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ABSTRACT

The Impact of Family Co-Residence and Childcare on Children's Cognitive Skill*

We investigate the impact of family co-residence structure and the allocation of major childcare responsibility across generations on a child's cognitive development. Using data from China, we find that children living in multigenerational families generally perform better in their cognitive tests after controlling for other factors. This result holds only for elementary school children, but not for middle school children. However, children who live only with their parents and children who live only with their grandparents (the left-behind children) do not show a significant difference in their cognitive performance. Moreover, we find that the effect of family environment differs between boys and girls. Girls from multigenerational families with grandparents as the main caregiver generally do better than other girls; while for boys, three-generation co-residence has a positive impact regardless of who the main caregiver is. Additionally, there is some evidence that the co-residence and childcare arrangements respond to the cognitive performance of girls more than boys. Our exploration of behavioral factors as potential operating mechanisms in explaining our findings indicates that the influences of family environment are complex and subtle.

JEL Classification: I21, I2

Keywords: family environment, family co-residence, childcare structure, child cognitive skill, China family panel survey

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I. Introduction

The influence of family environment on child cognitive and noncognitive development is very complex (for example, Todd and Wolpin 2003, 2007, Cunha and Heckman 2007, 2008, 2009). In the economics literature, numerous studies have investigated the role of family inputs, such as family income or mother's time spent with a child, in child development (for example, Loken et al. 2012, James-Burdumy 2005, Bernal 2008, and Bernal et al. 2011). However, due to the complexity of the relationship among family inputs, it is difficult to identify the effect of a particular factor without taking into account the overall family environment.[1] Psychology studies report that measures of home environment, such as physical environment, interactions between parents and children, the extent of grandparents' involvement, and interactions with extended family members, play important roles in child development (see, for example, Bengtson 2001, Jaeger 2012). Belsky (1984) and Bradley et al. (1989) show that home environment affects both the quantity and quality of the social, emotional and cognitive support available to a child.

A problem in investigating how family environment affects child cognitive and noncognitive performance is the multiplicity of input measures for family environment that are highly correlated with each other. To help overcome the seemingly conflicting problems of too many input variables and the lack of good measures for many inputs in investigating the impact of family environment on child development, psychologists developed the Home Observation for Measurement of the Environment (HOME) (Caldwell and Bradley 1979) to measure the quality of a child's home environment. Because the HOME survey includes both observational measures and interview-based information, it is very costly to implement.[2]

Two potential proxies that may capture many measured and unmeasured factors of family environment are co-residence and childcare arrangements, which reflect many key factors that influence child development. They emphasize family as "a shared environment" in which

[1] For example, family income may be an inadequate measure of resources for a child because it may not be invested in the child and/or it may be generated at the expense of reduced parenting time. Conversely, an increase in parenting time may result in lower family income and thus less family goods to invest in child development.
[2] The HOME score is available in the National Longitudinal Survey of Youth (NLSY).

members interact and influence each other (Feinberg and Hetherington 2001). These factors may include the formal and informal interactions between parents/grandparents and children as well as between siblings, and the support provided by adults to children. The influence of such family environmental factors can occur at any stage of child development and can be long lasting. Family co-residence and childcare arrangements embody many of these factors and we use them to study the effect of family environment on child cognitive development.

Most children live with their parents in the so-called nuclear family in many countries, making it difficult to investigate the impact of family environment as manifested by family co-residence and childcare arrangements. However, in China, especially in rural areas, family co-residence and childcare arrangements vary widely. Besides nuclear families, there are families with multiple generations living together in one residence, as well as families consisting of grandparents and (grand) children whose parents are working in distant urban areas. In many families, grandparents are the main caregiver for children, even though the parents are around. In China, 48% and 54% of the population over the age of 65 live with their adult children in urban and rural areas, respectively.[3] About 67% of the elderly population are the main caregivers of their grandchildren.[4] There were an estimated 169 million rural migrants employed outside their home areas for a period of over six months, of which over 135 million were individual migrants who left their family members behind in rural areas, according to a 2016 report from the National Bureau of Statistics.[5]

The variation in family co-residence and childcare arrangements in China offers a unique opportunity to investigate how these two aspects of general family environment affect child cognitive development. Using data from China, we estimate an expanded version of the production function of cognitive skills that incorporates the role of family co-residence and childcare arrangements. We explore potential channels through which family co-residence and childcare arrangements affect child cognitive development. We also employ the instru-

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3 http://www.stats.gov.cn/tjsj/pcsj/rkpc/6rp/indexch.htm
4 Aging Research Center in China, China's elderly population survey data analysis [R], 2010.
5 http://www.stats.gov.cn/tjsj/zxfb/201704/t20170428_1489334.html.

mental variables approach to address the potential endogeneity problem associated with our measures of family environment.

This study is among the first to use both co-residence and childcare arrangements as proxies for family environment, in addition to other measures of family environment used in the literature. Most of the existing studies that use data from China examine the impact of family environment in the context of parental migration. For example, Zhang et al. (2014) examine the effect of parental absence on cognitive achievements of the left-behind children and find a significant and negative effect when both parents are absent but no significant impact when only one parent is absent. Zhao et al. (2014), and Meyerhoefer and Chen (2011) report similar findings. However, using school-level data, Chen et al. (2000) find no significant impact of parental migration on children's educational performance. While parental absence is an important aspect of family structure, it fails to capture other dimensions of family environment.

We find that children living in multigenerational families generally perform better in cognitive tests than those living with either parent only or grandparents only. The impact is statistically significant for elementary school children, not for the middle school children. The results show no significant performance difference between children living only with their parents and children living only with their grandparents. We also find that the effect of family environment varies between boys and girls. Similar results emerge when we treat the family co-residence and childcare arrangements as endogenous variables, albeit our instruments may not be particularly strong. It is safe to conclude that our results definitively show a strong association between a child's cognitive development and general family environment.

The rest of the paper is organized as follows. Section II introduces our empirical models. Section III describes the data used. Section IV presents our baseline empirical results. In Section V, we examine the possible mechanisms that may drive the empirical findings. Section VI explores the potential endogeneity issues. Section VII concludes.

II. Family features in rural China and an empirical model

We focus on children living in rural China, where family co-residence and childcare arrangements vary considerably across families. Multigenerational co-residence is a convenient living arrangement for the exchange of services between generations (Chu et al. 2011). Grandchild care also reflects the norm of reciprocity, where taking care of grandchildren can be seen as a bargaining strategy for old age support (Croll 2006). Grandparents' participation in childcare may alleviate parents' burden (Chen et al. 2000), when it enables parents to pursue economic opportunities such as working in urban areas outside their home village (Liu and Reilly 2004) --the household registration system (*hukou*) makes it difficult and costly for migrant parents to bring their children with them to receive education in urban areas.

In the process of child development, parents initially transmit endowments such as innate ability, health, and other characteristics to children through genes (e.g., Wardle et al. 2008), and then create the environment in which their children live. Residence structure can significantly change the shared environment among family members, and its influences go beyond socioeconomic status (Rowe et al. 1999). The "family capital" that provides support and wellbeing to family members (e.g., Swartz 2008) depends on the overall quality of family relations (Jaeger 2012).

We use family co-residence and childcare structure as indicators of family environment. The family environment represented by co-residence and childcare in general capture many measurable inputs and unobservable factors that may have explicit or implicit impacts on children.[6] For example, when three generations of people live in the same household, the behavior of the parents may differ from that in a nuclear family (Chen et al. 2000); and grandparents as main caregivers may also behave differently when parents are not present in the household. Therefore, household co-residence and childcare arrangement can capture important aspects of family environment, such as the overall quality of the relationship among family members that may affect the child's development (Jaeger 2012). Presumably,

[6] As an alternative, Cunha and Heckman (2008) propose an estimation method that combines latent variables and instruments to aggregate inputs into low-dimensional indices. The technique, however, puts strong requirements on data. For example, it requires the information on adult outcomes such as earnings, which will not be available until the child grows up and enters the labor market.

families with good internal relations are more likely to live together and help take care of children.

Following Todd and Wolpin (2003, 2007) and Cunha and Heckman (2007, 2009), we model skill formation of a child with a production function containing three main components: endowment, investment, and family environment. Let A denote the endowment stock of the child (including inherited innate ability and all prior acquired skills and ties), $I(S)$ denote school investments in the child, and $I(G,F)$ denote family investments. The skill production function is written as

$$Y = f(A, I(S), I(G,F)), \quad (1)$$

where Y is a measure of cognitive outcome (e.g., a test score), and $I(G,F)$ includes family goods inputs (G) and family environment (F).[7]

In general, family plays a powerful role in shaping the abilities of a child through genetics, parental investments, and family environments (Heckman 2008). The family goods inputs (G) are associated with the family resources, such as nutrition, school supplies, books, and health care, which are highly associated with parental education and family income among other socioeconomic factors (Todd and Wolpin 2003, 2007 and Heckmen 2008). There is evidence suggesting that the conventional measures of family investment, such as family income, are only crude proxies for family inputs in child development (Rutter 1971, Mayer 1997, Harris et.al 1986). Moreover, Cunha and Heckman (2007) show that socioemotional (noncognitive) skills are an important product of successful family environment and successful intra-family interventions. Therefore, these studies suggest that child development is also a function of the quality of the nurturing environment, in addition to the financial resources available.

Studies in psychology and psychiatry also suggest that the measures of childhood adversity commonly used by social scientists, such as family economic constrain and poverty situation, could be insufficient (Heckman 2008). For example, affluent families may provide

[7] In various Heckman models of skill (capability) formation, such as the one in Cunha and Heckman (2007), the skill production function is formulated as a dynamic model with a multistage technology. Due to the limitation of our data, we simplify it into a static model.

impoverished child-nurturing environments, while economically poor families may provide ideal parenting environments. Therefore, efficient targeting of family investment would take into account the quality of family environments in addition to the financial resource available to families.

Family inputs and family environment could be distinguished by the nature effect and nurture effect (Sacerdotal 2007, Heckman 2008). Many studies attempt to detangle these two effects. For example, Heckman (2008) compares the single -parent families with those of intact families to capture the influence of family environment on child development. And psychologists and sociologists use adoption data to examine the effect of family environment (nurture effect) (Sacerdotal 2007, Bjorklund et al. 2006). Cunha and Heckman (2007, 2008) suggest that good family environment enhances the effectiveness of all investments in child development.

We further define family environment as a function of the quality of the caregiver Q and household structure H,

$$F = g(Q, H(C, R)). \qquad (2)$$

The household structure is related to childcare arrangement C and co-residence R, i.e., $H = \{(C,R): C = (C_p, C_g), R = (R_p, R_m, R_g)\}$, where C_p and C_g represent parents and grandparents as the main caregiver, respectively, and R_p, R_m and R_g denote three types of co-residence arrangements: parents-children, multigeneration, and grandparents-grandchildren, respectively.[8]

Combining equations (1) and (2) and assuming a linear functional form, we obtain the following empirical model of cognitive skill production:

$$Y = \beta_1 R_m + \beta_2 R_g + \varphi_1 (C_g \cdot R_m) + Q\xi + G\phi + S\alpha + A\eta + u, \qquad (3)$$

Where $C_g \cdot R_m$ is the interaction term between grandparent-care and multigenerational family indicating that grandparents are the main caregiver in a multigenerational family, vector Q in-

[8] We do not consider other cases where a child is living with other relatives or family friends or being taken care of using market services. As shown in the section on data below, those types of care are very rare in rural China.

cludes human capital indicators of the main caregiver, vector G represents family goods inputs, S represents school inputs, A represents endowments, and u is the error term.

III. Data and sample description

Our data come from the China Family Panel Studies of 2010 (hereinafter referred to as "CFPS-2010") conducted by the Institute of Social Science Survey (ISSS) at Peking University. The survey is modeled on the Panel Study of Income Dynamics (PSID) of the United States.[9] The CFPS data contains detailed information on family structure and individuals and has been used in several studies, for example, Gustafsson et al. (2014) and Li and Wu (2014).[10] The CFPS-2010 contains 14,789 families (including 8,890 children) across 25 provinces in China.

The cognitive tests (Chinese language and math) were administered to 2250 children between 10 to 15 years of age. We focus on non-urban areas of China (including villages, and suburb and town areas).[11] Our final sample includes 1702 children, of which 66% are attending elementary school and 34% are attending middle school.

We distinguish between two types of main caregivers, parents (C_p) and grandparents (C_g), based on the answer to the question "who is the main caregiver for a specific child in the most recent month when the parents were not on vacation?" The co-residence structure is based on the answer to the question "Whether you co-reside within this family for a special adult who share the same family ID with this family? " We identify three types of living arrangement: i) parent-children family (R_p), where a child lives only with their parents; ii) multigenerational family (R_m), where, in addition to parents, at least one grandparent lives in the

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[9] The detailed information is available on the official website: http://www.isss.edu.cn/cfps/sj/.

[10] In addition to CFPS-2010, data from the 2012-wave and 2014-wave are also available. It would be desirable to use all three waves of data to estimate a multi-period model. However, the test scores on cognitive skills, which are our outcome variables, are not comparable between the 2010 and 2012 waves (see Li and Wu 2014). In particular, the 2012-wave CFPS replaced 34 questions in Chinese language tests and 24 questions in mathematical tests contained in the 2010 wave with 10 questions on short-term memory and 15 questions on logic analysis. Moreover, for the 2014-wave, since by 2014 most of the children in the age group we study in 2010 have grown out of the sample age.

[11] We also exclude children who are taken care of by relatives outside the household (34 observations), and children who live with a single parent because of divorce or the death of one parent (68 observations). No child in the 10-15 age group is cared for by paid services. As well, no child in this sample migrated to city. That is all of them lived in their home/birth location. We also exclude 24 children with 0 score on Chinese language and math tests.

household on a long-term basis; iii) grandparent-grandchildren family (R_g), where a child lives with grandparent(s) because their parents are migrant workers in cities.

Combining childcare choice and co-residence arrangement, we have four family types: 1) parent-only family (R_p/C_p), a child lives only with parents and is taken care of by parents; 2) multigeneration-parent (R_m/C_p), a child living in a three-generation family and being taken care of by parents; 3) multigeneration-grandparent (R_m/C_g), a child living in a three-generation family and being taken care of by grandparents; and 4) grandparent-only family (R_g/C_g), a child lives only with grandparents and is taken care of by grandparents.

Table 1 shows the sample distribution of family structure. About 16% of the children are primarily taken care of by their grandparents and 84% by their parents. In terms of co- residence types, 55.6% of the children live in parent-child families, 37.6% in multigenerational families, and the remaining 6.8% in grandparent-only families. Among children living in multigenerational families, about 25% are taken care of by grandparents and 75% by parents.

In CFPS-2010, elementary and middle school children are asked to take tests on Chinese language and math. We use the reported test scores on Chinese language and math as the measures of cognitive skill. These tests are similar to the Peabody Individual Achievement Test (PIAT) and the Armed Forces Qualifying Test (AFQT), which have been widely used as indicators of child cognitive development (see, for example, Cunha and Heckman 2007, Todd and Wolpin 2007).

The Chinese language test contains 34 questions and the math test contains 24 questions. In both tests, questions are arranged in ascending order of difficulty. Elementary school students are required to start from the first question and middle school students from the ninth question of the tests. The test score is determined by the rank of the last question that a student answered correctly before failing the next three questions in a row. The minimum score is 0 for elementary school students and 8 for middle school students.[12] Since measured abilities, though inherited to some extent, are susceptible to environmental influences (Cunha and

[12] For example, if a middle-school student fails to answer questions 9, 10, and 11, the test ends and his/her score is recorded as 8 (9 minus 1). Otherwise, the student continues to answer the remaining questions until failing the next three questions in a row. The details can be found at the CFPS website, http://www.isss.pku.edu.cn/cfps/wd/.

Heckman 2007, Manuelli and Seshadr 2014), the test scores we use reflect inherited and acquired abilities and learned skills. We use the term "cognitive skill" and "cognitive ability" interchangeably.

We use the average of both scores rescaled to a maximum of 100 to measure a child's cognitive outcome. Our procedure is similar to those employed by Cunha and Heckman (2007) and Todd and Wolpin (2007) in their treatments of cognitive tests in PIAT and AFQT.[13] Table 2a presents summary statistics of the average test scores on a 100-point scale. The combined test score is generally consistent with the student's performance in school. Students who perform better in the cognitive tests also tend to do well in school. For example, for elementary students, those who ranked in the top 10% in his/her class in the most recent exam have an average cognitive test score of 48.0; but for those ranked between 50-60%, the average cognitive test score is 40.7. The same pattern can be found for middle school students.

The descriptive statistics of other variables are reported in Table 2b. In terms of caregiver's human capital, parenting parents are better educated (41% of them having middle school education or above), compared to parenting grandparents (8%). Most of the caregivers (76% of the parenting parents and 69% of the parenting grandparents) consider themselves to be at least as healthy as their peers in answering the survey question: "How is your health condition compared with your peers?" Other family variables include family income and the number of siblings, which affect the child cognitive outcome both directly as family resources and indirectly through influencing co-residence and childcare arrangements. The family income per person varies considerably across families, ranging from 1,380 to 63,300 Yuan with a sample average of 5,520 Yuan. The number of siblings varies from 0 to 7 with a sample average of 1.38.[14] Additionally, we use parental education to proxy the inherited ability and other endowments, and it is measured based on the highest education level one of

[13] The cognitive score=(100*Chinese language/34+100*math/24)/2. The correlation between the scores for the Chinese language test and math test is 0.7. Moreover, among children with a math score at the 80th percentile or above, only 4% have a Chinese language test score that is at the 20th percentile or lower. The corresponding number for math score is 3%.
[14] According to the 2010 China Statistical Yearbook, the national average income was 19,109 and 5,919 Yuan for urban and rural China, respectively.

the parents achievement. In the sample, 60% of parents have education at middle school level or above.[15]

An important data limitation is that the measures for school inputs are not available. A common solution is to use school fixed effects to capture the impact of school inputs and quality. Because school information for the child is not available, we cannot define a school fixed effect. One option is to use village fixed–effects, assuming that children from the same village attend the same school. However, since the data contain 431 villages and each village on average has around 4 observations in our sample, a village-fixed-effects specification would result in a substantial loss of degrees of freedom.

To compensate for the difficulty of identifying or holding constant school-level inputs, we use location dummies to capture broad similarities of schools within each of the three regions: towns, suburbs and villages.[16] Schools in towns are generally of better quality and have more resources than those in villages, and thus they can afford to invest more in each student. Moreover, a town has higher aggregate human capital stock in general. There are relatively more educated people and higher degree of accessibility to the outside world via radio, TV, Internet, etc. in towns than in villages Therefore, children in towns are in a better position to benefit from human capital and knowledge spillovers (Heckman et al. 2003).

In addition to the regional variables described above we use two additional proxy variables to control for variations in school inputs and quality within region but between different local communities. The two variables are: i) distance between home and the nearest medical center, and ii) distance between home and the nearest high school.[17] The choice of the former is motivated by Glaeser and Mare (2001) and by Hanushek et al. (2013) who argue that the distribution of medical centers can serve as a proxy for the local public infrastructure including schools. Dis-

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[15] There may be high correlation between caregiver's education and parental education when one of the parents assumes the role of main caregiver. The sample statistics does not show a concern because the correlation is less than 60%.

[16] According to the CFPS2010, "Town" refers to the area where the government of a designated county or township is located; "Rural village" refers to an area populated by people who mainly participate in agricultural work; and "Suburb" refers to the periphery of a city with high population density that connects to rural villages.

[17] In general, a medical center is in a relatively more developed place. Additionally, rural village may have elementary schools, and some may have middle schools, but high schools are generally located in more populated and relatively developed locations. Under China's Compulsory Education Law, school-age children are required to attend a school that is closest to home.

tance to high school is a good proxy for the quality and inputs of elementary and middle schools because in rural China high schools are typically located in relatively more resource-rich areas.

IV. The effect of family structure on a child's cognitive performance

We begin by estimating the baseline models specified in equation (3) using the full sample. Following Heckman et al. (2003) and Hanushek and Woessmann (2012), we convert the combined Chinese language and math score into a Z-score and use it as the dependent variable in our regression analyses.

In estimating the model, one particular concern is whether the family environment represented by co-residence *R* and childcare arrangement *C* responds to the child's cognitive performance. If this is the case, those variables will be endogenous. However, because co-residence and childcare arrangement is generally a long-term family decision and cannot be changed instantaneously, we believe that the exogeneity assumption is reasonable. The decisions, such as whether multigenerational people live together under one roof and whether having grandparents take care of children, are usually made long in advance, most likely even before a child is born or starts school. Therefore, it is unlikely that the co-residence and childcare arrangement is simultaneously made in response to a child's cognitive outcome. Additionally, living and childcare arrangement also depends on family members' geographic location, employment status, and health conditions, among many other factors, and those factors are generally very difficult to change in respond to a child's cognitive performance. To examine the stability of household structure, we utilize different waves of the CFPS survey. Based on the data, from 2010 to 2012, 92% co-residence and childcare stay the same; while from 2010 to 2014, 90% co-residence structure and 91% childcare type show no change.

Even if some families may change household structure in response to a child's cognitive development, the responses are unlikely to be in one direction, and thus they may offset each other statistically in terms of bias. For example, for some families, if a child is doing well in school, the parents may choose to move to urban areas to work and leave him/her to be cared for by grandparents, or very differently, may choose to stay home and spend more time to take care of the child. Based on our sample, we found that the correlation coefficient between the change of childcare type from 2010 to 2012 and cognitive test score in 2010 is 0.04 (and -0.39 from 2010 to 2012). The correlation between the change of living arrangement and cognitive skill from 2010 to 2012 is 0.02, and from 2010 to 2014, is -0.32.

Therefore, we estimate the model first using the OLS. Nevertheless, we will investigate the potential endogeneity issue in next section using Instrumental Variable estimation. The baseline results are reported in Table 3. Columns (1) and (2) present the estimates associated with childcare arrangement alone, while Column (2) includes region fixed effects and the proxy variables mentioned above as controls for school inputs and quality. The estimates show that children having grandparents as the main caregiver perform better in cognitive tests than those with parents as the main caregiver. The positive effect of grandparents is statistically significant when school inputs and quality are controlled for.

Columns (3) and (4) focus on the effect of co-residence structure. The estimates suggest that children living in multigenerational families obtain significantly higher test scores than those living with parents or grandparents only. According to the estimate reported in Column (4), multigenerational co-residence is associated with a 0.12 standard deviation point increase in cognitive test scores. The positive influence on child development from living in a multi-generation family is probably related to the involvement of both parents and grandparents and other family environment factors.[18] Based on Bengtson (2001) and Jaeger (2012), extended family members can affect a child's cognitive outcomes by providing material and affective support to parents and children and thus contribute to children's educational success.

When childcare arrangement and co-residence structure are introduced into a regression separately, each reveals an influence child cognitive development. However, the impact of childcare may be conditional on co-residence structure, and vice versa. Moreover, child-care arrangement and household living structure are likely to be correlated with each other, and to

[18] This result is consistent with a recent survey, which shows that in urban China more than 80% grandparents take care of children and multigenerational co-residences do better for child development. http://society.people.com.cn/n1/2017/1107/c1008-29632162.html

control for the interaction between childcare and co-residence types, we introduce them simultaneously and report the estimates in columns (5) and (6).[19]

The estimated coefficients on multigenerational-grandparent-care are positive and statistically significant. Moreover, our estimation results suggest that the impact of grandparents as the main caregiver depends on co-residence structure and that the impact is positive only in multigenerational families. The estimates reported in column (6) indicate that the test score of children cared for by grandparents in multigenerational families is about 0.31 standard-deviation higher (i.e., calculated based on (β_1+φ_1).) than that of children cared for by parents in parent-children families (the benchmark group). This difference is equivalent to an improvement from the 50th to 62th percentile in the distribution of the test score.[20] This inference holds whether or not we account for school inputs and quality.[21]

Children from families of the other three co-residence and childcare combinations do not seem to be significantly different from each other in terms of the test scores. Additionally, co-residence structure only shows a significant impact when grandparents act as the main caregiver. When parents are the main caregivers, co-residence structure does not have a significant effect.

Additionally, it is interesting to note that our estimates suggest that children living with grandparents alone slightly outperform children living with their parents alone, although the difference is not statistically significant. This evidence contradicts some studies (as reviewed in Section I) that find that parental migration has an adverse effect on school performance of the children left behind. This result may be associated with the mixed effects of limited involvement of parents in caregiving when they need to work and grandparents' involvement when parents are not around (Edwards and Uretab 2003). Parents who are present at home

[19] In our setup, the benchmark group is the parent-children family with parents as the main caregiver. The coefficient (β_1) measures the effect of living in a multigenerational family and being taken care of by the parents (R_m/C_p), and the coefficient (β_2) captures the effect of grandparent-grandchildren family (R_g/C_g). The coefficient (φ_1) measures the difference between grandparent-care and parent-care in a multigenerational family.

[20] Hereafter we interpret our estimates in terms of changes of percentile for the average student who has a z-score of zero and thus is located at the 50th percentile.

[21] We believe that our current model specification with the interaction terms between co-residence type and childcare type can better capture the differences in family environment. The results based on a more conventional specification that includes directly all four combinations of co-residence and childcare arrangements are reported in Table A1 of the Appendix.

may have limited time and energy to take care of their children if they have full–time jobs. In our sample, among parent-only families, 91% of the fathers and 81% of the mothers work full time. Among multigenerational families, when parents are the main caregivers, 95% of the fathers and 85% of the mother work full time; when grandparents are the main caregiver, 98% of the fathers and 89% of the mother work full time. Clearly, it shows that multigenerational co-residence helps free up parents to work.

The expected negative impact of absent parents on their children's development may be mitigated by modern communication tools (such as telephone) that allow migrant parents to keep in contact with left-behind children. Lu (2012) suggests that the presence of grandparents could provide supplementary tangible and intangible resources that help lessen the negative impact of parental migration. Additionally, parental migration could also bring about social remittances of non-monetary nature from their migration experience, such as knowledge and perceptions. They could raise children's educational aspirations and thus lead to increases in children's schooling and skill formation (McKenzie and Rapoport 2011, Liu et al. 2018).

The estimates reported in Table 3 also indicate that child cognitive performance varies significantly with age, gender, and school level attended. Holding everything else constant, performance improves with age and school level, and girls perform better than boys. The estimates associated with the variables controlling for school quality all have expected signs and are statistically significant. Specifically, children living in towns generally have higher scores than those living in suburbs or villages, and both proxy measures of school inputs and quality (based on distances to medical center and high school) are significantly and negatively associated with performance as hypothesized.

The characteristics of the main caregiver are shown to have the expected effects on child cognitive development. Specifically, a child's performance is positively associated with the educational attainment of the main caregiver. This is consistent with the findings of Duncan (2003) that more educated caregivers have more parenting knowledge and skill, which in turn can translate into better educational outcomes for children. The caregiver's age is negatively associated with child cognitive outcome, presumably because older caregivers tend to be less energetic and therefore can only offer very limited help to children (Bernal and Keane 2010). Caregiver's health condition does not seem to have a significant impact on a child's cognitive performance after controlling for other variables.

Educational attainment of parents, a proxy for ability endowment (Bernal 2008, Cunha and Heckman 2007, 2009), is positively associated with child cognitive development. Our estimates show children of parents with high school education or above achieve test scores in 64.0th percentile, compared to 50th percentile for children of parents with less than elementary school education.[22]

As discussed above, household income is an important determinant of the parental investment in their children, and the number of children is likely to affect the amount of resources allocated to each child (Bernal and Keane 2011). Our estimates show that child cognitive performance is positively associated with household income and negatively associated with the number of siblings. Consistent with Cunha and Heckman (2009), our estimates indicate that family environment measured by the co-residence and childcare structure also matters after controlling for family income. To the extent that family income and family structure are correlated, omitting household structure in the regression, as is the case in some studies, would lead to omitted-variables bias.

VI. An investigation into the channels of influence of the family structure

There are a number of possible channels through which family environment can influence child cognitive performance. From the psychological and behavioral perspectives, differences in child development reflect differences in the learning environment to which they have been exposed (Darling and Steinberg 1993), and parenting behavior has different effects on children of varying characteristics in different family environments (Maccoby 2000). In this section, we first investigate the heterogeneous effects of the family environment on sub-

[22] The parenting parent may not be the one with the highest education. Mother is typically the main caregiver and usually has relatively lower educational attainment than the father.

groups of children. Then, we examine the potential factors of the family environment that may be related to how family co-residence and childcare structure affect child development.

We first separate elementary school children from middle school children because they are at different stages of development. As discussed in section IV, the efficiency of cognitive skill production, which is a function of family environment, varies across stages of child development. Cunha and Heckman (2007, 2008, 2009) show that the influence of family environment on cognitive abilities is more effective at relatively young ages. Todd and Wolpin (2007) suggest that elementary school students are more responsive than middle school students to family environment.

The estimates reported in columns (1) and (2) of Table 4 show that the effects of co-residence and childcare structure are significant for elementary school children, but not for middle school children. For the middle school children sample, none of the family structure variables attains a statistically significant coefficient estimate. Additionally, for the middle school sample, the Wald test on the sum of the estimates $(\beta_1 + \varphi_1)$ suggests that there is no significant difference in cognitive performance between children from grandparent-care multigenerational families and those from parent-only families.[23] These suggest that the results reported in Table 3 based on the full sample may be mostly driven by the elementary school children. This finding is consistent with Cunha and Heckman (2007) who suggest that the most "sensitive" period for cognitive development is the early stage in the life cycle of the child.[24]

For elementary school children, the estimated coefficient of (φ_1), which measures the differential effect of grandparent-care and parent-care in multigenerational families, is statistically significant. Moreover, the estimated coefficient of (β_1) is positive and statistically

[23] Another possible reason is that in China some middle school students live in school. Since these children do not live in home most of the time, the home environment has less impact on their cognitive performance. About 19% of the middle school children in our sample live in school. When we exclude them from the sample, the results remain virtually unchanged.

[24] Cunha and Heckman (2008) refer the ages at which parental inputs have higher marginal productivity as "sensitive" periods.

significant, indicating that parents as the main caregiver in multigenerational families also have a positive and greater influence than parents in parent-only families.

The results again show that the multigenerational family has a positive and statistically significant effect on child development compared to other co-residence types. One important reason is likely to be higher level of care and attention resulting from more family members living together with the child. Ermisch (2008) and Heckman (2006) suggest that the absence of parents results in the loss of parental attention and supervision over the children; it negatively affects the children's psychological wellbeing, causing academic, behavioral, and socio-emotional problems. Multigenerational co-residence is an effective mechanism to mitigate problems associated with parental absence while away working. Many other studies also find that members of an extended family affect child outcomes such as cognitive development, academic achievement, health, and emotional well-being (see, for example, Modin and Fritzell 2009, Fergusson et al. 2008).

We also conduct regression analysis separately for girls and boys. Triado et al. (2005) suggests that girls and boys have different degree of emotional closeness and tendency of seeking help to their grandparents. These behaviors can impact child cognitive development. Moreover, the gender difference may also be associated with the Chinese culture that skews intra-household allocation in favor of sons (Connelly and Zheng 2003, Brown and Park 2002, and Song et al. 2006).

The estimates reported in columns (3) through (4) of Table 6 are consistent with the preceding arguments. The most noticeable difference between girls and boys is that girls in multigenerational families with grandparent-care perform significantly better than girls in other types of families, while boys in multigenerational families perform significantly better, regardless whom the main caregiver is, than boys in parent-child only or grandparent-grandchild only families. These results indicate that the impact of parent-care and grandparent-care differs significantly for boys and girls: girls are mostly affected by their caregivers and by those they live with, but boys are mostly affected by the co-residence structure.[25] More specifically, among boys, living in multigenerational families is estimated to increase their cognitive test scores by 0.178 standard deviations, which is equivalent to a rise from the 50th to 57th percentile. However, for girls, those from multigenerational- grandparent-care families achieve on average 0.36 standard deviation higher test scores than girls from multigenerational-parent-care families.

One possible explanation for the cross-gender differences related to the impact of family structure is that, in a multigenerational family, even though the grandparent serves as the main caregiver, the parents may intentionally or unintentionally provide more care for sons than for daughters. Similarly, the co-residing grandparents may do the same, i.e., providing more care for grandsons than for granddaughters when the parents are the main caregivers. Such a gender bias may reduce the impact of the main caregiver for boys in multigenerational families. However, co-residing grandparents may reduce sibling competition between girls and boys. For example, girls are generally less affected by changes in family structure under grandparent-care (Chen 2005, Chu et al. 2011). This is especially the case when parents have two children and the younger one is a boy (Bengtson 2001). In our sample, 78% of families have 2 or more children, and among two-children families, 81.1% have at least one boy.

To investigate the mechanisms through which family structure may affect a child's cognitive outcomes, we examine behavioral differences among families of different structures. However, the influences of family environment can be very complex. Given the data limitation, we study three behaviors that may impact a child's cognitive performance: i) how well the parents know their child; 2) whether someone checks the child's homework, and iii) the extent to which the child helps with household chores on weekdays.[26] These variables are related to parents' material, time and emotional support and cognitive stimulation that a child receives in his/her home environment. For example, how well the parents know the child is

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[25] We also run regression models using Chinese language and math test scores separately as the dependent variable. The results are reported in Table A2 in the Appendix. The estimates are generally similar to those based on the average score of the two tests.

[26] The indictor "how well the parents know their child" is based on the answer to the following two questions, "the degree of your parents know where you are when you are not at home" and "the degree of your parents know your friends." The answer is measured on a 1 to 5 scale, with 5 indicating the highest degree. Our indicator takes the average value of the two scores.

related to the parent-child attachment and emotional closeness (Maccoby 2000), which can influence a child's cognitive development either directly (e.g., by giving tutelage or supervision) or indirectly (e.g., by emotional or mental support).

The average values of these variables by family types are reported in Table 5. The better cognitive achievement of elementary school girls in multigenerational-grandparent-care families seems to be consistent with the estimation results reported above. Compared with other types of families, girls living in a multigenerational family with grandparents as their main caregiver are known by their parents the best, most likely to have someone check their homework and spend the least amount of time in helping with the household chores. Boys living in multigenerational families, however, get the most help on homework (approximately 60% of them have someone check homework); while left-behind children get the least help on homework.[27]

The behavioral factors discussed above offer some support for the regression results, but they cannot explain all the results. To further investigate the channels through which family structure influences child development, we introduce these behavior variables into our regression models as additional explanatory variables. The estimates are reported in columns (5) and (6) of Table 4. The estimated coefficients on these behavior variables generally have the expected signs and some are statistically significant. In particular, greater parental attention is associated with better cognitive performance. Help with homework has a positive effect mostly for boys, while more time spent on household chores is associated with lower test scores mostly for girls. The estimation results with behavior variables provide additional information on factors that influence a child's cognitive performance. Yet, the inclusion of those variables does not reduce the effect of family structures. We conjecture that the influence of family environment is likely to operate through more complicated channels than we are able to specify and estimate.

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[27] The US National Public Radio had a comprehensive news report on "left-behind children" in rural China. The report shows that left-behind children depend on grandparents for care, but grandparents are generally not capable of helping them with their homework: http://www.npr.org/sections/goatsandso da/2015/10/20/448545307/a-child-who-feels -left-behind-can-still-get-ahead

VI. Potential endogeneity of childcare and co-residence structure

The estimation results presented above suggest that children of multigenerational families with grandparents as the main caregiver have generally better cognitive outcomes, and there is no significant difference between children living only with parents and only with grandparents. These inferences provide interesting facts about how family environment associated with a child's development. The causality implications of the above results depend on the exogeneity assumption of family structure to a child's cognitive performance. We discussed above that the exogeneity assumption is reasonable due to the long-time nature of family arrangement. It is yet desirable to investigate the sensitivity of the results to this assumption.

To investigate the effect of potential endogeneity, we apply the Instrumental Variables (IVs) method. We identify four IVs that play a role in affecting family co-residence and childcare arrangements but are unlikely to be correlated with the child cognitive development. Ideally, the instrument should come from exogenous shocks to the family that may affect the household structure. Such possible shocks include, for example, changing in one-child policy, family relocation due to family land development. Unfortunately, such data are not available. Then we consider potential instruments using other household information available in the data. The first instrumental variable is the number of younger brothers the father has. The more younger brothers the father has, the less likely that his parents (i.e., grandparents here) live together with his/her family and help care for grandchildren.[28] Our second instrumental variable is parents' average age (the middle generation). Generally, younger parents are more likely to work outside the local area and leave their children in the care of their grandparents. The third instrumental variable is the size of family's farm land per person. The more land the family owns, the more likely that the parents will stay at home to cultivate the land. On the other hand, more land may also mean more family resources. We control the family resources with family income in the model and thus this IV should satisfy the exclusion re-

[28] The number of father's siblings may affect father's human capital development, but this is controlled for in the model via parental education.

strictions. The fourth instrumental variable is the proportion of women in the village who have tentatively migrated to urban areas for work, a proxy for social networks, which helps sharing job-related information among people from the same village (Ao et al. 2016). This IV also serves as a proxy for peer effect on migration (Munshi 2003, Calvo-armengol and Jackson 2004). A mother is more likely to work in the urban area and leave the children to grandparents, if more women in the village do so. Additionally, due to the non-linear interaction terms between the two potential endogenous variables in the model, co-residence and childcare, we also include three interaction terms of instruments as additional IVs, as shown in Table A3, to improve efficiency, based on their correlation.

The summary statistics of these instrumental variables and the estimates for the IVs in the first stage regressions are reported in Table A3 in the Appendix. Our IVs performed well in the first stage regressions, obtaining their expected signs. There are some noticeable differences in the magnitudes of the first-stage estimates across subsamples of boys and girls. For example, family land size seems to have a larger impact for the boys' sample than for the girls' sample, and the proportion of women migrants in the village has a larger impact for the girls' sample than for the boys' sample.

We obtain both 2SLS and Generalized Method of Moments (GMM) estimates, because the GMM estimator is more efficient than the 2SLS estimator when the error terms are not homoscedastic or are correlated. Since we have more instruments than needed to identify the model, we conduct overidentification restriction tests to check the validity of the instruments. The tests fail to reject the null hypothesis that our instruments are uncorrelated with the error term in all the regression models, conditional on that a subset of instruments is valid.

The IV estimation results for the full sample are reported in Table 6a, and they show that family environment has positive effects on cognitive outcomes for elementary school students. The results are generally consistent with the discussion above, but the magnitudes differ, probably because of weak instruments and finite sample bias in the IV estimation. Table 6b presents the instrumental variables estimates based on the elementary school children, as they appear to drive the results reported above. The 2SLS and GMM estimates are very similar in both the magnitude and statistical significance, and they are generally comparable to their OLS counterparts reported above, especially for the sample of boys. Boys from multi-generational co-residence families do better regardless the parents or grandparents are the main caregivers. However, girls from multigenerational families with grandparents as the main caregiver generally do better, albeit the IV estimate is statistically significant only at the 15% level.[29]

Interestingly, as can be seen in Table 6b, the Hausman Test for the null hypothesis that co-residence and childcare arrangement are exogenous is rejected for the sample of girls, but not for the sample of boys, in both 2SLS and GMM estimation.[30] If we ignore the issue of the low power of the Hausman Test, one possible explanation is the tradition of son-bias in China, and as a result, family arrangements are more responsive to girl's school performance than to boy's in rural China. There exists some evidence on that. For example, Brown and Park (2002) find that family investment in children's education depends on the gender and school performance of the child: girls who perform poorly in school are more likely than boys to drop out of elementary school. Meyerhoefer and Chen (2011) find that temporary migration of the parents in rural China is only associated with a delay in education for girls (not for boys). They take this finding as evidence suggesting a re-allocation of girls' time towards home production.

Given the above result on testing endogeneity and the fact that Hausman Test generally has low power, we further investigate the endogeneity issue between household structure and children's cognitive performance by estimating a household choice model. In particular, we estimate models of household's choices of co-residence structure and childcare arrangement, with a child's academic performance as an explanatory variable, in order to test whether a child's performance affects such choices. Given three different co-residence options and two

[29] Given the existence of the nonlinear terms, i.e., the interaction terms between co-residence and childcare, we also estimate the model using the Control Function approach to improve efficiency, and the results are generally consistent with the 2SLS and GMM estimates.

[30] The distributions of co-residence and childcare structures are very similar for boys and girls. For example, in the sample, 54% of the boys and 51% of the girls live in parent-only families, and 17.8% of the boys and 18.8% of the girls live in Grandparent-only families.

childcare options, we estimate a Binary Logit model for family childcare choice and Multinomial Logit (Mlogit) model for family co-residence structure, respectively.

Considering that not all children in the sample (e.g., those outside the age range of 10-15) took the tests administered during the survey and most families have more than one child, we use a measure of school performance that is available for all children, instead of the test scores from the survey, because the family decision on co-residence and childcare is presumably related to all children in the household. In particular, we measure the child's cognitive skills based on his/her relative ranking in math and Chinese language performance in school, and average those two rankings as the child's cognitive measure.[31] As discussed in the data section, the test scores from the survey are generally consistent with a student's academic performance in school. For families with more than one child, we average the children's ranking scores so that each family has one performance indicator. Other explanatory variables include family characteristics and parental characteristics. We introduce the number of boys and girls as separate regressors to test the gender difference in the decisions.

The results are reported in Table 7. It appears that the number of girls and boys both have significant and positive influence on the childcare choice and on the co-residence arrangement. The marginal effects of the number of boys are larger than the number of girls in increasing the chance of grandparent-care and in living with grandparents. Additionally, as expected, the number of father's brothers and the age of parents both have a negative effect on the probability of grandparent-care and on not living in a nuclear family. The amount of farm land increases the probability of grandparent-care but reduce the probability of parent migration (children living with grandparents only). Those results are generally consistent with the first-stage results of the IV estimation reported in table A3 of the Appendix.

However, for both the childcare and co-residence models, the academic performance in school does not appear to have a statistically significant effect. Moreover, to test the differ-

[31] The questions on math and Chinese language ranking in the CFPS2010 is: what was your math / Chinese language rank in your last midterm exam in your class? The minimum and maximum value of the math and Chinese language rank both are 1 and 60, and 1 means on the top. The mean values are 13 and 14 for math and Chinese, respectively. We change the ranking into a negative value so that an increase in the value represents an improvement in the performance. One limitation for the data is that we do not know the relative ranking and we need to make an assumption that the sizes of all classes in rural China are comparable.

ence between boys and girls, we include an interaction term between the gender dummy and school performance. The estimate for the interaction term is statistically significant, and the results show that, girls' better school performance reduces the likelihood of parents' migration and leaving the girl to live with grandparents. This result is consistent with the Hausman test results on endogeneity.

The results on the choice of family structure are generally consistent with our arguments that the family arrangements for childcare and co-residence do not appear to be strongly endogenous to the child's cognitive performance. Additionally, the results based on the IV estimation are generally consistent with the results reported in the above sections.

One caveat is that the correlation between our instruments and family structure may be weak, as indicated in the weak instruments test reported in the tables. Weak instruments may result in large bias and incorrect inference.[32] However, even with the limitation of the availability of instruments, our results are still robust in showing the association between family environment and a child's development.

VII. Conclusions

We investigate how family environment as represented by the co-residence structure and childcare arrangement affects a child's cognitive development. Using individual-level data for rural China, we find that, after controlling for school inputs, child's ability endowment, family goods inputs, caregiver's quality, the family co-residence and childcare structure have significant effects on a child's cognitive performance.

We find that three-generation co-residence generally has a positive and significant impact on a child's cognitive outcome. This result holds only for elementary school students, but not for middle school students. We also find no statistical difference in cognitive outcome between children living only with parents (the nuclear family) and living only with grandparents (the left-behind children).

[32] We conducted weak instruments test based on the Cragg-Donald Wald test under homoscedasticity assumption, as well as the Kleibergen–Paap LM test under heteroskedasticity. Both tests cannot reject the null of weak instruments.

Moreover, the effect of family environment appears to differ between boys and girls. For boys, three-generation co-residence has a positive impact regardless of whether the main caregivers are parents or grandparents. However, girls do better when they live in a multi-generational family and are mainly taken care of by grandparents. Additionally, there is some evidence that the family co-residence and childcare structure seems to be relatively more responsive to girls' cognitive performance than to that of boys.

We also investigate the channels through which family environment affects a child's cognitive development using behavioral variables that potentially represent the working mechanisms of family environment, including the degree of parental knowledge about the child, adult homework supervision, and the amount of time the child spent on housework. These variables show a significant effect on a child's cognitive outcome, but they do not lower the explanatory power of the family co-residence and childcare arrangement. This result indicates that the mechanisms through which the family environment affects child development are complex and complicated.

This study sheds new light on the impacts of two important aspects of family environment on a child's cognitive outcome, namely, co-residence and childcare arrangement. Our findings are robust in showing the association between family environment and the child's cognitive performance. The results also show the complexity of the mechanisms through which the various family environment factors can shape child development.

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Table 1. Household structure distribution

Co-residence type	Childcare type	Family structure	Obs	%
Parent-child (R_p) →	Parent →	Parent-only (R_p /C_p)	946	55.58
Multigeneration (R_m) ↗	Parent →	Multi-parent (R_m/C_p)	481	28.26
↘	Grandparent →	Multi-grandparent (R_m/C_g)	159	9.34
Grandparent-grandchild (R_g) →	Grandparent →	Grandparent-only (R_g/C_g)	116	6.82
			1702	100

Note: 1. Data Sources: CFPS 2010.

2. "R_p / C_p": Parent-only family; "R_m / C_p": Multi-parent family (multigenerational-parent-care family);"R_m/ C_g": Multi-grandparent (multigenerational-grandparent-care family); "R_g / C_g": Grandparent-only family.

Table 2a. Summary statistics of cognitive test score by household structures

						Mean comparison			
	Mean	SD	Min	Max	Obs	R_p /C_p	R_m /C_p	R_m /C_g	R_g /C_g
Full sample	53.8	17.3	3.6	100	1702	54.9	53.1	52.0	50.1
Elementary school	46.1	15.0	3.6	100	1131	46.3	45.9	47.0	43.9
Middle school	69.2	9.8	36.8	100	571	69.6	68.7	69.3	66.2

Note: 1. We convert the scores of Chinese language and math test into 0-100 scale, and then take the average of the two scores as the cognitive measure.

2. "R_p / C_p": Parent-only family; "R_m / C_p": Multi-parent family (multigenerational-parent-care family);"R_m/ C_g": Multi-grandparent (multigenerational-grandparent-care family); "R_g / C_g": Grandparent-only family.

Table 2b. Summary statistics of the full sample

	Mean	SD	Min	Max	Obs
Main caregiver-Parent					
Gender (female=1)	0.88	0.33	0	1	1427
Age	38.88	4.61	28	58	1427
Illiterate/semiliterate	0.32	0.47	0	1	456
Elementary school	0.28	0.45	0	1	398
Middle school or above	0.41	0.62	0	1	573
Health condition -Better than the peers	0.15	0.36	0	1	218
Health condition-Same as the peers	0.61	0.49	0	1	868
Health condition -Worse than the peers	0.24	0.43	0	1	341
Main caregiver-Grandparent					
Gender (female=1)	0.58	0.50	0	1	275
Age	64.69	5.77	52	80	275
Illiterate/semiliterate	0.35	0.48	0	1	96
Elementary school	0.57	0.5	0	1	156
Middle school or above	0.08	0.38	0	1	23
Health condition -Better than the peers	0.22	0.42	0	1	61
Health condition-Same as the peers	0.47	0.50	0	1	128
Health condition -Worse than the peers	0.31	0.46	0	1	86
Child characteristics					
Age (in year)	12.41	1.71	10	15	1702
Gender (girl=1)	0.49	0.5	0	1	1702
Elementary school	0.66	0.47	0	1	1131
Middle school	0.34	0.34	0	1	571
Family characteristics					
Annual family income (1000 RMB/per person)	5.52	5.69	0.125	63.3	1698
Number of child's siblings	1.38	1.07	0	7	1702
Parents education					
Parents-Illiterate/semiliterate	0.14	0.35	0	1	235
Parents-Elementary school	0.26	0.44	0	1	451
Parents-Middle school	0.44	0.50	0	1	750
Parents-High school or above	0.16	0.36	0	1	230
School quality control					
Home-high school distance (10 km)	1.77	1.9	0.0001	12	1702
Home-medical center distance (10 km)	0.19	0.3	0.0001	3	1702
Town	0.16	0.37	0	1	277
Village	0.78	0.42	0	1	1322
Suburb	0.06	0.24	0	1	103

Note: 1. There are 104 observations missing family income, their values are predicted using family expenditure.
2. One Mu is equal to 0.67 square kilometer.
3. Women migration rate (%)=migrating women of the village / number of female labor force of the village.

Table 3. Childcare and co-residence structure and the child's cognitive skill

Independent variables	Childcare types		Co-residence types		Joint effect	
Childcare and co-residence type	(1)	(2)	(3)	(4)	(5)	(6)
Grandparent-care C_g	0.167 (0.120)	0.198* (0.118)				
Multigeneration R_m (β_1)			0.100* (0.054)	0.120** (0.054)	0.073 (0.057)	0.085 (0.057)
Grandparent-only R_g /C_g (β_2)			-0.146 (0.114)	-0.111 (0.114)	0.041 (0.164)	0.081 (0.162)
Grandparent-care · Multigeneration $C_g \cdot R_m$ (φ_1)					0.296* (0.167)	0.301** (0.169)
Main caregiver's characteristics						
Elementary school	0.179*** (0.490)	0.171*** (0.050)	0.203*** (0.050)	0.192*** (0.050)	0.205*** (0.050)	0.195*** (0.050)
Middle school or above	0.246*** (0.054)	0.222*** (0.055)	0.244*** (0.055)	0.217*** (0.055)	0.256*** (0.055)	0.229*** (0.055)
Age	-0.007* (0.004)	-0.008* (0.004)	-0.001 (0.002)	-0.001 (0.002)	-0.007* (0.004)	-0.008* (0.004)
Gender (female=1)	0.013 (0.050)	0.007 (0.050)	0.017 (0.050)	0.013 (0.049)	0.013 (0.049)	0.009 (0.050)
Health condition-Better than the peers	-0.001 (0.056)	-0.011 (0.055)	-0.008 (0.056)	-0.019 (0.055)	-0.011 (0.055)	-0.022 (0.055)
Health condition -Same as the peers	-0.036 (0.042)	-0.039 (0.042)	-0.036 (0.042)	-0.038 (0.042)	-0.038 (0.042)	-0.04 (0.042)
Child characteristics						
Age	0.239*** (0.016)	0.241*** (0.016)	0.235*** (0.015)	0.237*** (0.015)	0.240*** (0.016)	0.242*** (0.016)
Gender (girl=1)	0.103** (0.035)	0.104** (0.034)	0.109** (0.035)	0.111** (0.034)	0.107** (0.035)	0.109** (0.034)
Middle School=1	0.622*** (0.054)	0.618*** (0.054)	0.621*** (0.054)	0.617*** (0.054)	0.622*** (0.054)	0.618*** (0.054)
Family characteristics						
Family income per person (log)	0.073*** (0.019)	0.058** (0.019)	0.074*** (0.019)	0.059** (0.019)	0.071*** (0.019)	0.056** (0.019)
Number of siblings	-0.065*** (0.016)	-0.060*** (0.016)	-0.08*** (0.018)	-0.082*** (0.018)	-0.080*** (0.018)	-0.081*** (0.018)
Parents' education						
Parents -elementary school	0.322*** (0.069)	0.281*** (0.070)	0.307*** (0.070)	0.269*** (0.070)	0.302*** (0.070)	0.263*** (0.070)
	0.399***	0.344***	0.387***	0.334***	0.378***	0.324***

	(1)	(2)	(3)	(4)	(5)	(6)
Parents - middle school	(0.069)	(0.070)	(0.070)	(0.070)	(0.070)	(0.070)
Parents -high school	0.451***	0.388***	0.431***	0.370***	0.427***	0.364***
	(0.082)	(0.082)	(0.082)	(0.083)	(0.082)	(0.083)
School quality control						
Town		0.123		0.142*		0.144*
		(0.077)		(0.077)		(0.077)
Village		0.075		0.095		0.096
		(0.072)		(0.072)		(0.072)
Home-medical center distance (10 km)		-0.176**		-0.177**		-0.182**
		(0.065)		(0.065)		(0.065)
Home-high school distance (10 km)		-0.028**		-0.026**		-0.026**
		(0.010)		(0.010)		(0.010)
Constants	-3.943***	-3.728***	-4.142***	-3.980***	-3.922***	-3.751***
	(0.295)	(0.314)	(0.275)	(0.295)	(0.297)	(0.316)
N	1698	1698	1698	1698	1698	1698
Adj. R-sq.	0.521	0.525	0.521	0.526	0.522	0.527

Note: 1. Robust standard errors are reported in parentheses. ***, **, *, † denotes statistical significance at 1%, 5%, 10% and 15% level, respectively.

Table 4. The joint effects of childcare and co-residence structure on subgroups

Independent variables	Elementary school	Middle school	Elementary school			
			Girls	Boys	Girls	Boys
Childcare and co-residence type	(1)	(2)	(3)	(4)	(5)	(6)
Multigeneration R_m (β_1)	0.108*	-0.005	0.053	0.167**	0.052	0.178**
	(0.058)	(0.059)	(0.083)	(0.083)	(0.083)	(0.084)
Grandparent-only R_g /C_g (β_2)	0.150	-0.130	0.212	0.058	0.148	0.047
	(0.159)	(0.191)	(0.225)	(0.224)	(0.222)	(0.222)
Grandparent-care · Multigeneration $C_g \cdot R_m$ (φ_1)	0.300*	0.091	0.358 †	0.187	0.320 †	0.203
	(0.159)	(0.209)	(0.222)	(0.259)	(0.216)	(0.229)
Child Age (in year)	0.276***	0.104*	0.279***	0.277***	0.272***	0.271***
	(0.018)	(0.028)	(0.025)	(0.026)	(0.026)	(0.027)
Child Gender (girl=1)	0.059	0.180*				
	(0.045)	(0.048)				
Main caregiver's characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Family characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Parents 'education	Yes	Yes	Yes	Yes	Yes	Yes
School quality control	Yes	Yes	Yes	Yes	Yes	Yes
Family involvement						
Degree of parents know about you					0.125*	0.013
					(0.076)	(0.068)
Housework time (Hours/per day)					-0.123**	0.008
					(0.053)	(0.059)
Somebody check your homework					0.069	0.114*
					(0.069)	(0.069)
Constant	-4.309***	-0.873	-3.950***	-4.570***	-3.760***	-4.470***
	(0.398)	(0.555)	(0.576)	(0.559)	(0.585)	(0.566)
N	1129	569	547	582	545	581
Adj. R-sq.	0.276	0.058	0.288	0.261	0.294	0.264

Notes: 1. The joint effect of (β_1+φ_1) is not statistically significant for the mid-school sample.

2. Robust standard errors are reported in parentheses. ***, **, *, † denotes statistical significance at 1%, 5%, 10% and 15% level, respectively.

Table 5. Summary statistics of family involvement

Variables		Elementary school	R_p / C_p	R_m / C_p	R_m / C_g	R_g / C_g
Family member Involvement	How well the parents know their child	Girl	2.96	2.95	3.02	2.86
		Boys	2.82	2.79	2.82	2.52
	Someone checks the child's homework (%)	Girl	0.46	0.54	0.67	0.26
		Boys	0.49	0.60	0.56	0.21
Child behaviors	Child helps with house-work on weekdays (hours/per day)	Girl	0.55	0.61	0.52	0.64
		Boys	0.39	0.40	0.54	0.63

Note: 1. "R_p / C_p": Parent-only family; "R_m / C_p": Multi-parent family (multigenerational-parent-care family);"R_m/ C_g": Multi-grandparent (multigenerational-grandparent-care family); "R_g / C_g": Grandparent-only family.

2. The variable "How well the parents know their child" include two elements: "degree of parent know where you are when not at home" and "degree of parents know your friends" with 1-5 grade, respectively.

3. The variable "Someone checks the child's homework (%)"is asked as "Last semester, whether your family members tutored your homework?" with the answer of "Yes" and "No".

4. The variable "Child helps with housework on weekdays (hours /per day)"is asked as "In the latest month that was not a vacation, on average, how many hours you spend on housework/farm work per day?"

Table 6a. 2SLS and GMM estimates of the effect of household structure

	2SLS results			GMM		
Independent variables	Full sample	Elementary school	Middle school	Full sample	Elementary school	Middle school
Childcare and co-residence type	(1)	(2)	(3)	(4)	(5)	(6)
Multigeneration R_m (β_1)	0.808**	0.680*	-0.270	0.767**	0.640*	0.080
	(0.311)	(0.382)	(1.536)	(0.309)	(0.382)	(1.390)
Grandparent-only R_g /C_g (β_2)	-0.590	-1.350	0.216	-0.672	-0.672	0.560
	(0.656)	(0.976)	(1.989)	(1.989)	(0.909)	(1.826)
Grandparent-care · Multigeneration $C_g \cdot R_m$ (φ_1)	0.920 †	1.520*	0.116	1.370	1.260 †	0.743
	(1.447)	(0.920)	(3.080)	(1.378)	(0.845)	(2.779)
Main caregiver's characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Child characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Family characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Parents' education	Yes	Yes	Yes	Yes	Yes	Yes
School quality control	Yes	Yes	Yes	Yes	Yes	Yes
N	1694	1125	569	1694	1125	546
Weak instruments test (F statistic)	1.447	1.009	0.799	1.479	1.009	0.799
Over-identification test (Ch^2)	1.956	0.545	1.322	1.956	0.545	1.322
(p value)	0.742	0.972	0.864	0.742	0.972	0.864
Endogenous test	19.421	18.868	3.984	19.172	18.154	3.535
(p value)	(0.0003)	(0.0003)	(0.260)	(0.0003)	(0.0004)	(0.309)

Note: 1. Robust standard errors are reported in parentheses. ***, **, *, † denotes statistical significance at 1%, 5%, 10% and 15% level, respectively.

2. The Over-identification test is based on Sargan statistic. And does not reject the null, and thus there is no evidence to against the instruments.

3. The weak instrument test is based on Kleibergen–Paap LM test, and the critical F statistic to reject weak IVs at the 10% level is 8.5, and thus we cannot reject the null hypothesis of weak instruments.

Table 6b. 2SLS and GMM estimates based on the sample of elementary school students

	Elementary school			
	2SLS		GMM	
Independent variables	Girls	Boys	Girls	Boys
Childcare and co-residence type	(1)	(2)	(3)	(4)
Multigeneration R_m (β_1)	0.401	0.800**	0.474	0.802**
	(0.424)	(0.396)	(0.425)	(0.398)
Grandparent-only R_g /C_g (β_2)	-1.146	1.163	-1.225	1.205
	(1.180)	(0.995)	(1.197)	(0.956)
Grandparent-care · Multigeneration	1.713 †	-1.048	1.709 †	-1.119
$C_g \cdot R_m$ (φ_1)	(1.141)	(0.958)	(1.155)	(0.945)
Main caregiver's characteristics	Yes	Yes	Yes	Yes
Child characteristics	Yes	Yes	Yes	Yes
Family characteristics	Yes	Yes	Yes	Yes
Parents' education	Yes	Yes	Yes	Yes
School quality control	Yes	Yes	Yes	Yes
N	546	579	546	579
Weak instruments test (F statistic)	0.767	0.847	0.767	0.847
Over-identification test (Ch^2)	1.642	4.038	1.642	4.038
(p value)	(0.807)	(0.419)	(0.807)	(0.419)
Endogeneity test (Ch^2)	18.868	5.422	19.225	4.787
(p value)	(0.0002***)	(0.132)	(0.0002***)	(0.180)

Note: 1. Robust standard errors are reported in parentheses. ***, **, *, † denotes statistical significance at 1%, 5%, 10% and 15% level, respectively.

2. The Over-identification test is based on Sargan statistic and does not reject the null, and thus there is no evidence to against the instruments.

3. The weak instrument test is based on Kleibergen–Paap LM test, and the critical F statistic to reject weak IVs at the 10% level is 8.5, and thus we cannot reject the null hypothesis of weak instruments.

Table 7. Binary Logit Model and Multinomial Logit Model estimation on a family's choice of childcare and co-residence structure

	Logit model	Mlogit model	
	Childcare types	Co-residence types	
Independent variables	Grandparent care=1	Multigeneration	Grandparent-child
Average rank of math and Chinese	-0.001 (0.007)	-0.006 (0.005)	0.000 (0.012)
Gender*Average rank (girl=1)	0.008 (0.008)	0.003 (0.006)	0.025** (0.011)
Number of boys	1.168*** (0.175)	0.482*** (0.141)	1.921*** (0.269)
Number of girls	0.449** (0.147)	0.417** (0.132)	0.711** (0.222)
Family income per person (log)	0.104 (0.143)	-0.144 (0.099)	0.022 (0.235)
Parents-elementary school	0.891 (0.512)	0.207 (0.315)	0.541 (0.731)
Parents-middle school	0.982** (0.501)	0.352 (0.298)	0.753 (0.715)
Parents-high school above	0.803 (0.569)	0.541 (0.347)	-0.205 (1.012)
Number of father's younger brother	-0.999*** (0.253)	-1.153*** (0.154)	-1.254** (0.400)
Average age of parents	-0.177*** (0.034)	-0.130*** (0.023)	-0.225*** (0.053)
Women migration rate of this village	-0.601 (0.761)	0.158 (0.551)	1.154 (1.189)
Farm land per person	0.185** (0.088)	0.034 (0.028)	-0.288* (0.179)
Constant	2.060 (1.734)	5.161*** (1.221)	2.486 (2.814)
N	727	727	
Pseudo R2	0.201	0.192	

Note: 1. Robust standard errors are reported in parentheses. ***, **, *, † denotes statistical significance at 1%, 5%, 10% and 15% level, respectively.

2. The baseline of the co-residence types in the Multinomial Logit model is parent-child family.

Appendix Table A1. Estimates with multigeneration-grandparent-care type as the baseline

		Elementary school		
Independent variables	Full sample		Girls	Boys
Childcare and co-residence type	(1)	(2)	(3)	(4)
Parent-only R_p/C_p (β_0)	-0.318** (0.124)	-0.405** (0.151)	-0.411* (0.212)	-0.354* (0.162)
Multi-parent R_m/C_p (β_1)	-0.254** (0.128)	-0.297* (0.159)	-0.360* (0.222)	-0.190 (0.229)
Grandparent-only R_g/C_g (β_2)	-0.236** (0.090)	-0.255** (0.111)	-0.199 0.152)	-0.297* (0.162)
Main caregiver's characteristics	Yes	Yes	Yes	Yes
Child characteristics	Yes	Yes	Yes	Yes
Family characteristics	Yes	Yes	Yes	Yes
Parents' education	Yes	Yes	Yes	Yes
School quality control	Yes	Yes	Yes	Yes
N	1698	1129	547	582
Adj. R-sq.	0.528	0.276	0.288	0.261

Note: 1. Robust standard errors are reported in parentheses. ***, **, *, † denotes statistical significance at 1%, 5%, 10% and 15% level, respectively.

Appendix Table A2. Estimates based on Chinese language or math test score separately

	Elementary school			
	Chinese language test		Math test	
Independent variables	Girls	Boys	Girls	Boys
Childcare and co-residence type	(1)	(2)	(3)	(4)
Multigeneration R_m (β_1)	0.110 (0.097)	0.176* (0.100)	-0.020 (0.110)	0.171* (0.099)
Grandparent-only R_g/C_g (β_2)	0.331 (0.255)	0.071 (0.271)	0.045 (0.232)	0.040 (0.241)
Grandparent-care · Multigeneration $C_g \cdot R_m$ (φ_1)	0.320 (0.268)	0.370 (0.272)	0.430† (0.271)	-0.080 (0.268)
Main caregiver's characteristics	Yes	Yes	Yes	Yes
Child characteristics	Yes	Yes	Yes	Yes
Family characteristics	Yes	Yes	Yes	Yes
Parents' education	Yes	Yes	Yes	Yes
School quality control	Yes	Yes	Yes	Yes
N	547	582	547	582
Adj. R-sq.	0.236	0.191	0.205	0.239

Note: 1. Robust standard errors are reported in parentheses. ***, **, *, † denotes statistical significance at 1%, 5%, 10% and 15% level, respectively.

Appendix Table A3. First stage results of IV estimation for elementary school children and summary statistics of the instrumental variables

	Girls			Boys		
Independent variables	R_m	R_g	$C_g \cdot R_m$	R_m	R_g	$C_g \cdot R_m$
Number of younger brothers of fathers (Z_1)	-0.192***	0.019	-0.018	-0.149	0.045**	-0.036*
	(0.042)	(0.019)	(0.020)	(0.041)	(0.020)	(0.017)
Average age of child's parents (Z_2)	-0.014***	-0.015**	-0.019**	-0.02*	-0.013***	-0.02**
	(0.004)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)
Family land per person (Z_3)	0.021*	-0.005	0.018*	0.024	-0.005*	0.005*
	(0.012)	(0.005)	(0.005)	(0.017)	(0.006)	(0.006)
Women migration rate of this village (Z_4)	-0.003	0.101†	-0.110*	0.197	0.077	-0.056
	(0.151)	(0.066)	(0.072)	(0.148)	(0.073)	(0.075)
Interaction terms						
$(Z_1 \cdot Z_3)$	-0.003	0.003	-0.005	-0.000	-0.004	0.004
	(0.011)	(0.005)	(0.005)	(0.014)	(0.005)	(0.004)
$(Z_1 \cdot Z_4)$	0.190 †	-0.025	0.055	0.020	-0.085†	0.081†
	(0.103)	(0.047)	(0.051)	(0.012)	(0.061)	(0.056)
$(Z_3 \cdot Z_4)$	-0.069	0.020	-0.020	-0.048	0.010	-0.015
	(0.052)	(0.024)	(0.025)	(0.055)	(0.020)	(0.018)
Main caregiver's characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Child characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Family characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Parents' education	Yes	Yes	Yes	Yes	Yes	Yes
School quality control	Yes	Yes	Yes	Yes	Yes	Yes
N	546	546	546	579	579	579
Adj. R-sq.	0.322	0.389	0.586	0.359	0.346	0.578

Instrumental variables	Mean	SD	Min	Max	Obs
Number of father's younger brothers	0.52	0.76	0	5	1702
Average age of child's parents	39	4.36	29	60	1698
Farm land per person (Mu)	0.62	0.59	0	3.95	1698
Women migration rate of this village (%)	0.24	0.17	0	0.7	1702

Note: 1. Z_1: Number of younger brothers of fathers, Z_2: Average age of the child's parents, Z_3: Size of family farm-land per person, Z_4: Women migration rate of the village.

2. "C_g": Grandparent-care; "R_m ": Multigenerational family; "R_g ": Grandparent-only family;

3. Robust standard errors are reported in parentheses. ***, **, *, † denotes statistical significance at 1%, 5%, 10% and 15% level, respectively.