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Absent to Care? The Effect of Parental Migration on Children's Nutrition, Health, and Cognition in Rural Gansu Province of China

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ABSTRACT

The nutrition, health, and cognitive ability of left-behind children directly determine the human capital level of China's future workforce. The net impact of parental migration on children's development outcomes remains an empirical question. In this article, we use survey data from rural Gansu Province to study the effects of different combinations of parental migration (namely, any parent migrated, both parents migrated, and only one parent migrated) on children's nutrition, health, and cognition. Results from the instrumental variable approach show that left-behind children perform worse in terms of nutrition, health, and cognitive development compared to their non-left-behind peers. Specifically, migration of any parent increased the probability of stunting by 52 percentage points and wasting by 25.7 percentage points, with even stronger effects when only one parent migrates. Migration of both parents, only one parent, and any parent reduced children's probability of good health by 75.9, 73.2, and 54.7 percentage points, respectively. Moreover, parental migration negatively affected children's vocabulary comprehension and working memory, with the greatest negative impact on children when both parents migrated. Children's age moderated the negative effects of parental migration. The mechanism analysis suggests that reduced caregiving quality is a primary channel through which migration harms child outcomes, while remittances provide only partial compensation by slightly increasing food and educational spending. These findings highlight three implications: enhancing direct support for left-behind children, promoting the effective use of remittances for child development, and reducing the developmental costs of parental absence.

1 | Introduction

China's large-scale migration of the rural labor force to seek employment in urban areas has caused millions of children to be left behind in rural areas by their parents. In 2022, the total number of migrant workers in China reached 295.62 million, of which 171.9 million migrated out of their villages or towns (NBS 2023a). Due to the household registration system and related policies, many migrant workers from rural areas are unable to bring their children with them, creating a potentially vulnerable group of "left-behind" children in rural areas who receive care from other caregivers. In 2022, 10.87 million rural children at the stage of compulsory education were left without parental care or with care from only one parent (NBS 2023b).

Children's nutrition, health, and cognition outcomes are crucial for human development and the formation of human capital. The accumulation of knowledge and skills depends on health, nutrition, and family resources in early childhood, as well as on educational opportunities for older children and adolescents (Black et al. 2022; Walker et al. 2007). Substantial evidence shows that the impact of parental migration on children's nutrition, health, and cognition development works mainly through income effect and absence effect (Chang et al. 2019; Li and Sun 2020; Zhou et al. 2015). However, there is a lack of consensus on the net impact of parental migration on rural children's nutrition, health, and cognitive development in previous research (Zheng et al. 2022), which remains an empirical question.

A close examination of previous studies reveals at least two potential gaps. First, most studies examine the effects of parental migration on children only from one or two dimensions of child development, rather than conducting a comprehensive examination of multiple dimensions, such as nutrition, health, and cognition. Second, the existing evidence is limited by the indicators used to measure children's outcomes. Most studies use specific nutrients such as calories, fat, protein, and carbohydrates (Tian et al. 2018; Zhang et al. 2016), but ignore the fact that children's nutritional status also relates to other indicators such as dietary diversity (Tontisirin et al. 2002). Moreover, the literature assesses children's health using short-term morbidity or body mass index (BMI), which are hardly comprehensive measures of a child's health status (Ding and Xu 2018; Li et al. 2015; Tong et al. 2015). Furthermore, many studies measure children's cognition through children's academic performance in a specific subject, such as Chinese language or mathematics, which fails to capture important components of children's cognitive ability, such as working memory (WM) and verbal comprehension skills (Li and Sun 2020; Zhang et al. 2014).

Given the potential gaps in the existing literature, it is essential to examine the impact of parental migration on children's nutrition, health, and cognition outcomes. We aim to fill the gaps in the existing literature. We conduct a field investigation covering dietary information, physical examinations, and cognitive ability tests of children, which allows us to examine the impact of parental migration on child development across three dimensions: children's nutrition, health, and cognition. Specifically, we use stunting, wasting, and zinc deficiency to measure children's nutritional status, in addition to self-rated health indicators. We also use the Wechsler Intelligence Scale to assess children's cognitive abilities. The investigation took place in Gansu Province, a less-developed region in northwest China. To overcome the potential endogeneity of parental migration decisions due to reverse causality and omitted variable bias, we employ an instrumental variable (IV) approach where parental migration is instrumented with the proportion of households with at least one migrated parent at the village level. Our results indicate that left-behind children experience worse outcomes in nutrition, health, and cognitive development compared to their non-left-behind peers. These findings are robust across multiple model specifications and outcome measures. We also examine the mechanisms through which parental migration affects children's developmental outcomes. Reduced caregiving quality emerges as a key channel, while remittances provide only limited compensation.

The remainder of the article is structured as follows: Section 2 reviews the literature. Section 3 presents the data and descriptive statistics. Section 4 introduces the estimation methods. Section 5 analyses the results and robustness checks. Section 5.4 presents the mechanism analysis. Section 6 concludes with further discussion.

2 | Literature Review

The existing literature has proposed two main possible channels through which parental migration might affect children's nutrition, health, and cognition. One is the income effect. Family income is recognized as an important driver of children's nutritional status, health, and cognition development (Acosta 2011; Hou et al. 2021; Jacobson 2000; Ren et al. 2019; Tian and Yu 2015). Increases in remittances from migrating parents benefit left-behind children by improving investments in their nutrition, health, and cognitive development. In particular, increased off-farm income from parental migration improves children's nutrition by increasing the ability of households to purchase food. Parental remittances enhance children's short-term nutritional status by improving their nutritional and caloric intake, as well as their residential conditions, such as access to piped water (Antén 2010; Azzarri and Zezza 2011; Mu and de Brauw 2015). Moreover, children benefit from the greater income security and material benefits of remittances, which may lead to improved health status and facilitate access to healthcare (Fellmeth et al. 2018). The income effect helps to improve children's learning conditions, school attendance, and academic performance, which further enhances children's cognition development (Anger and Heineck 2010; Edwards and Ureta 2003; Kandel and Kao 2001). In addition, parental migration may also help parents acquire knowledge related to child-rearing from their peers in urban areas, and parents' regular return home contributes to improving children's nutrition, health, and personal development, enriching the traditional income effect (Liu et al. 2020; Macours and Vakis 2010).

The other channel is the absence effect. Parental migration can lead to a shortage of parental care, protection, and supervision. Parenting time is a key input for ensuring child nutrition outcomes as it shapes practices around food consumption, child feeding, and child care (Johnston et al. 2018). Children with migrant parents are mostly cared for by grandparents, and the grandparents focus more on preparing starchy staple foods than on meat, dairy, and eggs (Zhang et al. 2015), which leads to a reduction in children's dietary diversity and thus reduces children's nutritional status. Parents' companionship and care play an irreplaceable role in children's physical and mental development and health (Bonke and Greve 2012). Without adequate parental care, left-behind children are more likely to get sick or develop chronic conditions than those who live with their parents (Li et al. 2015). Moreover, parental migration raises a series of risks, including inappropriate parenting, lack of supervision, and insufficient caregiving, which are detrimental to left-behind children's cognition development (Zhang et al. 2014).

Since the income effect and the absence effect of parental migration work in opposite directions for children, their net impacts on children's nutrition, health, and cognition remain an empirical question. Some studies find a positive impact of parental migration on children's outcomes (Bai et al. 2018; Kandel and

Kao 2001; Nguyen and Nguyen 2015; Tian et al. 2018). Others demonstrate that parental migration has no impact or a negative impact on children's nutrition, health, and cognition development (Gibson et al. 2011; Lei et al. 2018; Li 2013; Zhou and Yang 2018).

3 | Data and Descriptive Statistics

3.1 | Data Sources

This study uses data collected by the authors from the baseline survey of the Gansu Smallholder Farmers Growing Zinc-enriched Potatoes Pilot initiated by the World Food Programme (WFP) in Gansu Province, northwestern China. The survey was conducted in September 2019 in two nationally designated poverty counties at the time: Anding in Dingxi City and Dongxiang in Linxia Hui Autonomous Prefecture. Within each county, two townships with matched socioeconomic status and infrastructure were selected (Dashu and Beiling in Dongxiang; Lujiagou and Gejiacha in Anding). Within each township, we targeted students from the central primary school and the central preschool. The survey covered 868 pupils and 412 preschoolers as well as their families, and these 1280 children became our final sample for analysis. After excluding observations with incomplete data, the final analytical sample consists of 1100 children.

This study mainly uses three modules from the rich information collected in the survey. The first module comes from the questionnaire of primary caregivers. In the survey, trained enumerators asked children's primary caregivers questions about the basic characteristics of the children and their households, as well as children's dietary information. The second module is children's physical check-ups and the hair zinc test. In this module, registered nurses measured the physical data of the children, including their weight and standing height. They also collected their hair samples with stainless steel scissors from the occipitonuchal region of the children's heads, within 3 cm of the hairline. The final module is the cognition test. Following the literature, we focus on assessing two areas of cognitive ability: vocabulary comprehension (VC) and working memory (WM) by using a battery of eight subtests taken from the Mandarin-language version of the latest Wechsler Preschool Primary Scale of Intelligence for Children Fourth Edition (WPPSI-IV) and Wechsler Intelligence Scale for Children Fourth Edition (WISC-IV). WPPSI-IV was for children aged 30 to 83 months, whereas WISC-IV was for children aged 84–191 months. As it turned out, 659 of the sample children had the hair zinc test, and 690 (670) of the sample children were individually administered the core subtests of VC (WM) by trained examiners, respectively.

3.2 | Variables

3.2.1 | Outcome Variable

We focus on three indicators of children's nutritional outcomes: the prevalence of stunting and wasting, and their zinc status. Children's height and weight are used to construct height-for-age z-scores (HAZ), weight-for-height z-scores (WHZ), and BMI-for-age z-scores (BMIZ). According to the World Health Organization (WHO) Child Growth Standards for children aged under 5 and WHO growth reference values for children aged 5–19, stunting is defined as children with $[\text{HAZ}] < -2$; wasting is defined as children aged under 5 with $[\text{WHZ}] < -2$, or children from 5 to 19 with $[\text{BMIZ}] < -2$. Following the Chinese Society for Trace Element Science guidelines, zinc deficiency is defined as children's zinc levels in hair below 90 μg/g.

For children's health status, we use the rating by their primary caregivers. Caregivers were asked to select from a list of options ranging from "very unhealthy" to "very healthy". Based on their responses, we create a dummy variable that takes the value of one if children rated by their primary caregiver as better than fair, and zero otherwise (Krzyzanowski and Wysocki 1986).

Children's cognitive ability is assessed using the Vocabulary Comprehension Index (VCI) and the Working Memory Index (WMI). Specifically, the VCI measures the child's comprehension and reasoning using his/her verbal skills, the child's knowledge already gained, and how well he/she responds to verbal cues. The WMI measures the child's ability to memorize new information, hold it in short-term memory, concentrate, manipulate that information to produce some result or reasoning processes, and resist interference from previously memorized items. The index scores are converted from the raw scores obtained from the WPPSI-IV and the WISC-IV tests.

3.2.2 | Key Explanatory Variables

The key explanatory variable in this article is the status of parental migration. Following the National Bureau of Statistics, we define a parent as a migrant if they have worked outside their township of Hukou registration for at least 6 months in the last year. Since different combinations of parental migration may have different effects on children, we construct three dummy variables to indicate parental migration: any parent migrated, both parents migrated, and only one parent migrated.

3.2.3 | Control Variables

We include a county dummy to control for factors at the county level and above that may influence children's nutrition, health, and cognition. We also control for the village's per capita income in 2018 and the distance to the township government, as these variables capture local infrastructure, economic conditions, and access to public services such as healthcare and education. At the child level, we control for age, gender, birth weight, and whether the child is a picky eater. Since nearly all children in Dongxiang County are Dongxiang (99.68%) and those in Anding District are Han (99.58%), ethnicity is highly correlated with county and is thus not separately controlled. At the parental level, we control for both parents' education and health status, as well as the total duration of parental absence since the child's birth. We also include characteristics of the primary caregiver, such as average daily hours spent on housework, playtime with the child, care for the child's diet and daily needs, and farm work. Since 97.6% of primary caregivers are parents or grandparents and only a small fraction are other relatives, caregiver identity is not separately controlled in the analysis. At the household level, we control for annual income (Currie 2009; Currie and Stabile 2003; Ren et al. 2019; Tian and Yu 2015); family size, number of siblings, and whether the household was a single-parent household to capture family demographic background (Anger and Schnitzlein 2017; Wu 2016). Household living conditions are measured by access to tap water and a separate kitchen (Jalan and Ravallion 2003; Zhang 2012).

3.3 | Descriptive Statistics

Table 1 presents descriptive statistics for key variables based on a sample of 1100 children. In terms of nutrition outcomes, 10% of children were stunted, 6.9% were wasted, and 20.6% were zinc-deficient. Regarding health outcome, 93.2% were reported to be in good health by their parents. Cognitive measures include the VCI and WMI, with means of 77.35 and 83.69, respectively. Key explanatory variables related to parental migration show that 28.7% of children have at least one parent who has migrated, with 23.3% have only one parent migrated, and only 5.5% have both parents migrated. Control variables related to community characteristics reveal that 57.2% of the sample resides in Dongxiang County, with an average village annual per capita income of 4.04 thousand yuan. The mean village distance to the nearest township is 2.89 km. Child-specific characteristics show an average age of 7.4 years, with nearly equal gender distribution (49.5% boys). Birth weight averages 2.96 kg, and 19.5% of children are identified as picky eaters. Parental characteristics include a mean of 3.22 years of education for mothers and 4.61 years for fathers. The health status of both parents is measured on a scale of 1–5, with the mean of 3.59 for mothers and 3.6 for fathers. On average, mothers have been away for 8.38 months and fathers for 26.6 months since the child's birth. Caregiver characteristics show that, on average, caregivers spend 4.57 h per day on housework, 3.77 h on farm work, 0.68 h on playtime, and 2.17 h on daily work. Household characteristics indicate an average household income of 38.84 thousand yuan, with 6.1 family members and 1.83 siblings per household. Single-parent households are rare, comprising only 6.5% of the sample. The access rates for tap water and a separate kitchen are 87.4% and 79.5%, respectively.

4 | Estimation Methods

4.1 | Baseline Estimation

To estimate the relationship between parental migration and children's nutritional status, health and cognition, we conducted the model as follows:

$$Y_i = \beta_0 + \beta_1 Migrant_i + \beta_2 Age_i + \beta_3 Migrant_i * Age_i + \gamma X_i + \varepsilon_i \tag{1}$$

where Y_i denotes child i's nutritional status, including stunting, wasting and zinc deficiency, the child's health, and the child's cognition variables VCI and WMI. For the binary selection variables, we use the Probit model to estimate and report the coefficients. $Migrant_i$ is the combinations of parents' migration for child i, including any parent migrated, both parents migrated, and only one parent migrated. X_i is a vector of control variables. To test the potential influence of changes in the child's age on the effect of parental migration on the child's cognition, we also include an interaction term between parental migration and the child's age $Migrant_i * Age_i$ in the child cognition model. ε_i is the error term, and all the standard errors were clustered at the village level.

4.2 | IV Estimation

The effectiveness of model (1) might be decreased by potential endogeneity, which has two main sources. One source is the reverse causality between parental migration and child outcomes (Chen et al. 2017; Nguyen and Nguyen 2015; Ren et al. 2019). Specifically, parents' decisions to migrate may affect the nutritional, health, and cognitive status of rural children. However, parents' decisions to out-migrate may also be influenced by their children's nutritional, health, and cognitive status (Antén 2010; Ding and Xu 2018). Another source of potential endogeneity is the issue of omitted variables. Although we have controlled for left-behind experiences in early childhood, regression estimates may still be affected by omitted variable bias. For example, we are unable to observe factors that influence children's outcomes, such as children's childhood environment and the extent to which parents care for their children (Zheng et al. 2022).

To overcome the potential endogeneity of parental migration, we adopt an IVs approach. Following Ding and Xu (2018) and Li et al. (2015), we use the proportion of households (excluding the household under discussion) with at least one migrant parent at the village level as an instrument for parental migration. The validity of this IV lies in the fact that farmers' migration to cities is highly correlated with their social networks. Fellow villagers' migration would affect farmers' access to information about migration and change their perception about migration, which in turn affects their propensity to migrate outside the village (Chen et al. 2010; Du et al. 2005; Lee 1995). At the same time, the proportion of migration at the village level does not have a direct impact on the nutrition, health, and cognitive status of children from any specific household. To address the potential concerns regarding the validity of this village-level IV, particularly the possibility of heterogeneity across villages that may threaten its exogeneity, we take the following steps. First, we control for key village-level characteristics, including average per capita income and distance to the township government, which serve as proxies for local economic development and accessibility to public services. Second, after controlling for the county dummy, our sampling strategy was carefully designed to minimize within-county heterogeneity across villages. In each of the two selected counties in Gansu Province, we purposively sampled two townships that are closely matched in terms of socioeconomic status and public service provision. Within each township, we surveyed students attending the central primary school and preschool, which serve all villages in the area. This design ensures that after controlling for the county dummy, children from different villages share a similar educational environment, reducing concerns that school quality or access to public services may vary systematically across villages. To further address any remaining concerns about intra-village correlation, we use village-level clustered standard errors, which provide robust inference and improve the reliability of standard error estimates (Zhao and Chen 2022).

TABLE 1 | Descriptive statistics of key variables.

Variable	Obs.	Mean	Std. dev.	Min	Max
Outcome variables					
Children's nutrition					
Stunting (1 = yes, 0 = no)	1100	0.100	0.300	0	1
Wasting (1 = yes, 0 = no)	1100	0.069	0.254	0	1
Zinc-deficient (1 = yes, 0 = no)	660	0.206	0.405	0	1
Children's health					
Health (1 = yes, 0 = no)	1100	0.932	0.252	0	1
Children's cognition					
VCI (Vocabulary Comprehension Index)	690	77.348	15.125	45	149
WMI (Working Memory Index)	670	83.694	14.136	45	124
Key explanatory variables					
Any parent migrated (1 = yes, 0 = no)	1100	0.287	0.453	0	1
Both parents migrated (1 = yes, 0 = no)	1100	0.055	0.227	0	1
One parent migrated (1 = yes, 0 = no)	1100	0.233	0.423	0	1
Control variables					
Community characteristics					
County (1 = Dongxiang, 0 = Anding)	1100	0.572	0.495	0	1
Village annual per capita income (1000 yuan)	1100	4.037	0.391	3.150	5.200
Village distance to township (km)	1100	2.893	3.670	0.100	30
Child characteristics					
Age (year)	1100	7.406	2.743	2	16
Gender (1 = boys, 0 = girls)	1100	0.495	0.500	0	1
Birth weight (kg)	1100	2.964	0.520	0.900	4.550
Picky eater (1 = yes, 0 = no)	1100	0.195	0.397	0	1
Parent characteristics					
Mother's education (years)	1100	3.219	4.140	0	19
Father's education (years)	1100	4.605	4.258	0	19
Mother's health status	1100	3.585	0.953	1	5
Father's health status	1100	3.598	0.908	1	5
Mother's absence duration (months)	1100	8.384	22.326	0	120
Father's absence duration (months)	1100	26.599	30.134	0	168
Primary caregiver characteristics					
Caregiver's housework (hours per day)	1100	4.567	2.383	0	16
Caregiver's farm work (hours per day)	1100	3.770	3.239	0	12
Caregiver's playtime (hours per day)	1100	0.681	0.964	0	10
Caregiver's daily work (hours per day)	1100	2.167	1.364	0	8
Household characteristics					
Household income (1000 yuan)	1100	38.841	48.765	0.240	486.696

(Continues)

TABLE 1 | (Continued)

Variable	Obs.	Mean	Std. dev.	Min	Max
Number of family members	1100	6.103	1.539	2	14
Number of siblings	1100	1.831	1.255	0	9
Single parent family (1 = yes, 0 = no)	1100	0.065	0.247	0	1
Tap water (1 = yes, 0 = no)	1100	0.874	0.332	0	1
Separate kitchen (1 = yes, 0 = no)	1100	0.795	0.404	0	1

Specifically, for binary indicators of children's nutritional status (stunting, wasting, and zinc-deficient) and health, we constructed an IV-Probit model as follows:

$$Migrant_i = \alpha Migrant\_rate_i + \delta X_i + \mu_i \quad (2)$$

$$Y_i^* = \theta Migrant_i + \rho X_i + \vartheta_i \quad (3)$$

$$Y_i = 1\left[Y_i^* > 0\right] \quad (4)$$

where $Migrant\_rate_i$ is an IV. Y_i denotes the nutrition outcome variables for child i, including stunting, wasting, zinc-deficient, and health. Y_i^* is the latent variable. X_i is the vector of control variables.

For continuous variables of children's cognition (VCI and WMI), we specify the 2SLS model accordingly,

First stage:

$$\widehat{Migrant}_i = \alpha Migrant\_rate_i + \delta X_i \quad (5)$$

$$(\widehat{Migrant_i * Age_i}) = \pi\left(Migrant_{rate\,i} * Age_i\right) + \sigma X_i \quad (6)$$

Second stage:

$$Cognition_i = \theta_1 \widehat{Migrant}_i + \theta_2 Age_i + \theta_3 (\widehat{Migrant_i * Age_i}) + \rho X_i + \vartheta_i \quad (7)$$

where $Migrant\_rate_i$ is an IV. $Migrant\_rate_i * Age_i$ is the interaction term of IV and child's age; $\widehat{Migrant}_i$ and $\widehat{Migrant_i * Age_i}$ are the values from the first-stage estimation. $Cognition_i$ denotes VCI or WMI for child i. X_i is the vector of control variables.

5 | Results

5.1 | Impact of Parental Migration on Children's Nutrition Outcome

Table 2 presents Probit and IV-Probit estimates of the impact of parental migration on children's nutritional outcomes, measured by stunting, wasting, and zinc deficiency. The reported marginal effects are derived from the IV-Probit models, which account for the potential endogeneity of parental migration. The IV results in Panels A and B indicate significant adverse effects of parental migration on child nutrition. Specifically, left-behind children with any migrant parent are 52 percentage points more likely to be stunted and 25.7 percentage points more likely to be wasted compared to their non-left-behind peers. The adverse effects are even greater when only one parent migrates, raising the risk of stunting by 56 percentage points and wasting by 37 percentage points. The Wald tests of endogeneity reject the null hypothesis of no endogeneity in the specifications for any parent migrated and one parent migrated, with p values consistently below 0.05, justifying the use of IV methods. In contrast, the results in Panel C show no statistically significant association between parental migration and zinc deficiency, regardless of the model specification. These findings suggest that physical growth indicators are more responsive to parental absence than micronutrient status, possibly because zinc concentrations in hair reflect longer-term accumulation and are less immediately responsive to short-term changes in care or diet.

5.2 | Impact of Parental Migration on Children's Health Outcome

Table 3 reports Probit and IV-Probit estimates of the effect of parental migration on children's overall health status. The marginal effects of the IV-Probit results reveal a significant negative impact: the migration of any parent reduces the probability of good health by approximately 54.7 percentage points, with larger negative effects of about 75.9 percentage points when both parents migrate and about 73.2 percentage points when only one parent migrates. Across all specifications, the Wald tests reject the null hypothesis of no endogeneity, supporting the use of the IV strategy. In contrast, conventional Probit models yield insignificant effects, indicating that endogeneity bias masks the true health costs of parental migration. Overall, the evidence underscores that parental absence, particularly when both parents migrated, undermines child health outcomes beyond nutritional measures, highlighting the critical role of parental presence in child well-being.

5.3 | Impact of Parental Migration on Children's Cognition Outcome

The results in Table 4 indicate that parental migration has a negative impact on children's cognition outcomes, specifically the VCI and WMI. The IV (2SLS) estimates reveal substantially larger negative effects of parental migration compared to OLS, underscoring the importance of addressing endogeneity. The F-statistics of the first-stage estimation for both Panels

TABLE 2 | Probit and IV-Probit estimates of the impact of parental migration on children's nutritional status.

Variable	(1) Probit	(2) IV-Probit	(3) Marginal effect	(4) Probit	(5) IV-Probit	(6) Marginal effect	(7) Probit	(8) IV-Probit	(9) Marginal effect
Panel A. Dependent variable: Stunting									
Any parent migrated	−0.003	2.137***	0.520***						
	(0.166)	(0.298)	(0.160)						
Both parents migrated				0.323	2.463	0.442			
				(0.347)	(1.811)	(0.405)			
One parent migrated							−0.050	2.244***	0.560***
							(0.175)	(0.283)	(0.191)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald test of endogeneity		19.890			1.000			20.470	
Prob > chi^2		0.000			0.317			0.000	
Observations	1100	1100	1100	844	844	844	1040	1040	1040
Panel B. Dependent variable: Wasting									
Any parent migrated	−0.014	1.674**	0.257*						
	(0.169)	(0.653)	(0.154)						
Both parents migrated				0.069	−1.262	−0.162			
				(0.329)	(2.580)	(0.352)			
One parent migrated							−0.069	2.049***	0.370*
							(0.179)	(0.581)	(0.224)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald test of endogeneity		3.910			0.230			4.690	

(Continues)

TABLE 2 | (Continued)

Variable	(1) Probit	(2) IV-Probit	(3) Marginal effect	(4) Probit	(5) IV-Probit	(6) Marginal effect	(7) Probit	(8) IV-Probit	(9) Marginal effect
Prob > chi^2		0.048			0.632			0.030	
Observations	1100	1100	1100	844	844	844	1040	1040	1040
Panel C. Dependent variable: Zinc_deficient									
Any parent migrated	0.171	−0.390	−0.107						
	(0.164)	(1.500)	(0.420)						
Both parents migrated				−0.307	3.023	0.991			
				(0.377)	(2.988)	(1.546)			
One parent migrated							0.207	−0.787	−0.228
							(0.168)	(1.826)	(0.584)
Wald test of endogeneity		0.130			0.630			0.250	
Prob > chi^2		0.719			0.427			0.619	
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	660	660	660	513	513	513	620	620	620

Note: Standard errors clustered at the village level. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Reported marginal effects are derived from the IV-Probit models. Control variables include community-level characteristics (county, village annual per capita income, and village distance to township), child characteristics (age, gender, birth weight, and picky eating behavior), parental characteristics (mother's and father's years of education, health status, and absence duration), primary caregiver characteristics (time spent on housework, farm work, playtime, and total daily work), and household characteristics (household annual income, number of family members, number of siblings, single parent status, access to tap water and separate kitchen).

TABLE 3 | Probit and IV-Probit estimates of the impact of parental migration on children's health outcomes.

Variable	(1) Probit	(2) IV-Probit	(3) Marginal effect	(4) Probit	(5) IV-Probit	(6) Marginal effect	(7) Probit	(8) IV-Probit	(9) Marginal effect
Any parent migrated	−0.065	−2.395***	−0.547*						
	(0.171)	(0.386)	(0.320)						
Both parents migrated				−0.143	−4.045***	−0.759*			
				(0.345)	(1.021)	(0.459)			
One parent migrated							−0.038	−2.556***	−0.732*
							(0.180)	(0.283)	(0.431)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald test of endogeneity		7.100			4.720			8.890	
Prob > chi^2		0.008			0.030			0.003	
Observations	1100	1100	1100	844	844	844	1040	1040	1040

Note: Standard errors clustered at the village level. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Reported marginal effects are derived from the IV-Probit models. Control variables include community-level characteristics (county, village annual per capita income, and village distance to township), child characteristics (age, gender, birth weight, and picky eating behavior), parental characteristics (mother's and father's years of education, health status, and absence duration), primary caregiver characteristics (time spent on housework, farm work, playtime, and total daily work), and household characteristics (household annual income, number of family members, number of siblings, single parent status, access to tap water and separate kitchen).

TABLE 4 | OLS and 2SLS estimates of the impact of parental migration on children's cognition outcome.

Variable	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS
Panel A. Dependent variable: Vocabulary Comprehension Index (VCI)						
Any parent migrated	−9.417**	−41.270***				
	(3.815)	(13.430)				
Both parents migrated			−5.958	−93.020**		
			(6.488)	(37.890)		
One parent migrated					−10.030**	−44.910***
					(3.680)	(17.32)
Age	−0.876	−2.313***	−0.954	−1.872***	−0.850	−2.196***
	(0.745)	(0.488)	(0.748)	(0.402)	(0.754)	(0.622)
Age*Migrated	1.884***	9.557**	1.817*	15.610*	1.913***	10.360**
	(0.632)	(3.712)	(1.016)	(8.309)	(0.629)	(5.168)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic		602.330		123.060		132.080
Observations	690	690	514	514	645	645
Panel B. Dependent variable: Working Memory Index (WMI)						
Any parent migrated	−8.325**	−50.982***				
	(3.890)	(12.330)				
Both parents migrated			−11.320	−83.174***		
			(7.470)	(32.059)		
One parent migrated					−7.639*	−57.119***
					(4.008)	(14.855)
Age	−2.368***	−4.248***	−2.438***	−3.178***	−2.374***	−4.296***
	(0.635)	(0.508)	(0.591)	(0.351)	(0.630)	(0.590)
Age*Migrated	1.316**	8.323***	1.925	13.370*	1.151*	9.572**
	(0.617)	(3.161)	(1.202)	(7.245)	(0.614)	(3.845)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic		954.180		165.980		142.420
Observations	670	670	495	495	625	625

Note: Standard errors clustered at the village level. ***$p<0.01$, **$p<0.05$, *$p<0.1$. Control variables include community-level characteristics (county, village annual per capita income, and village distance to township), child characteristics (age, gender, birth weight, and picky eating behavior), parental characteristics (mother's and father's years of education, health status, and absence duration), primary caregiver characteristics (time spent on housework, farm work, playtime, and total daily work), and household characteristics (household annual income, number of family members, number of siblings, single parent status, access to tap water and separate kitchen).

A and B were larger than 10, indicating the IV is not weak. Compared to their non-left-behind peers, children with any migrant parent experience reductions of approximately 41.27 points in VCI and 50.98 points in WMI. The negative effects are even more pronounced when both parents migrate, with estimated declines of 93.02 points in VCI and 83.17 points in WMI, respectively. When only one parent migrates, the reductions are somewhat smaller, but remain statistically significant. Notably, the positive and significant interaction term between age and parental migration suggests that the negative impact of parental migration on children's cognition outcomes is dampened by children's age. This age-mitigating effect likely reflects the greater dependence on parental care during early childhood; as children grow older, schooling and peer interactions may increasingly buffer the adverse consequences of parental absence.

5.4 | Robustness Checks

We conduct a series of robustness checks to validate the results. First, we test the robustness of the main results by using alternative measurements for outcome variables. For nutrition, binary indicators of stunting and wasting are replaced with continuous height-for-age z-scores and BMI-for-age z-scores. For health, the general health indicator is replaced with the number of five common illnesses (fever, cough, diarrhea, stomach pain, and vomiting) reported in the past 2 weeks. Regarding cognition, we supplement the raw index scores of the Vocabulary Comprehension Index (VCI) and Working Memory Index (WMI) with categorical rankings, which classify children into seven cognitive ability levels from "extremely low" to "very superior." Across all specifications, the negative effects of parental migration remain robust, consistent with the main results in Tables 2–4. Detailed estimation results are reported in Table A1. Notably, the robustness checks also show that older children appear better able to withstand these adverse effects on cognition, as indicated by the positive and significant interaction terms between children's age and parental migration.

To address potential concerns regarding the validity of the instrument, we substitute the IV, the village-level migration rate, with the corresponding lagged migration rate in 2017. The lagged migration rate predates the child outcomes, which helps mitigate potential endogeneity concerns. Using the lagged migration rate also allows us to capture the long-term impact of migration rates on parental migration decisions, minimizing the influence of short-term fluctuations. The results, presented in Table A2, remain consistent with the main findings, reinforcing the robustness of our analysis and supporting the validity of the IV.

We further conduct subsample analyses by gender, confirming that the results are robust across different demographic groups. The results in Table 5 indicate that parental migration has a more pronounced negative effect on girls' nutrition, especially in terms of stunting and wasting. Boys tend to experience more severe consequences for overall health. The results from Panels D and E confirm that parental migration has a significant negative effect on children's cognitive outcomes. Boys generally experience a larger decline in both VCI and WMI scores. However, the changes for girls are more statistically significant. Moreover, the results for boys are insignificant when only one parent migrates or when both parents migrate together, suggesting that the effects on boys' cognitive outcomes are less robust in these scenarios. Overall, the analysis confirms that the main findings are robust, with gender differences highlighting the importance of considering these effects in policy discussions regarding parental migration.

6 | Mechanism Analysis

To better understand the underlying pathways through which parental migration affects child outcomes, this section explores two potential mechanisms. First, the absence of parents may reduce the quality of caregiving, leading to a decline in children's dietary diversity. Second, migration may also increase household resources through remittances, which could improve investments in children's food consumption and education. The empirical analysis below examines the relative strength of these two channels.

6.1 | Parental Migration and Children's Dietary Diversity

A key mechanism through which parental migration affects child nutrition is the reduction in dietary diversity due to the absence of caregivers. Adequate dietary diversity is essential for ensuring sufficient micronutrient intake and overall nutritional adequacy, health, and cognition development. According to FAO guidance (Kennedy et al. 2011), we construct the dietary diversity score (DDS) to assess the nutritional quality of children's diets. The DDS is based on 12 standard food groups (which include: cereals, white roots and tubers, vegetables, fruits, meats, eggs, fish and seafood, legumes, nuts, and seeds, milk and dairy products, oils and fats, sweets, and spices, condiments, and beverages) and reflects the number of food categories consumed over 30 days, with scores ranging from 0 to 12. The dietary data used to construct the DDS were collected through our household survey, where caregivers reported children's food consumption over the past month. Table 6 presents 2SLS estimates showing that parental migration significantly reduces children's DDS. Specifically, any parent migration reduces the DDS by 2.84 points at the 5% significance level, and this effect is particularly pronounced when only one parent migrates, with a reduction of 3.31 points at the 5% significance level. The coefficient for both parents migrating is negative but not statistically significant. These results indicate that parental absence may lead to disruptions in food preparation and lower dietary diversity, which in turn mediates the adverse nutritional effects observed earlier.

6.2 | Remittances and Household Investments in Food and Education

To explore whether remittances mitigate the negative effects of parental migration, the analysis further examines household expenditure patterns. We calculate the annual remittances (in thousand yuan) sent by migrants, including both cash transfers and in-kind items converted into cash equivalents. Table 7 presents OLS estimates indicating that remittances are positively associated with increased monthly food expenditures for children. Specifically, a 1000 yuan increase in annual remittances is associated with a 1.79 yuan increase in total monthly food expenditures at the 1% significance level. The results show that each additional 1000 yuan in annual remittances significantly increases monthly spending on snacks (0.52 yuan), fruit (0.68 yuan), and meat, eggs, and milk (0.5 yuan). However, spending on nutritional supplements is not significantly affected. These findings suggest that remittances may help improve children's access to a wider variety of food products, which could potentially enhance their overall dietary intake despite the reduced diversity caused by parental absence.

We further extend the analysis to educational investment. According to Table 8, annual remittances significantly increase yearly spending on books. Specifically, for every 1000 yuan increase in annual remittances, spending on books increases by 0.76 yuan. This finding implies that remittance income could support cognition development through non-essential educational spending. At the same time, remittances do not significantly affect expenditures on tutoring or hobby classes,

TABLE 5 | Robustness check: Subsample analysis by gender.

	IV-Probit (marginal effect)						2SLS					
Variable	(1) Boys	(2) Girls	(3) Boys	(4) Girls	(5) Boys	(6) Girls	(7) Boys	(8) Girls	(9) Boys	(10) Girls	(11) Boys	(12) Girls
Panel A. Dependent variable: Stunting												
Any parent migrated	0.135	0.834***										
	(0.345)	(0.309)										
Both parents migrated			−0.090	0.893								
			(0.618)	(0.658)								
One parent migrated					0.265	0.837***						
					(0.450)	(0.319)						
Controls	Yes	Yes	Yes	Yes	Yes	Yes						
Observations	545	555	422	422	519	521						
Panel B. Dependent variable: Wasting												
Any parent migrated	0.199	0.355*										
	(0.211)	(0.208)										
Both parents migrated			−0.064	0.083								
			(0.366)	(0.698)								
One parent migrated					0.504	0.369*						
					(0.362)	(0.220)						
Controls	Yes	Yes	Yes	Yes	Yes	Yes						
Observations	545	555	422	422	519	521						
Panel C. Dependent variable: Health												
Any parent migrated	−0.933*	−0.220										
	(0.538)	(0.191)										

(Continues)

TABLE 5 | (Continued)

	IV-Probit (marginal effect)						2SLS					
Variable	**(1) Boys**	**(2) Girls**	**(3) Boys**	**(4) Girls**	**(5) Boys**	**(6) Girls**	**(7) Boys**	**(8) Girls**	**(9) Boys**	**(10) Girls**	**(11) Boys**	**(12) Girls**
Both parents migrated			−1.551	0.596								
			(1.021)	(0.455)								
One parent migrated					−0.974*	−0.323						
					(0.586)	(0.250)						
Controls	Yes	Yes	Yes	Yes	Yes	Yes						
Observations	545	555	422	422	519	521						
Panel D. Dependent variable: Vocabulary Comprehension Index (VCI)												
Any parent migrated							−79.340**	−29.820***				
							(36.180)	(10.170)				
Both parents migrated									−222.200	−52.490***		
									(163.000)	(18.830)		
One parent migrated											−90.310	−27.830*
											(69.490)	(14.630)
Age							−3.743***	−2.045***	−2.651**	−1.477***	−3.666**	−2.016**
							(1.071)	(0.544)	(1.131)	(0.504)	(1.797)	(0.918)
Age*Migrated							17.030***	4.071	43.810	4.131	19.630**	1.391
							(5.940)	(4.624)	(34.110)	(5.604)	(8.558)	(7.178)
Controls							Yes	Yes	Yes	Yes	Yes	Yes
Observations							327	363	247	267	309	336

(Continues)

TABLE 5 | (Continued)

Variable	IV-Probit (marginal effect)						2SLS					
	(1) Boys	(2) Girls	(3) Boys	(4) Girls	(5) Boys	(6) Girls	(7) Boys	(8) Girls	(9) Boys	(10) Girls	(11) Boys	(12) Girls
Panel E. Dependent variable: Working Memory Index (WMI)												
Any parent migrated							−95.960*	−40.720***				
							(51.310)	(10.910)				
Both parents migrated									−165.400	−58.130***		
									(114.800)	(13.640)		
One parent migrated											−140.400	−43.340***
											(108.600)	(13.030)
Age							−5.754***	−3.637***	−3.636***	−2.856***	−6.648**	−3.553***
							(1.675)	(0.437)	(0.725)	(0.234)	(2.968)	(0.496)
Age*Migrated							12.050	7.437*	28.400	8.576	14.650	8.437
							(7.775)	(4.163)	(22.690)	(5.225)	(12.830)	(5.923)
Controls							Yes	Yes	Yes	Yes	Yes	Yes
Observations							314	356	234	261	296	329

Note: Standard errors clustered at the village level. ***$p<0.01$, **$p<0.05$, *$p<0.1$. Control variables include community-level characteristics (county, village annual per capita income, and village distance to township), child characteristics (age, gender, birth weight, and picky eating behavior), parental characteristics (mother's and father's years of education, health status, and absence duration), primary caregiver characteristics (time spent on housework, farm work, playtime, and total daily work), and household characteristics (household annual income, number of family members, number of siblings, single parent status, access to tap water and separate kitchen).

indicating that while remittances may enhance children's access to learning materials, they may not be as effective in supporting more formal or extracurricular educational activities.

The findings above reveal two countervailing mechanisms: parental absence reduces dietary diversity and may deteriorate children's nutrition, while remittance inflows support greater food and education expenditures that could buffer or offset these harms. However, despite the compensatory effect of remittances on food and education expenditures, the overall evidence suggests that the negative caregiving effect of parental absence—manifested through reduced dietary diversity—dominates. This indicates that the absence of parents plays a more decisive role in shaping children's well-being than the financial gains from migration.

7 | Conclusions and Discussions

This study provides robust evidence that parental migration adversely affects children's nutrition, health, and cognition development. Using data from the Gansu Survey and instrumenting migration with the village-level share of households with at least one migrated parent, we apply IV-Probit and 2SLS methods to address endogeneity and uncover substantial impacts across domains. The main findings are as follows. (1) For nutrition, parental absence—particularly when only one parent migrates—substantially increases the likelihood of stunting and wasting, while zinc deficiency remains unaffected, likely due to its insensitivity to short-term dietary change. (2) For health, parental migration reduces the probability of good health, with the strongest adverse effects observed when both parents are absent. (3) For cognition, children with migrant parents exhibit significantly lower vocabulary comprehension and working memory scores, with effects most pronounced in early childhood and partially attenuated with age.

These negative impacts are overall consistent across alternative outcome measures, IVs, and gender-specific subsamples, reinforcing the validity of the results. Mechanism analyses reveal that reduced caregiving quality, indicated by lower dietary diversity, is a key pathway through which migration negatively impacts child outcomes. Although remittances partially compensate by increasing food and educational

TABLE 6 | 2SLS estimates of the impact of parental migration on children's dietary diversity score.

Variable	(1) 2SLS	(2) 2SLS	(3) 2SLS
Any parent migrated	−2.840**		
	(1.209)		
Both parents migrated		−5.618	
		(3.587)	
One parent migrated			−3.307**
			(1.549)
Controls	Yes	Yes	Yes
Observations	1100	844	1040

Note: Standard errors clustered at the village level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Control variables include community-level characteristics (county, village annual per capita income, and village distance to township), child characteristics (age, gender, birth weight, and picky eating behavior), parental characteristics (mother's and father's years of education, health status, and absence duration), primary caregiver characteristics (time spent on housework, farm work, playtime, and total daily work), and household characteristics (household annual income, number of family members, number of siblings, single parent status, access to tap water and separate kitchen).

TABLE 8 | OLS estimates of the impact of annual remittance on children's yearly education expenses.

	Book	Extracurricular tutoring	Hobby class
Variable	(1) OLS	(2) OLS	(3) OLS
Remittance	0.759*	−0.030	1.018
	(0.381)	(0.022)	(0.663)
Controls	Yes	Yes	Yes
Observations	1100	1100	1100
R-squared	0.283	0.022	0.048

Note: Standard errors clustered at the village level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Control variables include community-level characteristics (county, village annual per capita income, and village distance to township), child characteristics (age, gender, birth weight, and picky eating behavior), parental characteristics (mother's and father's years of education, health status, and absence duration), primary caregiver characteristics (time spent on housework, farm work, playtime, and total daily work), and household characteristics (household annual income, number of family members, number of siblings, single parent status, access to tap water and separate kitchen).

TABLE 7 | OLS estimates of the impact of annual remittance on children's monthly food expenses.

	Total food	Snacks	Fruit	Meat, egg and milk	Nutritional supplement
Variable	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
Remittance	1.794***	0.515***	0.676**	0.497**	0.615
	(0.474)	(0.106)	(0.292)	(0.223)	(0.392)
Controls	Yes	Yes	Yes	Yes	Yes
Observations	1100	1100	1100	1100	1100
R-squared	0.139	0.123	0.161	0.075	0.068

Note: Standard errors clustered at the village level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Control variables include community-level characteristics (county, village annual per capita income, and village distance to township), child characteristics (age, gender, birth weight, and picky eating behavior), parental characteristics (mother's and father's years of education, health status, and absence duration), primary caregiver characteristics (time spent on housework, farm work, playtime, and total daily work), and household characteristics (household annual income, number of family members, number of siblings, single parent status, access to tap water and separate kitchen).

expenditures, the mitigating effect is insufficient to offset the caregiving deficit. Overall, the findings highlight that the presence of parents is essential for child well-being and the formation of early-life human capital, and the absence of parents has far-reaching consequences that financial transfers alone cannot fully offset.

This study highlights several policy priorities to mitigate the developmental costs of parental migration. First, strengthen direct support for left-behind children across nutrition, health, and cognition. In terms of nutrition, access to diverse, nutrient-rich foods for left-behind children should be expanded through school feeding programs, food voucher schemes, and community-based nutrition initiatives. Special attention should be given to girls, as they are particularly vulnerable to nutritional deficiencies, especially stunting and wasting. Regarding health, regular health check-ups and pediatric services should be made more accessible in rural areas, especially for children whose parents have both migrated. Particular attention should also be given to boys, as they tend to face more severe health issues. For cognitive development, the most vulnerable are younger children, whose early-life stimulation depends heavily on direct parental interaction. Investment in rural early childhood education, home-based cognitive stimulation programs, and caregiver training can help fill this gap. These measures are particularly important when both parents migrate, as this pattern was found to have especially adverse effects on nutrition and cognition.

Second, leverage remittances to improve left-behind children's outcomes. Although remittances cannot fully compensate for parental absence, they can help improve child well-being when used effectively. The mechanism analysis shows that remittances are associated with higher food expenditures and modest increases in educational spending on items like books. To maximize these benefits, spending on nutrient-dense foods like fruit and animal-source products such as meat, egg, and milk should be encouraged, while overreliance on snacks lacking essential nutrients should be reduced. For children with poor nutritional status, nutritional supplements should also be considered. This underscores the need for targeted interventions, such as nutrition education programs, to ensure remittances enhance children's nutritional status. Additionally, money management training for migrant families should be promoted to guide remittance use toward child health and education. Conditional cash transfers or matched savings accounts tied to child-related spending could further maximize developmental returns.

Third, reduce the developmental costs of separation. Broader structural reforms are necessary to mitigate the long-term consequences of parental absence. Policies that facilitate family co-migration, such as easing residency restrictions and ensuring migrant children's access to urban public services, would allow more children to remain with their parents. For those who are left behind, enhancing the caregiving environment is crucial. This includes offering formal training to substitute caregivers (typically grandparents), providing community-based childcare and early learning centers, and establishing health and developmental monitoring systems. In addition, promoting regular parent–child communication through digital tools could also help maintain emotional bonds and partially mitigate the psychological impacts of separation.

We would also like to acknowledge two limitations of our study. First, while we control for many household and village-level socioeconomic factors—such as village annual per capita income and distance to the township—that partially capture community infrastructure and access to healthcare, some potentially important variables remain unobserved. For example, parental mental health and social support networks, which may influence child development, are not directly measured. However, given data constraints, these factors could not be included and should be explored in future research. Second, this study estimates only the direct effects of parental migration on children's cognition, without capturing indirect effects mediated through nutrition and health. Moreover, due to the cross-sectional nature of our data, the results represent short-term impacts. The cumulative long-term effects of parental migration on children's nutrition, health, and cognitive development may be larger and require a longitudinal study. Therefore, further research with richer data is needed to fully understand the complex and long-term consequences of parental migration on children.

Ethics Statement

The study has obtained ethical approval from the Institutional Review Board (IRB) at IFPRI Headquarter and at Peking University Health Science Center as well.

Consent

Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data were collected from vulnerable populations and involve indirect identifiers such as sex, ethnicity and left-behind status. Therefore, data cannot be shared publicly because of such potentially identifying participant information. Data may be made available from the corresponding author upon reasonable request by researchers who meet the criteria for access to confidential data.

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Appendix A

TABLE A1 | Robustness check: Alternative outcome measures for nutrition, health, and cognition outcomes.

Variable	(1) 2SLS	(2) 2SLS	(3) 2SLS
Panel A. Dependent variable: Height-for-age *z*-score			
Any parent migrated	−1.447**		
	(0.588)		
Both parents migrated		−1.166	
		(1.312)	
One parent migrated			−1.608**
			(0.703)
Controls	Yes	Yes	Yes
Observations	1100	844	1040
Panel B. Dependent variable: BMI-for-age *z*-score			
Any parent migrated	−1.533*		
	(0.804)		
Both parents migrated		−1.837	
		(1.297)	
One parent migrated			−2.319**
			(1.031)
Controls	Yes	Yes	Yes
Observations	1100	844	1040
Panel C. Dependent variable: Illness			
Any parent migrated	1.371**		
	(0.601)		
Both parents migrated		2.107**	
		(1.065)	
One parent migrated			1.429*
			(0.841)
Controls	Yes	Yes	Yes
Observations	1100	844	1040
Panel D. Dependent variable: VCI_ranking			
Any parent migrated	−2.485**		
	(1.083)		
Both parents migrated		−5.872**	
		(2.833)	
One parent migrated			−2.796*
			(1.443)
Age	−0.127***	−0.113***	−0.118**
	(0.041)	(0.035)	(0.055)
Age*Migrated	0.622**	0.918*	0.655*
	(0.282)	(0.531)	(0.374)
Controls	Yes	Yes	Yes
Observations	690	514	645
Panel E. Dependent variable: WMI_ranking			
Any parent migrated	−3.916***		
	(0.941)		
Both parents migrated		−6.805**	
		(2.773)	
One parent migrated			−4.228***
			(1.058)
Age	−0.339***	−0.274***	−0.336***
	(0.043)	(0.036)	(0.046)
Age*Migrated	0.722**	1.286*	0.807**
	(0.283)	(0.670)	(0.346)
Controls	Yes	Yes	Yes
Observations	670	495	625

(Continues)

Note: Standard errors clustered at the village level. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Control variables include community-level characteristics (county, village annual per capita income, and village distance to township), child characteristics (age, gender, birth weight, and picky eating behavior), parental characteristics (mother's and father's years of education, health status, and absence duration), primary caregiver characteristics (time spent on housework, farm work, playtime, and total daily work), and household characteristics (household annual income, number of family members, number of siblings, single parent status, access to tap water and separate kitchen).

TABLE A2 | Robustness check: Substitution of IV with lagged migration rate.

Variable	IV-Probit (marginal effect)			2SLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dependent variable: Stunting						
Any parent migrated	0.723***					
	(0.257)					
Both parents migrated		0.774				
		(0.500)				
One parent migrated			0.808***			
			(0.273)			
Controls	Yes	Yes	Yes			
Observations	1100	844	1040			
Panel B. Dependent variable: Wasting						
Any parent migrated	0.422**					
	(0.205)					
Both parents migrated		−0.0508				
		(0.412)				
One parent migrated			0.580*			
			(0.305)			
Controls	Yes	Yes	Yes			
Observations	1100	844	1040			
Panel C. Dependent variable: Health						
Any parent migrated	−0.458*					
	(0.250)					
Both parents migrated		−0.482**				
		(0.212)				
One parent migrated			−0.635*			
			(0.371)			
Controls	Yes	Yes	Yes			
Observations	1100	844	1040			
Panel D. Dependent variable: Vocabulary Comprehension Index (VCI)						
Any parent migrated				−35.050*		
				(18.000)		
Both parents migrated					−87.960**	
					(37.860)	
One parent migrated						−39.320*
						(23.840)
Age				−2.042***	−2.002***	−2.013**
				(0.724)	(0.469)	(0.916)
Age*Migrated				8.605**	13.870*	9.028*
				(3.894)	(7.639)	(4.750)

(Continues)

TABLE A2 | (Continued)

Variable	IV-Probit (marginal effect) (1)	(2)	(3)	2SLS (4)	(5)	(6)
Controls				Yes	Yes	Yes
Observations				690	514	645
Panel E. Dependent variable: Working Memory Index (WMI)						
Any parent migrated				−50.160***		
				(14.620)		
Both parents migrated					−56.460***	
					(18.800)	
One parent migrated						−57.060***
						(18.010)
Age				−4.194***	−4.251***	−4.293***
				(0.631)	(0.744)	(0.721)
Age*Migrated				7.357**	8.614**	8.627**
				(3.271)	(3.699)	(3.742)
Controls				Yes	Yes	Yes
Observations				670	495	625

Note: Standard errors clustered at the village level. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Control variables include community-level characteristics (county, village annual per capita income, and village distance to township), child characteristics (age, gender, birth weight, and picky eating behavior), parental characteristics (mother's and father's years of education, health status, and absence duration), primary caregiver characteristics (time spent on housework, farm work, playtime, and total daily work), and household characteristics (household annual income, number of family members, number of siblings, single parent status, access to tap water and separate kitchen).