.19<br>(0.07–0.55)  | 1.56<br>(0.45–5.38)  | 0.83<br>(0.29–2.33)  | 0.25<br>(0.12–0.51) | 2.03<br>(0.67–6.13) | 0.32<br>(0.16–0.61) |
| Hypergamy                                                                  | 0.68<br>(0.35–1.33) | 0.65<br>(0.29–1.47) | 0.18<br>(0.05–0.67)  | 2.47<br>(0.70–8.74)  | 1.03<br>(0.34–3.11)  | 0.21<br>(0.10–0.47) | 1.58<br>(0.48–5.25) | 0.42<br>(0.21–0.86) |
| Hypogamy                                                                   | 0.38<br>(0.17–0.85) | 0.16<br>(0.04–0.60) | 0.42<br>(0.14–1.20)  | 0.46<br>(0.07–2.89)  | 1.26<br>(0.39–4.05)  | 0.31<br>(0.13–0.72) | 1.23<br>(0.32–4.67) | 0.25<br>(0.11–0.58) |
| Husband–wife age gap categories (ref. = [–3, 3])<br>(3, 20]                | 0.79<br>(0.46–1.35) | 1.23<br>(0.63–2.39) | 0.79<br>(0.34–1.88)  | 0.95<br>(0.45–2.01)  | 0.87<br>(0.42–1.81)  | 0.60<br>(0.35–1.06) | 1.14<br>(0.61–2.16) | 0.95<br>(0.58–1.56) |
| Ethnicity of couples (ref. = At least one was non-Han)                     |                     |                     |                      |                      |                      |                     |                     |                     |
| Both were Han                                                              | 1.41<br>(0.60–3.29) | 1.02<br>(0.38–2.77) | 2.14<br>(0.45–10.25) | 1.35<br>(0.34–5.37)  | 2.21<br>(0.59–8.28)  | 1.29<br>(0.59–2.83) | 2.38<br>(0.70–8.12) | 0.95<br>(0.44–2.06) |
| Hukou status of couple (ref. = At least one had a rural hukou)             |                     |                     |                      |                      |                      |                     |                     |                     |
| Neither had a rural hukou                                                  | 1.37<br>(0.67–2.80) | 1.89<br>(0.65–5.50) | 2.80<br>(0.58–13.41) | 0.64<br>(0.31–1.31)  | 0.43<br>(0.20–0.93)  | 0.15<br>(0.08–0.29) | 0.78<br>(0.41–1.47) | 0.44<br>(0.26–0.74) |
| Party membership of couple (ref. = Neither was a communist party member)   |                     |                     |                      |                      |                      |                     |                     |                     |
| At least one was a communist-party member                                  | 3.68<br>(2.20–6.14) | 2.83<br>(1.49–5.38) | 5.15<br>(2.42–10.96) | 3.21<br>(1.47–6.97)  | 1.18<br>(0.44–3.18)  | 2.34<br>(1.27–4.30) | 1.63<br>(0.75–3.52) | 2.14<br>(1.20–3.80) |
| Types of enterprises before first marriage (ref. = Neither in state-owned) |                     |                     |                      |                      |                      |                     |                     |                     |
| At least one in state-owned                                                | 0.65<br>(0.37–1.13) | 1.92<br>(0.77–4.78) | 0.50<br>(0.21–1.18)  | 0.09<br>(0.04–0.20)  | 0.12<br>(0.05–0.26)  | 0.16<br>(0.09–0.29) | 0.04<br>(0.01–0.09) | 0.02<br>(0.01–0.04) |
| Birth cohort of husband (ref. = 1970–1999)                                 |                     |                     |                      |                      |                      |                     |                     |                     |
| <1960                                                                      | 2.88<br>(1.43–5.82) | 1.12<br>(0.47–2.67) | 2.24<br>(0.81–6.15)  | 6.01<br>(2.02–17.88) | 0.35<br>(0.12–1.00)  | 0.00<br>(0.00–0.00) | 2.64<br>(1.18–5.89) | 1.40<br>(0.74–2.65) |
| 1960–1969                                                                  | 2.51<br>(1.33–4.74) | 1.11<br>(0.52–2.39) | 1.40<br>(0.55–3.56)  | 6.55<br>(2.39–17.95) | 1.15<br>(0.55–2.40)  | 0.02<br>(0.01–0.05) | 2.33<br>(1.11–4.89) | 1.99<br>(1.15–3.45) |
| Age at first marriage of husband                                           | 0.96<br>(0.92–1.00) | 0.96<br>(0.91–1.03) | 0.95<br>(0.88–1.03)  | 0.92<br>(0.85–0.99)  | 1.05<br>(0.99–1.11)  | 1.34<br>(1.26–1.42) | 0.97<br>(0.92–1.03) | 1.01<br>(0.97–1.06) |
| Parenthood status (ref. = Had no children)                                 |                     |                     |                      |                      |                      |                     |                     |                     |
| Had one child                                                              | 1.14<br>(0.60–2.17) | 1.57<br>(0.60–4.08) | 1.47<br>(0.55–3.96)  | 0.82<br>(0.32–2.13)  | 2.78<br>(0.77–10.09) | 0.37<br>(0.20–0.70) | 0.83<br>(0.38–1.84) | 1.11<br>(0.59–2.09) |
| Had at least two children                                                  | 0.81<br>(0.39–1.68) | 2.37<br>(0.84–6.69) | 1.02<br>(0.30–3.45)  | 1.44<br>(0.57–3.60)  | 2.47<br>(0.64–9.53)  | 0.17<br>(0.08–0.40) | 1.04<br>(0.46–2.35) | 1.40<br>(0.71–2.77) |
| Geographical region (ref. = East)                                          |                     |                     |                      |                      |                      |                     |                     |                     |
| Middle                                                                     | 0.69<br>(0.36–1.29) | 1.08<br>(0.46–2.53) | 1.17<br>(0.42–3.30)  | 1.12<br>(0.47–2.65)  | 0.74<br>(0.29–1.88)  | 1.13<br>(0.56–2.26) | 0.27<br>(0.12–0.60) | 0.67<br>(0.35–1.27) |
| West                                                                       | 0.64<br>(0.36–1.14) | 1.36<br>(0.65–2.84) | 1.65<br>(0.67–4.06)  | 0.58<br>(0.25–1.38)  | 0.94<br>(0.41–2.19)  | 1.58<br>(0.86–2.90) | 0.43<br>(0.22–0.85) | 1.02<br>(0.58–1.80) |

**Notes:**

1. Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Entry-level female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual miss-ingness.

2. RRR represents relative risk ratios. 95% confidence intervals in parentheses.

Type 7 (young dual earners), and Type 9 (dual missingness) were 0.45, 0.33, 0.19, 0.25, and 0.32 times that of couples in Type 4 (dual manual workers), respectively. The relative risks (hypergammy relative to high-level homogamy) of couples in Type 3 (entry-level female breadwinner), Type 7 (young dual earners), and Type 9 (dual missingness) were 0.18, 0.21, and 0.42 times of couples in Type 4 (dual manual workers), while the relative risks (hypogamy relative to high-level homogamy) of couples in Type 1 (high-level male breadwinner), Type 2 (entry-level male breadwinners), Type 7 (young dual earners), and Type 9 (dual missingness) were 0.38, 0.16, 0.31, and 0.25 times of couples in Type 4 (dual manual workers).

Because the multinomial logit model in Table 3 only displayed the result using Type 4 as the base outcome and high-level homogamy as the reference group of educational assortative mating, it could not show the full picture of the associations between educational assortative mating and couples' paired occupational trajectories. To aid the interpretation of educational assortative mating patterns, we plotted marginal predicted probabilities of cluster membership in Fig. 3 based on the results from the model of Table 3.<sup>10</sup>

Regardless of educational assortative mating, couples were more likely to be in Type 4 (dual manual workers), Type 7 (young dual earners), and Type 9 (dual missingness), as compared to other types (the absolute probabilities were highest among the three types). Within Type 1 (high-level male breadwinner) and Type 2 (entry-level male breadwinner), couples were most likely to be hypergammy and high-level homogamy, as compared to other types. Within Type 3 (entry-level female breadwinner), couples were most likely to be high-level homogamy and hypogamy, as compared to other types. Within Type 4 (dual manual workers), couples had the highest probability of being hypogamy and low-level homogamy and the lowest probability of being high-level homogamy and hypergammy. Within Type 5 (dual farmers), couples were most likely to be hypergammy and low-level homogamy, as compared to other types. Within Type 6 (dual self-employed), couples were most likely to be hypogamy as compared to other types and the lowest probability of being high-level homogamy. Within Type 7 (young dual earners), couples were most likely to be high-level homogamy, followed by hypogamy, and then the other two types. Within Type 8 (dual joblessness/instability), couples had the highest probability of being low-level homogamy and hypogamy and the lowest probability of being high-level homogamy. Within Type 9 (dual missingness), couples had the highest probability of being high-level homogamy and the lowest probability of being hypogamy.

Comparing across types of couples' occupational trajectories (except for Type 9<sup>11</sup>), couples of high-level homogamy relative to those of low-level homogamy were more likely to be Type 3 (entry-level female breadwinner), and Type 7 (young dual earners; relative risk >1; i.e., the probability of being in high level homogamy is higher than that of being in low-level homogamy) and less likely to be Type 4 (dual manual workers), Type 5 (dual farmers), and Type 8 (dual joblessness/instability; relative risk <1; i.e., the probability of being in high level homogamy is lower than that of being in low-level homogamy). This finding suggests that high-level homogamy is associated with relatively higher-status and more stable occupational trajectories (e.g., entry-level female breadwinner and young dual earners), as compared to low-level homogamy.

Couples of hypergammy relative to those of low-level homogamy were more likely to be Type 1 (high-level male breadwinner; relative risk >1) and less likely to be Type 4 (dual manual workers; relative risk <1). In comparison, couples of hypergammy relative to those of high-level homogamy were more likely to be Type 4 (dual manual workers), Type 5 (dual farmers) and Type 8 (dual joblessness/instability; relative risk >1) and less likely to be Type 3 (entry-level female breadwinner) and Type 7 (young dual earners; relative risk <1). This finding provides partial evidence for Hypothesis 1a that compared to couples in educational homogamy, couples in educational hypergammy are more likely to have a pattern of occupational trajectories with husbands having an advantaged occupational trajectory, and this gender gap is diverging over the marital course. This evidence is more apparent among the reference group—low-level homogamy. This is because that occupational trajectories such as “dual farmers,” “dual manual workers,” and “dual joblessness/instability” are difficult to discern who had a more advantaged occupational trajectory than the other, as these types of occupations lack a standardized promotion process. Nevertheless, husbands still maintained a slight advantage over their wives in the job market (please see Table 1 for a more detailed description).

Couples of hypogamy relative to those of low-level homogamy were more likely to be Type 3 (entry-level female breadwinner), Type 4 (dual manual workers), Type 6 (dual self-employed), and Type 7 (young dual-earners; relative risk >1) and less likely to be Type 2 (entry-level male breadwinner), Type 5 (dual farmers), and Type 8 (dual joblessness/instability; relative risk <1). In comparison, couples of hypogamy relative to those of high-level homogamy were more likely to be Type 4 (dual manual workers), Type 6 (dual self-employed), and Type 8 (young joblessness/instability; relative risk >1) and less likely to be Type 2 (entry-level male breadwinner) and Type 7 (young dual-earners; relative risk <1). This finding provides partial evidence for Hypothesis 1b that compared to couples in educational homogamy, couples in educational hypogamy are more likely to have a pattern of occupational trajectories with wives having a more advantaged occupational trajectory than husbands, but this gender gap is stable over the marital course. However, our findings show little evidence for Hypothesis 2 that despite educational assortative mating, couples are more likely to have a pattern of occupational trajectories with husbands having more advantaged occupational trajectories than wives, and this gender gap is diverging over the marital course.

<sup>10</sup> For a robustness check, we have replicated results of Table 3 based on individual-level data rather than couple-level data. The covariates included were individual's age, ethnicity, hukou status, party membership, types of enterprises, birth cohort, age at first marriage, parenthood status, and region. The results are consistent and shown in Figure A-10.

<sup>11</sup> We excluded Type 9 (dual missingness) from the following comparison because of its ambiguous meaning. We performed a robustness check and omitted the trajectory type of “dual missingness” in the multinomial logistic regression model, and then re-estimated the marginal predicted probability of eight types of couple's occupational trajectories based on couple's educational assortative mating (please see Figure A-1). The main results remain consistent.

## 5. Discussion

The declining gender differences in educational attainment have significant influences on family lives including the pattern of educational assortative mating. Against this background, we examined how educational assortative mating shapes couples' occupational trajectories in China. By discovering the major types of couples' occupational trajectories, this study revealed how couples arrange and specialize their division of paid labor over the marital course. By examining how couples' educational assortative mating is associated with their occupational trajectories, this study contributes to our understanding of gender economic inequality in contemporary China.

The multi-channel sequence analysis discerned nine types of couples' occupational trajectories including high-level male breadwinner (Type 1), entry-level male breadwinner (Type 2), entry-level female breadwinner (Type 3), dual manual workers (Type 4), dual farmers (Type 5), dual self-employed (Type 6), young dual-earners (Type 7), dual joblessness/instability (Type 8), and dual missingness (Type 9). Among the nine types of couples' occupational trajectories, husbands were generally more likely to have a more advantaged or at least similar occupational trajectory than their wives (e.g., high-level male breadwinner, entry-level male breadwinner, dual manual workers, young dual-earners, dual self-employed, dual farmers, and dual joblessness/instability). As for types that wives had a slightly advantaged occupational trajectory than their husbands, both wives and husbands held low-level occupational positions (entry-level female breadwinner). These findings revealed gendered occupational trajectories over the marital course. Compared to wives, husbands were more likely to have a leading occupational advantage at the beginning of the marriage and to maintain and accumulate more advantages throughout the marriage. However, some wives might have a better occupational position than their husbands at the beginning of their marriage, but they had difficulty in maintaining, let alone expanding this advantage. Discrimination against women and gender segregation among industries in the labor market could lend some explanations to these gender differences (Honig and Hershatter, 1988; Wu, 2019). Moreover, women's heavier household responsibilities and unequal division of household unpaid work, especially after they transition into parenthood, may provide another explanation (Gonalons-Pons et al., 2021; Ji et al., 2017).

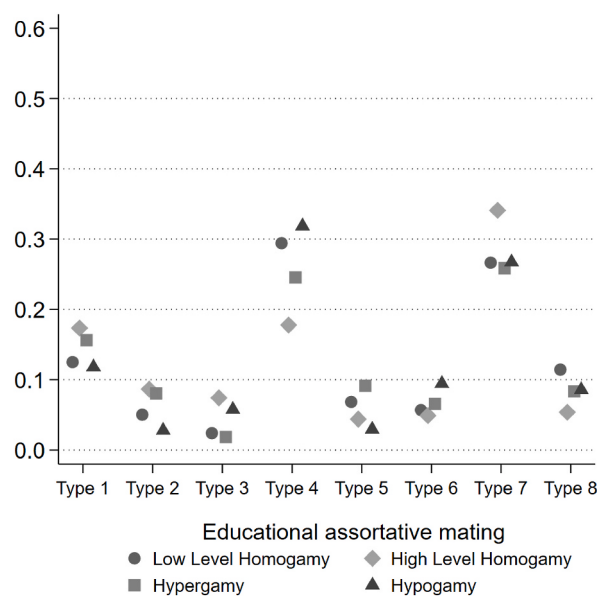
To further reveal how couples arrange and specialize their paid labor, we investigated how educational assortative mating shapes the evolution of occupational trajectory. We found partial evidence that compared to couples in educational homogamy, especially those in low-level educational homogamy, couples in educational hypergamy were more likely to have a pattern of occupational trajectories with husbands having advantaged occupational trajectories, and this gender gap was widening over the marital course. Moreover, we found partial evidence that compared to couples in educational homogamy, couples in educational hypogamy were more likely to have a pattern of occupational trajectories with wives having advantaged occupational trajectories than husbands, but this gender gap was stable over the marital course. These findings to some extent partially support the [Hypothesis 1a](#) and [Hypothesis 1b](#), which were derived from the specialization and resource-bargaining perspectives in the Chinese context.

These findings suggest that the specialization and resource bargaining perspectives are probably more appropriate than the "doing gender" perspective in explaining the evolution of couple's occupational trajectories by educational assortative mating in the Chinese context. In other words, despite China's long history of patriarchy, when it comes to the division of paid labor within couples, Chinese couples tend to choose the occupational arrangement that maximizes the family's economic interests rather than the one that best conforms to gender norms and expectations. In addition, previous empirical evidence that applied the specialization perspective to explain marriage premium is quite mixed (Cheng, 2016; Chun and Lee, 2001; Killewald and Gough, 2013; Ludwig and Brüderl, 2018). Most research apply this perspective by comparing wage differences between married and unmarried men or wage changes after marriage (Cheng, 2016; Chun and Lee, 2001; Ludwig and Brüderl, 2018). Only a few studies focus on the division of labor between couples and perceive between-gender differences as crucial as within-gender differences (Killewald and García-Mangano, 2016; Killewald and Gough, 2013). Our findings contribute to this line of literature through considering couple's joint occupational trajectories.

This study had two major types of limitations. The first type is the result of data limitations. Firstly, we paid less attention to the division of unpaid work such as housework and childcare because of the lack of information. When richer longitudinal data were available, examining the gendered division of both paid and unpaid work would better understand gender inequality within households. Secondly, while parenting and caregiving responsibilities for older parents significantly impact occupational trajectories of young couples, particularly for women, we did not include detailed information on these two factors, aside from the number of children, for two reasons. One is that the occupational trajectories of wives and husbands were based on a retrospective survey conducted in 2012; thus, the survey gathered time-varying measures, such as children's characteristics and intergenerational residence, only in that year. In the multinomial logistic regression models, we aimed to control for time-constant covariates and summarized covariates over an extended period of time (e.g., the number of children by 2012) to avoid controlling for covariates that occurred after the outcome. The other is that the China Labor-force Dynamics Survey (CLDS) primarily focuses on the labor force and provides limited information regarding children's and older parents' characteristics. Thirdly, certain trajectories, such as "dual farmers," "dual manual workers," and "dual self-employed," are difficult to evaluate in terms of who experienced advantageous occupational trajectories, as these occupations lack a standardized promotion process. Given that socio-economically disadvantaged couples are likely to occupy these roles, we may underestimate women's sacrifices in their careers, as these couples tend to exhibit more non-egalitarian gender roles. Fourthly, even though multi-channel sequence analyses could recognize missingness as a unique state, we still lose some information of those who failed to report job histories. The coarse granularity of data does not allow a more detailed analysis of unemployment history and job instability. When fine-grained data were available, we would encourage researchers to examine couples' paired unemployment histories and to investigate how couples' job instability influences each other. Fifthly, the 1980s–1990s birth cohorts were too young in 2012 to have a complete picture of their career trajectories in this study. We recommend

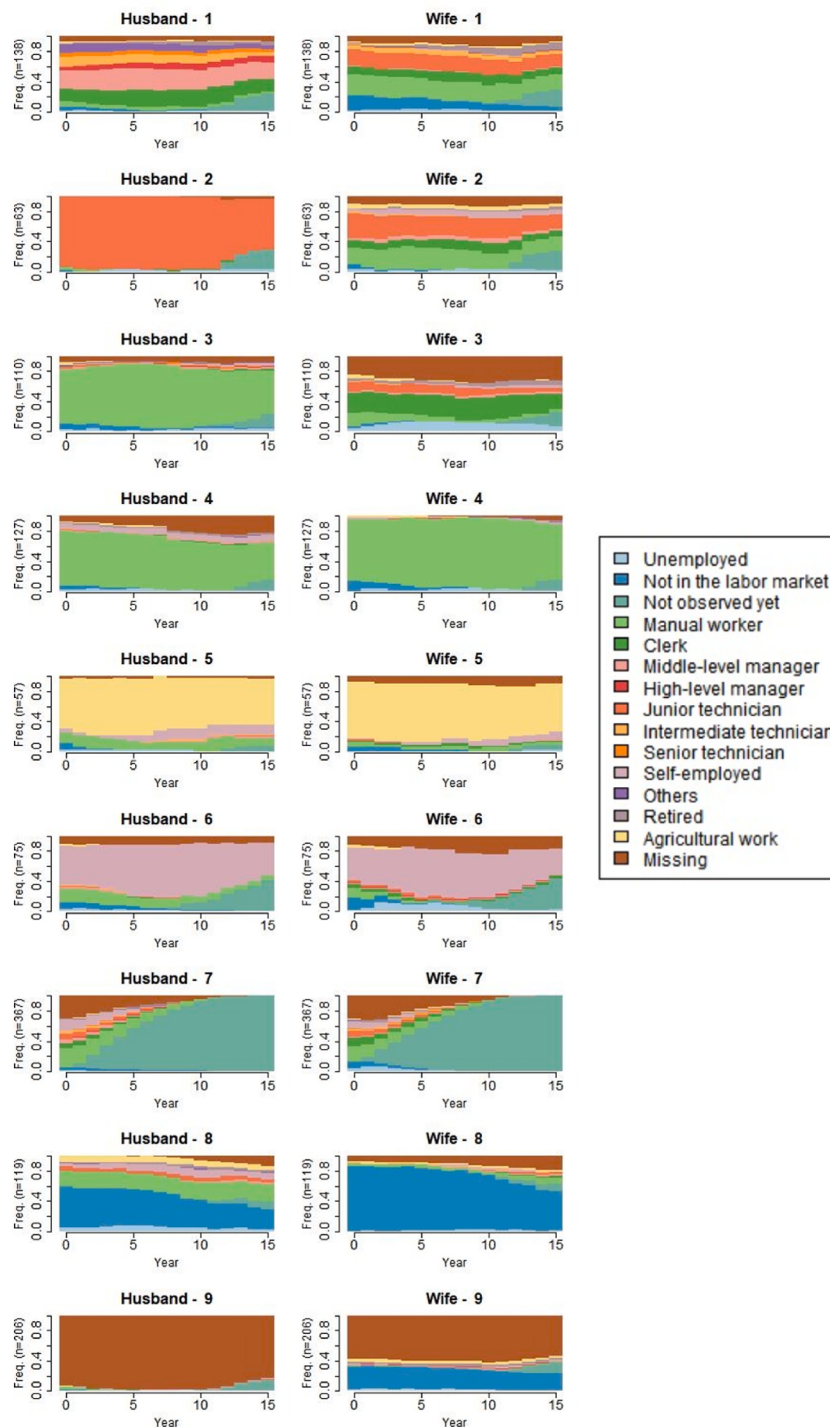
that researchers revisit these cohorts if appropriate data become available. Sixthly, due to the small sample size of the paired dataset, we have little power to investigate the exchanges within couples regarding other characteristics such as age, occupation, and income in relation to education, and the heterogeneity in the associations between educational assortative mating and occupation trajectories over time and across regions. When more suitable data become available, we encourage researchers to further explore these intriguing research questions. For the second type of limitation, we acknowledge the criticism of the use of sequence analysis in revealing underlying trajectory types. [Warren et al. \(2015\)](#) found that different methods for modeling age-graded trajectories may yield slightly different results. As highlighted previously, however, some trajectory models may not be easily estimable with high-resolution data. Despite these limitations in the certainty of clustering trajectories, we found that many aspects of our results align with past research, providing some measure of external validity. Our study is best interpreted as a constructive way to better describe idiosyncrasies in couples' trajectories not captured by previous studies and provide a better way forward in examining couples' occupational trajectories.

This study has methodological, theoretical and practical implications. By linking couples' occupational trajectories together, this current study points out the importance of scrutinizing couples' occupational trajectories dynamically and interactively. By linking educational assortative mating with couples' linked occupational trajectories, this study contributes to our understanding of how relative educational status has translated into changes in gender relations and power dynamics among heterosexual couples. Compared to the "doing gender" perspective, the specialization and resource-bargaining perspectives are more appropriate in understanding the couple's linked and gendered occupational trajectories in China, even though strong gender norms still persist. In other words, in terms of couples' occupational decisions, the practical intent to maximize individual or household economic benefits often trumps the compliance with gender norms. Moreover, the gendered occupational trajectories revealed in this study, to some extent, help unpack the puzzle that the gender gap in earnings persists despite the improvement in gender equity of educational attainment in China. Gendered household specialization partially accounts for the gender inequality in labor market performances, while gender discrimination against women and gender segregation in industries, in turn, may reproduce and strengthen gendered household specialization. Considering the interactions between the two spheres—families and the labor market, significant changes and reforms are necessary both within and outside families to alleviate gender disparity in labor market performances.

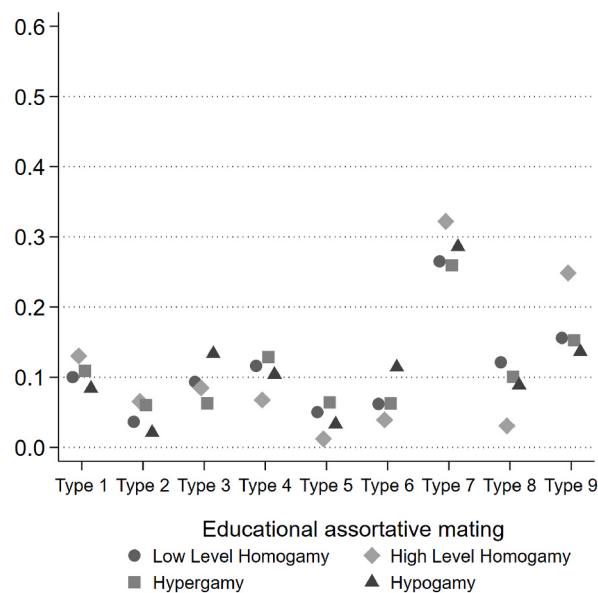


**Fig. A-1.** The predicted probability of eight types of couple's occupational trajectories by couple's educational assortative mating, excluding Type 9 (Dual Missingness).

*Notes:* Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Entry-level female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability.

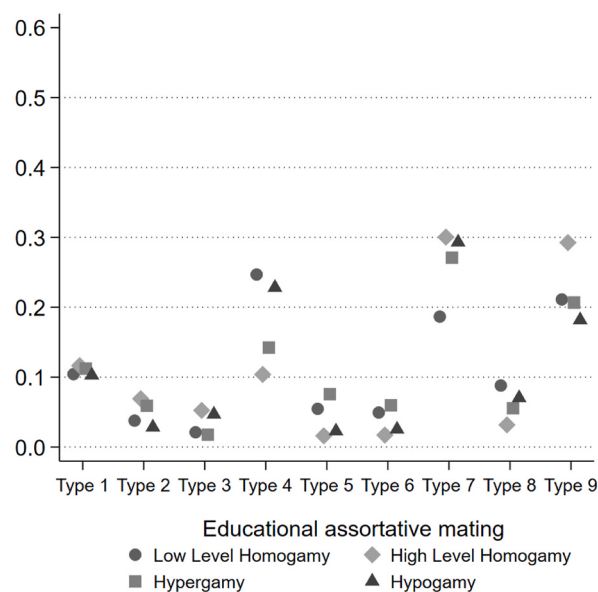


**Fig. A-2.** Sequence distribution plot for the types of occupational trajectories of couples, using the year of first marriage as a starting point.  
**Notes:** Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Entry-level female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness.



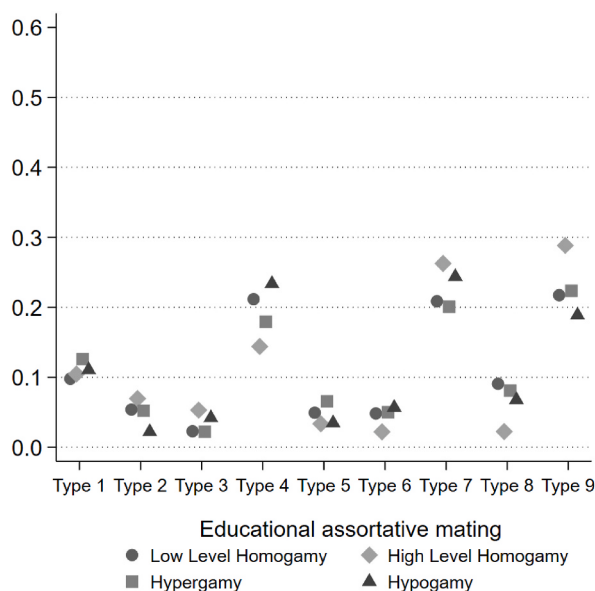
**Fig. A-3.** The predicted probability of nine types of couple's occupational trajectories by couple's educational assortative mating, using the year of first marriage as a starting point.

*Notes:* Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Entry-level female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness.



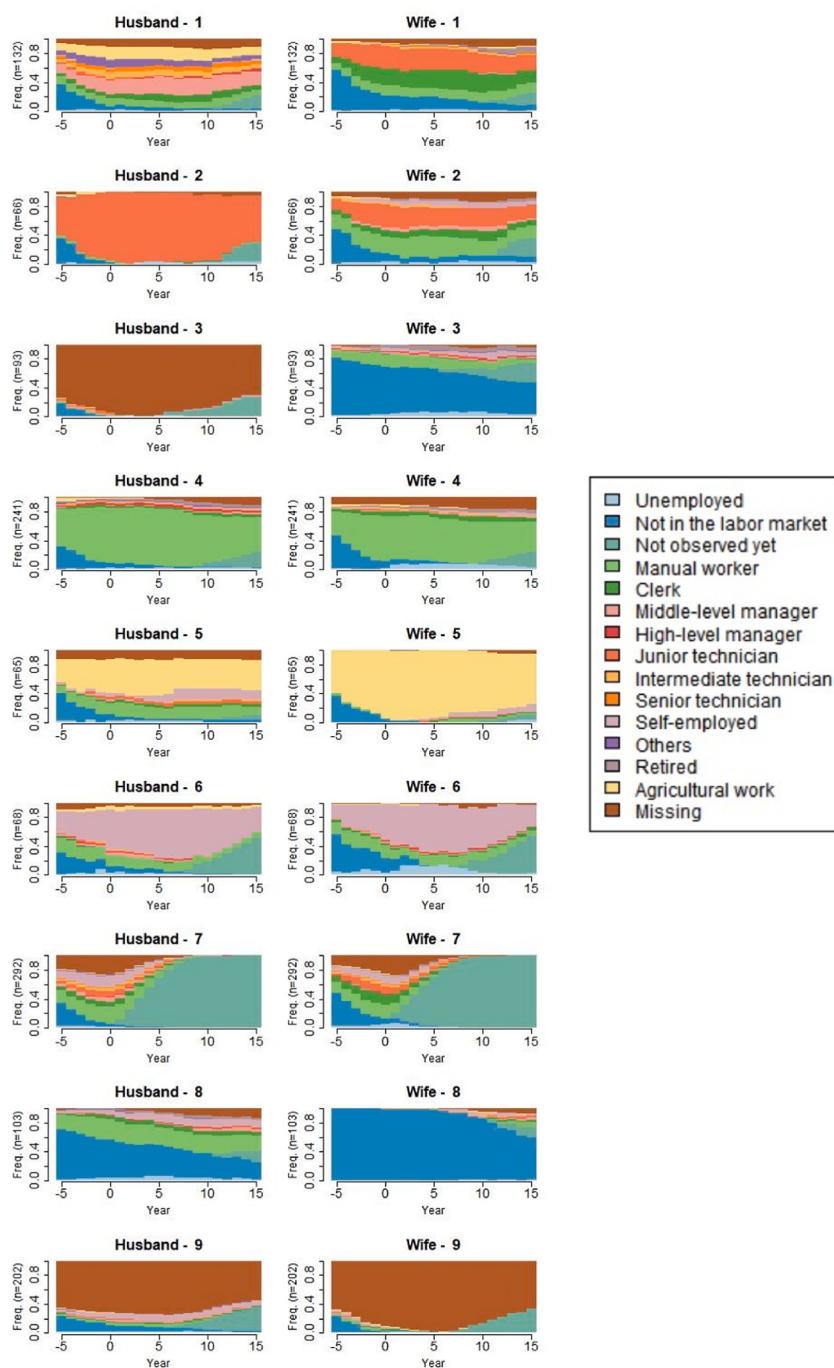
**Fig. A-4.** The predicted probability of nine types of couple's occupational trajectories based on couple's educational assortative mating, utilizing varied cutoffs by birth cohorts.

*Notes:* 1. Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Entry-level female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness. 2. We used a high school degree as the cutoff for birth cohorts prior to 1960 and for those born between 1960 and 1969, while a college degree serves as the cutoff for the 1970–1999 birth cohorts. The measure of educational assortative mating is categorized into four groups: low-level homogamy (neither had the cutoff degree), high-level homogamy (both had the cutoff degree), female hypergamy (the husband had the cutoff degree while the wife did not), and female hypogamy (the wife had the cutoff degree while the husband did not).



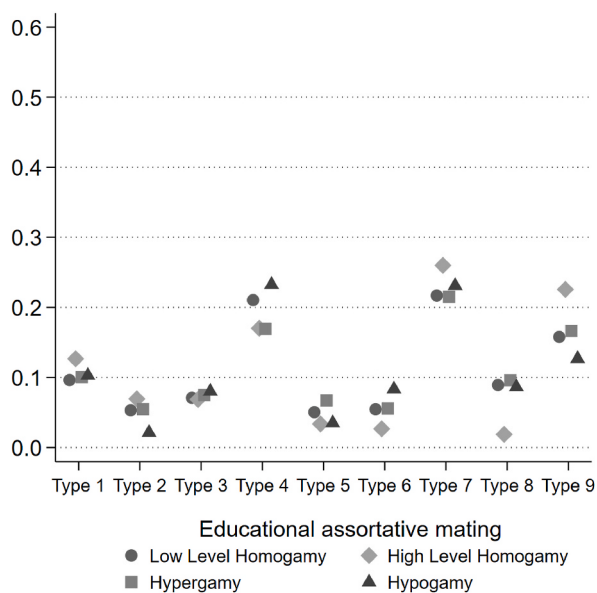
**Fig. A-5.** The predicted probability of nine types of couple's occupational trajectories by couple's educational assortative mating, without using cutoffs for spousal education comparison.

*Notes:* 1. Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Entry-level female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness. 2. The constructed measure of educational assortative mating comprises four categories: low-level homogamy (the husband and the wife had the same level of educational attainment but neither had a high school degree), high-level homogamy (the husband and the wife had the same level of educational attainment and both had a high school degree), female hypergamy (the husband had a higher level of educational attainment than the wife), and female hypogamy (the wife had a higher level of educational attainment than the husband).



**Fig. A-6.** Sequence distribution plot for the types of occupational trajectories of couples, using the method of dynamic hamming distance.

*Notes:* Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Male missingness and female job instability; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness.



**Fig. A-7.** The predicted probability of nine types of couple's occupational trajectories by couple's educational assortative mating, using the method of dynamic hamming distance.

*Notes:* Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Male missingness and female job instability; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness.

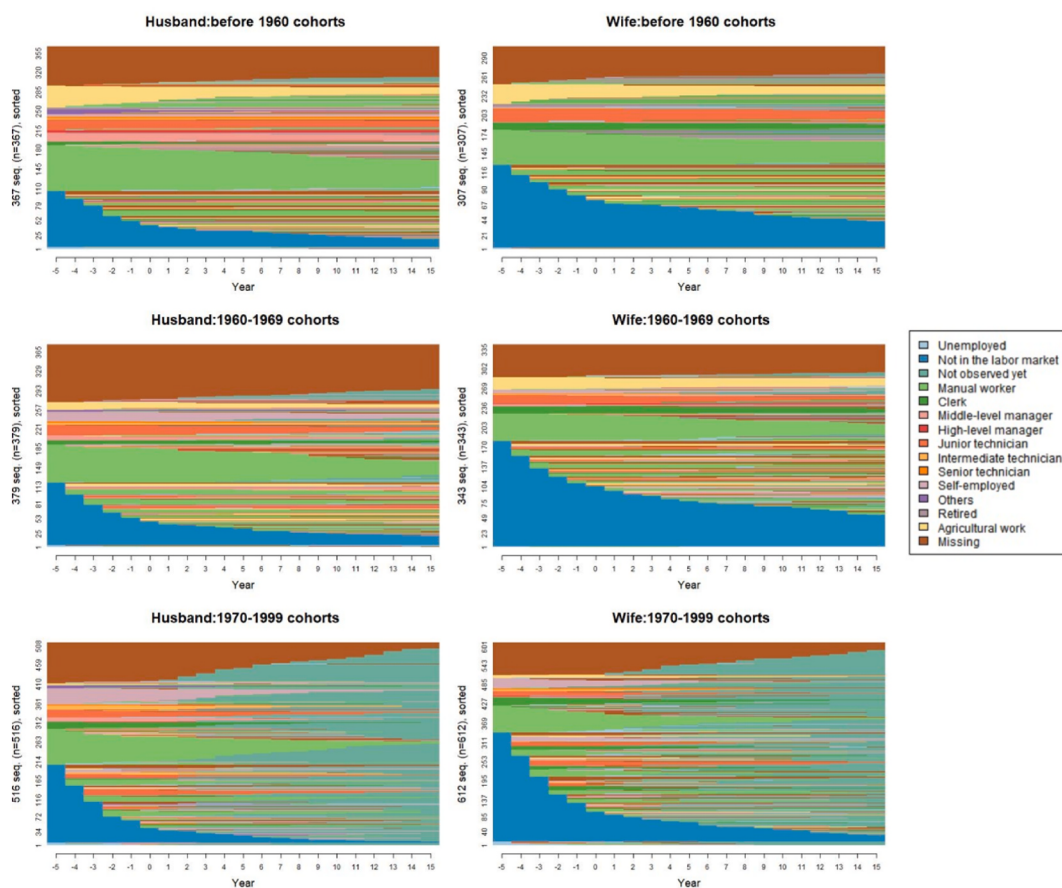
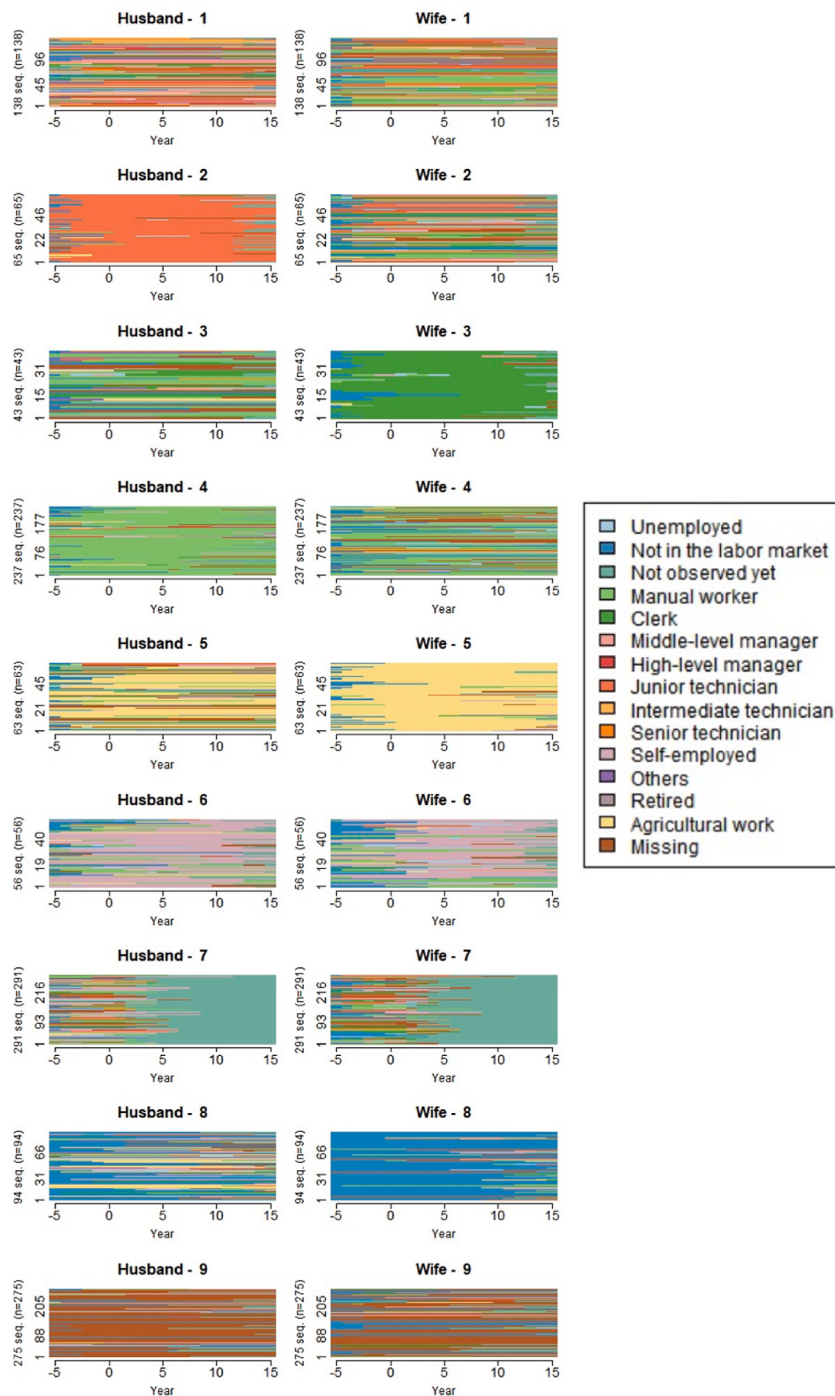
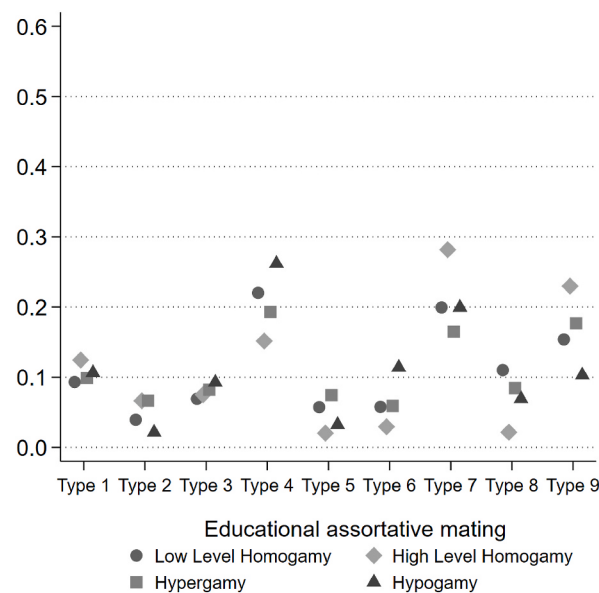


Fig. A-8. Sequence index plot of occupational trajectories by gender and birth cohorts of couples.



**Fig. A-9.** Sequence index plot for the nine types of couples' occupational trajectories.

*Notes:* Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness.



**Fig. A-10.** The predicted probability of nine types of couple's occupational trajectories by couple's educational assortative mating, based on individual-level data.

**Notes:** Type 1: High-level male breadwinner; Type 2: Entry-level male breadwinner; Type 3: Female breadwinner; Type 4: Dual manual workers; Type 5: Dual farmers; Type 6: Dual self-employed; Type 7: Young dual-earners; Type 8: Dual joblessness/instability; Type 9: Dual missingness.

**Table A-1**

Estimates from multinomial logit models for the associations between educational assortative mating and the types of couple's occupational trajectories.

| Ref. = Type 4                                                                      | Type 1              | Type 2              | Type 3              | Type 5              | Type 6              | Type 7              | Type 8              | Type 9              |
|------------------------------------------------------------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
|                                                                                    | RRR                 | RRR                 | RRR                 | RRR                 | RRR                 | RRR                 | RRR                 | RRR                 |
| Educational assortative mating (ref. = High level homogamy)                        |                     |                     |                     |                     |                     |                     |                     |                     |
| Low level homogamy                                                                 | 0.50<br>(0.25–0.97) | 0.36<br>(0.15–0.89) | 0.21<br>(0.07–0.63) | 1.25<br>(0.36–4.40) | 0.83<br>(0.29–2.38) | 0.24<br>(0.12–0.50) | 1.81<br>(0.59–5.53) | 0.31<br>(0.16–0.61) |
| Hypergamy                                                                          | 0.78<br>(0.39–1.56) | 0.73<br>(0.31–1.70) | 0.21<br>(0.06–0.82) | 1.93<br>(0.53–7.00) | 1.08<br>(0.35–3.30) | 0.22<br>(0.10–0.49) | 1.42<br>(0.42–4.78) | 0.42<br>(0.20–0.87) |
| Hypogamy                                                                           | 0.38<br>(0.16–0.86) | 0.17<br>(0.05–0.64) | 0.42<br>(0.14–1.27) | 0.45<br>(0.07–2.92) | 1.26<br>(0.39–4.08) | 0.30<br>(0.13–0.70) | 1.14<br>(0.30–4.42) | 0.24<br>(0.10–0.57) |
| Educational assortative mating upon first marriage (ref. = Neither in state-owned) |                     |                     |                     |                     |                     |                     |                     |                     |
| Both in state-owned                                                                | 0.72<br>(0.37–1.40) | 2.46<br>(0.89–6.79) | 0.36<br>(0.13–1.00) | 0.00<br>//          | 0.11<br>(0.03–0.37) | 0.11<br>(0.05–0.25) | 0.00<br>//          | 0.00<br>(0.00–0.02) |
| Only husband in state-owned                                                        | 0.39<br>(0.20–0.76) | 1.60<br>(0.60–4.28) | 0.19<br>(0.06–0.62) | 0.15<br>(0.06–0.34) | 0.08<br>(0.03–0.25) | 0.14<br>(0.07–0.29) | 0.06<br>(0.03–0.15) | 0.02<br>(0.01–0.04) |
| Only wife in state-owned                                                           | 1.69<br>(0.73–3.87) | 1.84<br>(0.48–7.04) | 2.45<br>(0.85–7.07) | 0.00<br>//          | 0.32<br>(0.08–1.26) | 0.42<br>(0.17–1.06) | 0.00<br>//          | 0.10<br>(0.04–0.27) |

### CRedit authorship contribution statement

**Jian Song:** Writing – review & editing, Writing – original draft. **Bo Hu:** Visualization, Methodology, Formal analysis. **Yang Zhang:** Writing – review & editing, Writing – original draft, Resources, Methodology, Funding acquisition, Conceptualization.

### Data availability

The data underlying this article are available at <http://css.sysu.edu.cn/Data>.

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## Conflict of interest

None.

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