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Parental migration and socio-emotional health inequalities among left-behind preschool children in rural China: evidence from a longitudinal study

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Research Article

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Abstract

Parental migration is a widespread phenomenon in developing countries and has important implications for population health. In China, large-scale rural-to-urban migration has resulted in millions of left-behind children, raising concerns about early-life health inequalities.

This study uses longitudinal data tracking 800 preschool-aged children in rural China across five survey waves from 2013 to 2017. Socio-emotional health was measured using the Ages and Stages Questionnaire: Social-Emotional (ASQ:SE). Child fixed-effects models and multi-period difference-in-differences approaches were applied.

Parental migration is associated with worse socio-emotional health outcomes. Maternal migration has the largest effect (0.478, $p < 0.05$), followed by joint parental migration (0.406, $p < 0.01$), while paternal migration has a smaller effect (0.171, $p < 0.01$). These effects operate through changes in caregiving environments, including reduced caregiving time and lower interaction quality.

Parental migration contributes to early-life health inequalities among left-behind children. Policies that improve family environments and access to child health services may help mitigate these disparities.

Keywords: parental migration; child health; health inequality; early childhood; China

1.Introduction

Parental migration is a defining feature of economic transformation in many low- and

middle-income countries and has important implications for population health[1–3]. In China, large-scale rural-to-urban migration[4, 5] has resulted in millions of children growing up separated from one or both parents[3, 6], raising concerns about early-life health inequalities.

Early childhood is a critical period for socio-emotional health[7–9]. Skills such as self-regulation, communication, and social interaction are shaped by caregiving environments and early parent–child interactions. Disruptions to these environments may have long-term consequences for children's health trajectories[10, 11]. From a public health perspective, early-life exposures play a critical role in shaping health trajectories across the life course, and disadvantages during this period may contribute to persistent health inequalities[12–15].

Existing research has extensively examined the impact of parental migration on children's educational performance, cognitive development, and mental health[16–22]. A substantial body of evidence also shows that left-behind children are more likely to experience emotional distress[23], including loneliness, anxiety, and depression[24–34]. However, findings regarding socio-emotional health remain mixed. Some studies report lower self-esteem and poorer behavioral adjustment among left-behind children[35–37], whereas others find no significant differences or even positive behavioral traits in certain contexts[38–43]. One important limitation of this literature is that many studies treat left-behind children as a homogeneous group, without distinguishing between paternal migration, maternal migration, and joint parental migration[44, 45].

Furthermore, relatively little attention has been paid to preschool-aged children. Most existing studies focus on school-aged populations, making it difficult to understand how

66 parental migration affects health during the earliest and most sensitive stages of life[19–21,
67 46–49]. This gap is important because socio-emotional skills are particularly malleable in
68 early childhood, and early disadvantages may accumulate over time[10, 11, 40, 45, 50–52].
69 This study addresses these gaps by providing longitudinal evidence on the socio-
70 emotional health of preschool children and by explicitly distinguishing between different
71 parental migration patterns. We examine paternal migration, maternal migration, and joint
72 parental migration separately, allowing us to identify heterogeneous effects across family
73 structures. In addition, we explore the mechanisms through which parental migration affects
74 children's health.
75 Our study contributes to the literature in three ways. First, it provides evidence on
76 preschool-aged children, a group that has received limited attention in the literature on left-
77 behind children. Second, it highlights heterogeneity across migration types, showing that the
78 health consequences of migration depend on which parent migrates. Third, by combining
79 longitudinal analysis with mechanism identification, the study offers a more comprehensive
80 account of how parental migration affects early socio-emotional health. These findings
81 provide important evidence for understanding the early-life determinants of health
82 inequalities and offer policy-relevant insights for population health interventions in
83 migration-affected settings.

84 **2. Conceptual Framework**

85 Parental migration can affect children's socio-emotional health through multiple
86 interrelated pathways that operate via changes in caregiving inputs. From a developmental

and public health perspective, early childhood outcomes are shaped not only by material resources but also by the quantity and quality of caregiver–child interactions. A large body of literature suggests that parental migration affects child health through a trade-off between increased household income and reduced parental caregiving inputs[53–55]. This study focuses on caregiving environments as the central mechanism linking parental migration to children's socio-emotional health. From a population health perspective, caregiving environments represent a key pathway through which early-life conditions influence child health outcomes.

We conceptualize the impact of parental migration as operating through two core dimensions of caregiving: the quantity of caregiving time and the quality of caregiver–child interactions. Both dimensions have been shown to play critical roles in shaping socio-emotional and behavioral outcomes in early childhood[10, 11, 56, 57].

First, parental migration may reduce the quantity of caregiving time. The physical absence of parents limits opportunities for supervision, daily interaction, and health-related developmental stimulation. Reduced time investment may weaken the formation of behavioral routines and hinder the formation of socio-emotional health capacities and communication skills[56, 57].

Second, migration may reduce the quality of caregiver–child interactions. High-quality interactions—such as responsive communication, storytelling, and play—are essential for fostering emotional bonding and social competence[58–60]. According to attachment theory, stable and responsive caregiver–child relationships are particularly important for emotional

regulation and early psychosocial health[61, 62]. When parents migrate, these interactions may weaken, especially if substitute caregivers are less able to provide consistent emotional support and health-related developmental stimulation.

Third, migration often leads to caregiver substitution, typically involving grandparents or other relatives[52, 63]. While such arrangements may partially compensate for the loss of parental time, substitute caregivers may differ substantially in interaction style, responsiveness, and health-related investment. As a result, caregiver substitution may preserve the quantity of care while reducing its quality[53, 63, 64].

Importantly, the relative importance of these mechanisms is likely to vary across parental migration patterns. In many rural contexts, mothers serve as primary caregivers during early childhood[65–68]. Maternal migration is therefore expected to affect both caregiving time and interaction quality. In contrast, paternal migration may primarily affect time allocation with more limited effects on interaction quality. Joint parental migration may rely heavily on substitute caregivers, making interaction quality the dominant channel.

Based on this framework, we derive the following testable hypotheses. First, parental migration reduces caregiving time and thereby worsens children's socio-emotional outcomes. Second, parental migration reduces the quality of caregiver–child interactions, which adversely affects socio-emotional health. Third, the magnitude and mechanisms of the effects differ across paternal, maternal, and joint parental migration. These hypotheses are directly examined in the empirical analysis. The main regression results identify the overall effects of different migration patterns, while the mechanism analysis provides evidence on the relative

importance of time and quality channels.

3. Methods

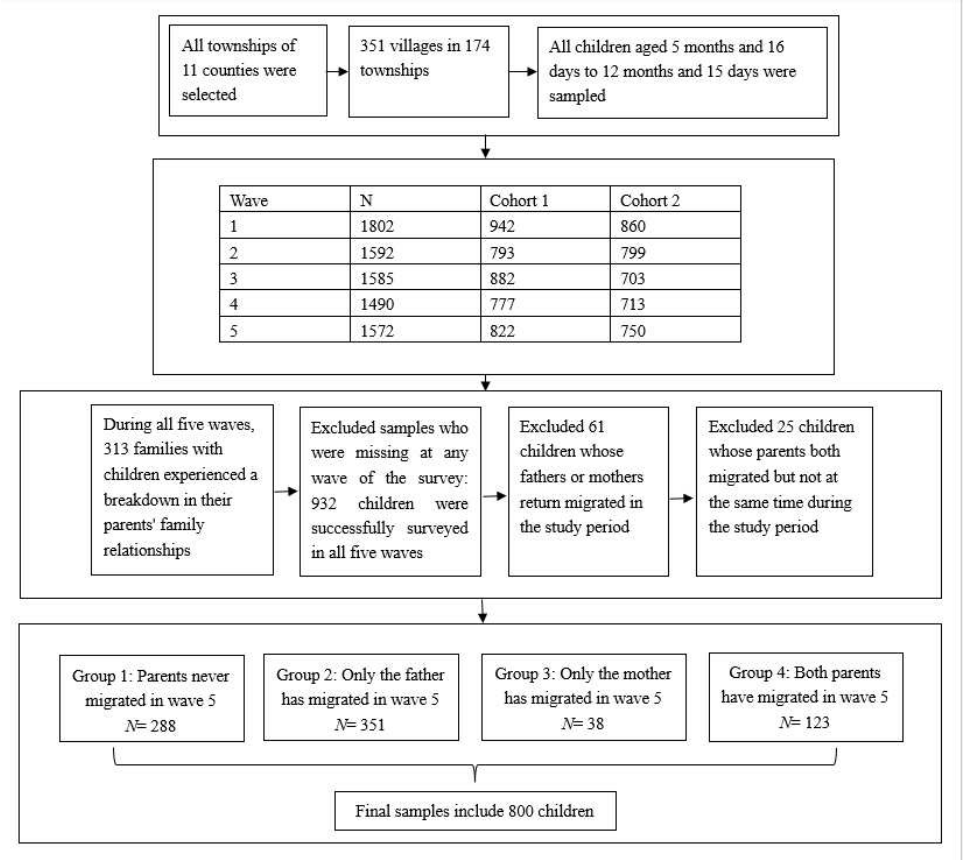
3.1 Study setting and sample

The empirical data were collected in the Qinba Mountain region of Shaanxi Province, an economically disadvantaged area in northwestern China. This region provides a highly relevant setting for examining the health consequences of parental migration because it combines high rates of rural labor out-migration with limited local caregiving and early-life health development resources[48].

We used a multistage cluster sampling design to select sample households. In the 11 study counties, all eligible townships were included in the sampling frame, except county seats and townships without a village of at least 800 residents. Among the 174 eligible townships, two villages were randomly selected from each township. From these villages, we obtained a baseline list of 1,802 children aged 5–12 months and their caregivers. These children and caregivers formed the original baseline sample.

Following the baseline survey in 2013, follow-up surveys were conducted every six months for three additional waves, and a fifth survey was conducted in 2017 when the children were approximately 49–65 months old. Across these five waves, 1802 children and caregivers were interviewed at baseline, 1,592 in wave 2, 1,585 in wave 3, 1,490 in wave 4, and 1,572 in wave 5. After excluding observations with missing survey waves, abnormal family relationships, parental return migration, and inconsistent parental migration timing, the final balanced analytical sample included 800 children observed across all five

150 waves[48]. The sample selection process is shown in Figure 1.



151

152 **Fig. 1.** Flowchart of the sampling process.

153 **3.2 Measures**

154 Children's socio-emotional health was assessed using the Ages and Stages

155 Questionnaire: Social-Emotional (ASQ:SE). The ASQ:SE is a widely used screening

156 instrument for young children's socio-emotional health and includes multiple domains such

157 as self-regulation, adaptive functioning, affect, communication, autonomy, compliance, and

158 interactions with others[69–71]. Caregivers were asked whether each behavior occurred

159 "most of the time", "sometimes", or "rarely/never" with higher scores indicating greater

160 socio-emotional difficulties. Because the ASQ:SE questionnaire differs by child age, scores

were standardized for empirical analysis. Higher ASQ:SE scores indicate worse socio-emotional health outcomes.

Parental migration was measured based on caregiver reports of parental presence between survey waves. If a child's father or mother had been away from home for more than half of the time between two surveys, that parent was defined as having migrated during that survey period. Based on this definition, children were classified into four groups: children living with both parents (reference group), children with only fathers migrating (FLBC), children with only mothers migrating (MLBC), and children with both parents migrating (BLBC). It should be noted that the number of observations in the maternal migration group is relatively small, which may limit statistical power. However, the consistency of results across multiple specifications supports the robustness of the findings.

We also included time-varying child and household covariates, including child age, gender, premature birth status, sibling structure, maternal education, subsistence allowance status, and household asset index. In addition, measures of mental and psychomotor development were included where appropriate to reduce bias from baseline developmental differences.

3.3 Empirical strategy

A key challenge in estimating the effect of parental migration on children's socio-emotional health is the potential endogeneity of migration decisions. Parents' migration choices may be correlated with unobserved factors, such as household shocks or child-specific conditions, which also affect health outcomes. Reverse causality may also arise if

parents adjust migration decisions in response to children's developmental status.

To address these concerns, we employ a child fixed-effects model that exploits within-child variation over time. This approach controls for all time-invariant observed and unobserved heterogeneity at the individual level. Our baseline specification is:

$$Y_{it} = \alpha + \beta_1 FLBC_{it} + \beta_2 MLBC_{it} + \beta_3 BLBC_{it} + \beta_4 C_{it} + \lambda_i + \gamma_t + s_{it} + \varepsilon_{it} \quad (1)$$

where Y_{it} denotes the socio-emotional health outcome of child i in survey wave t, measured by the ASQ:SE total score and its subdomains. $FLBC_{it}$, $MLBC_{it}$, $BLBC_{it}$ are dummy variables indicating whether only the father, only the mother, or both parents migrated. Children living with both parents serve as the reference group. C_{it} is a vector of time-varying child and household characteristics. λ_i represents child fixed effects, γ_t denotes survey-wave fixed effects, s_{it} is enumerator effects used to capture the measurement error, and ε_{it} is an error item. Standard errors are clustered at the village level to account for intra-village correlation.

This specification mitigates bias arising from time-invariant confounders and improves the credibility of the estimated associations by exploiting within-child changes over time.

To further strengthen robustness, we also apply a multi-period difference-in-differences approach following Callaway and Sant'Anna[72, 73]. This method is particularly useful in settings with staggered treatment timing and heterogeneous treatment effects across cohorts. In addition, we conduct parallel trend tests to assess whether children exposed to future parental migration followed similar pre-treatment trends as those remaining with both parents.

4. Results

4.1. Descriptive Statistics

Table 1. Summary statistics of child and household characteristics (wave=1)

Variable	Full Sample Mean (Std. Dev.)	NLBC Mean (Std. Dev.)	FLBC Mean (Std. Dev.)	MLBC Mean (Std. Dev.)	BLBC Mean (Std. Dev.)	(2)-(3) P-value	(2)-(4) P-value	(2)-(5) P-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Child Characteristics								
(1) Age of child (months)	9.564 (1.831)	9.513 (1.827)	10.123 (1.896)	10.037 (1.842)	9.815 (1.78)	0.038**	0.254	0.530
(2) Male (1 = yes; 0 = no)	0.526 (0.500)	0.532 (0.499)	0.475 (0.506)	0.444 (0.527)	0.487 (0.506)	0.397	0.501	0.620
(3) Premature birth (1 = yes; 0 = no)	0.039 (0.193)	0.039 (0.195)	0.075 (0.267)	0.000 (0.000)	0.000 (0.000)	0.970	0.152	0.622
(4) Has siblings (1 = yes; 0 = no)	0.480 (0.500)	0.497 (0.500)	0.400 (0.496)	0.333 (0.500)	0.282 (0.456)	0.010***	0.007***	0.009***
(5) Bayley mental development index	96.178 (17.058)	95.904 (17.043)	97.400 (18.195)	112.667 (21.101)	96.103 (13.51)	0.750	0.204	0.303
(6) Bayley psychomotor	89.521 (17.749)	89.273 (17.796)	90.750 (17.65)	103.000 (21.372)	89.667 (15.385)	0.714	0.287	0.33
Panel B: Household Characteristics								
(7) Mother completed junior high (1 = yes; 0	0.696 (0.460)	0.685 (0.465)	0.725 (0.452)	0.778 (0.441)	0.846 (0.366)	0.071*	0.033**	0.235
(8) Subsistence allowances (1 = yes; 0	0.244 (0.430)	0.245 (0.430)	0.250 (0.439)	0.333 (0.500)	0.205 (0.409)	0.719	0.801	0.234
(9) Asset index	-0.112 (0.633)	-0.098 (0.623)	-0.341 (0.740)	0.240 (0.668)	-0.226 (0.637)	0.012**	0.767	0.739
(10) Cohort	1.479 (0.500)	1.468 (0.499)	1.525 (0.506)	1.889 (0.333)	1.538 (0.505)	0.322	0.073*	0.269
N	800	712	40	9	39			

Note. NLBC means never left-behind children; LBC means left-behind children; FLBC means LBC with only fathers migrating; MLBC means LBC with only mothers migrating; BLBC means LBC with both parents migrating.

Table 1 presents baseline characteristics of the sample. The average age of children is approximately 9.56 months, with no significant differences across groups except for FLBC. The proportion of male children is balanced across groups. Notably, the proportion of children with siblings is significantly lower in migrant households, suggesting differences in

family structure. Maternal education levels are higher in migration households, particularly in MLBC and BLBC groups, indicating that migration decisions may be associated with human capital characteristics.

4.2. Development Trends

Table 2 presents summary statistics of children's socio-emotional health for Waves 1–2, Table 3 reports the corresponding statistics for Waves 3–4, and Table 4 presents the results for Wave 5. Overall ASQ:SE scores increase over time, indicating worsening outcomes as children age. Differences across migration groups become more pronounced in later waves. Figure 2 further illustrates the dynamic changes in family migration patterns over time, highlighting increasing parental absence as children grow older.

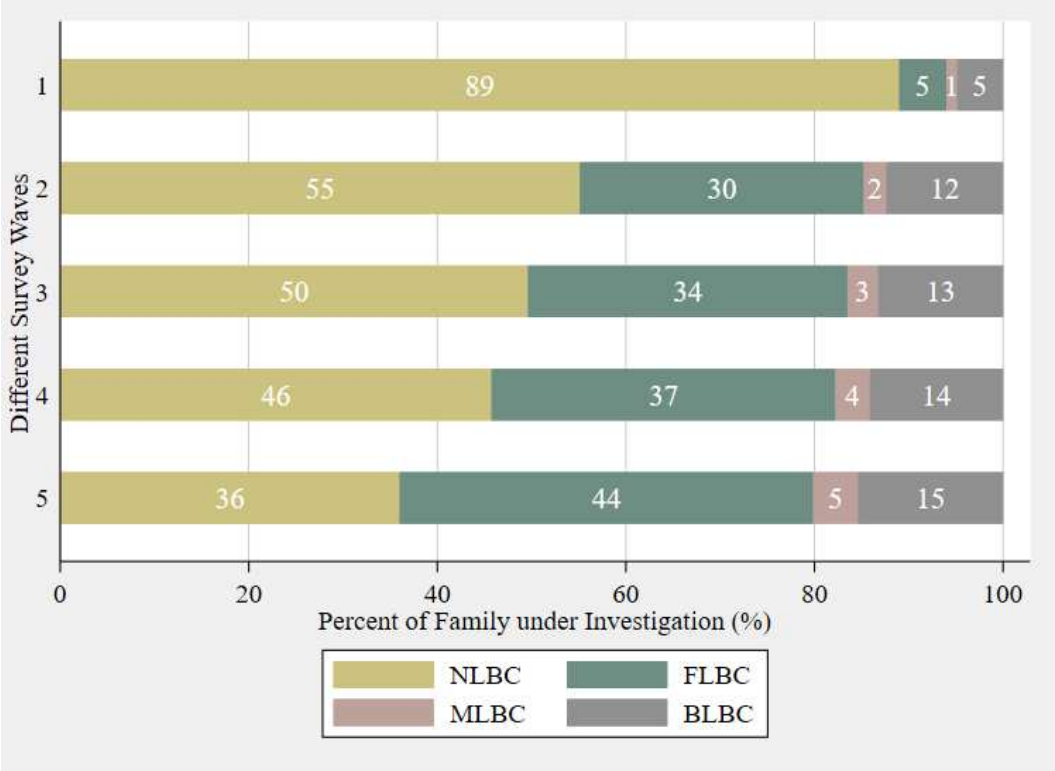


Fig. 2. Percent of Family by Survey Waves.

Table 2. Summary statistics of children's non-cognitive development in different survey waves (Waves 1-2)

Variable	Full Sample	NLBC	FLBC	MLBC	BLBC	(2)-(3)	(2)-(4)	(2)-(5)
	Mean (Std.	Mean (Std.	Mean (Std.	Mean (Std. Dev.)	Mean (Std.	P-value	P-value	P-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wave=1								
ASQ:SE	45.638	45.451	45.473	46.818	46.604	0.752	0.321	0.614
	(27.041)	(27.097)	(25.898)	(35.567)	(27.157)			
Self-regulation	15.256	15.417	14.649	17.19	15.542	0.134	0.193	0.284
	(12.602)	(12.495)	(11.973)	(16.967)	(13.283)			
Adaptive functioning	12.319	11.976	12.569	9.463	13.990	0.001***	0.054*	0.002***
	(10.482)	(10.092)	(10.734)	(8.893)	(11.675)			
Affect	6.806	6.715	6.632	9.008	7.104	0.720	0.002***	0.572
	(5.849)	(5.96)	(5.738)	(7.06)	(5.124)			
Communication	3.775	3.857	3.992	3.843	2.844	0.244	0.000***	0.000***
	(5.179)	(5.235)	(5.238)	(4.689)	(4.791)			
Interactions	5.338	5.302	5.331	6.033	5.344	0.981	0.587	0.294
	(7.108)	(7.199)	(6.631)	(8.06)	(7.58)			
N	800	712	40	9	39			
Wave=2								
ASQ:SE	53.950	52.634	55.749	52.934	55.771	0.001***	0.249	0.171
	(28.852)	(28.015)	(29.769)	(25.647)	(30.767)			
Self-regulation	15.375	14.775	15.845	15.909	16.823	0.001***	0.004***	0.02**
	(11.647)	(11.194)	(11.867)	(8.292)	(13.545)			
Adaptive functioning	10.519	10.202	11.209	10.041	10.375	0.008***	0.542	0.819
	(9.208)	(9.059)	(9.448)	(8.933)	(9.284)			
Affect	8.513	8.473	8.276	7.686	9.490	0.363	0.013**	0.000***
	(6.571)	(6.591)	(6.503)	(6.424)	(6.605)			
Compliance	2.702	2.796	2.775	2.500	2.202	0.221	0.009***	0.083*
	(3.756)	(3.702)	(3.807)	(2.646)	(4.057)			
Communication	4.506	4.637	4.720	3.678	3.583	0.308	0.000***	0.000***
	(5.915)	(5.8)	(6.382)	(5.582)	(5.177)			
Autonomy	1.974	1.871	2.167	2.434	1.881	0.248	0.946	0.628
	(3.711)	(3.625)	(3.678)	(4.725)	(3.864)			
Interactions	10.281	9.775	10.824	11.736	10.885	0.002***	0.033**	0.254
	(9.681)	(9.2)	(10.22)	(12.412)	(9.562)			
N	800	441	241	19	99			

Note. ASQ:SE questionnaire does not include Compliance and Autonomy in wave 1

Table 3. Summary statistics of children's non-cognitive development in different survey waves (Waves 3-4)

Variable	Full Sample	NLBC	FLBC	MLBC	BLBC	(2)-(3)	(2)-(4)	(2)-(5)
	Mean (Std.	Mean (Std.	Mean (Std.	Mean (Std. Dev.)	Mean (Std.	P-value	P-value	P-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wave=3								
ASQ:SE	56.756	56.152	57.577	49.298	59.365	0.026**	0.63	0.023**
	(32.109)	(31.341)	(33.074)	(32.018)	(32.899)			
Self-regulation	14.794	14.705	14.653	12.355	16.167	0.196	0.185	0.004***
	(12.159)	(12.016)	(12.116)	(12.026)	(12.83)			
Adaptive functioning	8.113	8.128	7.891	6.446	9.010	0.548	0.253	0.000***
	(8.879)	(8.807)	(8.744)	(6.691)	(9.901)			
Affect	7.888	8.029	7.782	6.901	7.75	0.341	0.204	0.034**
	(6.451)	(6.339)	(6.661)	(6.809)	(6.326)			
Compliance	2.494	2.452	2.552	1.364	2.823	0.052*	0.803	0.004***
	(3.767)	(3.78)	(3.747)	(2.887)	(3.904)			
Communication	4.538	4.598	4.828	2.727	3.99	0.625	0.000***	0.009***
	(5.555)	(5.567)	(5.555)	(5.041)	(5.518)			
Autonomy	2.050	1.890	2.192	2.231	2.385	0.004***	0.027**	0.777
	(3.656)	(3.478)	(3.84)	(4.181)	(3.807)			
Interactions	14.231	13.489	15.105	13.843	15.563	0.000***	0.016**	0.001***
	(10.833)	(10.52)	(11.177)	(10.95)	(11.089)			
N	800	397	271	26	106			
Wave=4								
ASQ:SE	71.438	70.29	71.255	67.769	78.083	0.014**	0.002***	0.008***
	(38.827)	(37.332)	(41.967)	(31.878)	(38.441)			
Self-regulation	25.606	25.163	24.967	20.826	30.438	0.007***	0.000***	0.000***
	(18.618)	(18.132)	(19.098)	(15.921)	(19.442)			
Adaptive functioning	6.475	6.259	6.598	6.198	7.229	0.033**	0.058*	0.100*
	(7.667)	(7.349)	(8.056)	(6.552)	(8.302)			
Affect	5.975	5.912	5.996	6.529	6.073	0.703	0.403	0.382
	(6.031)	(5.886)	(6.221)	(5.433)	(6.351)			
Compliance	4.956	5.134	5.092	3.967	4.052	0.144	0.000***	0.001***
	(5.967)	(6.097)	(6.118)	(4.912)	(5.066)			
Communication	5.219	5.034	5.485	4.215	5.656	0.006***	0.525	0.113
	(6.164)	(5.818)	(6.082)	(5.000)	(7.890)			
Autonomy	6.294	6.225	6.126	5.868	7.135	0.301	0.013**	0.085*
	(6.294)	(6.406)	(6.075)	(6.760)	(6.145)			
Interactions	14.450	14.106	14.594	18.347	14.688	0.388	0.015**	0.719
	(10.623)	(10.123)	(11.087)	(13.469)	(10.701)			
N	800	366	292	29	113			

Note. ASQ:SE questionnaire does not include Compliance and Autonomy in wave 1

Table 4. Summary statistics of children's non-cognitive development in different survey waves (Waves 5)

Variable	Full Sample	NLBC	FLBC	MLBC	BLBC	(2)-(3)	(2)-(4)	(2)-(5)
	Mean (Std.	Mean (Std.	Mean (Std. Dev.)	Mean (Std. Dev.)	Mean (Std. Dev.)	P-value	P-value	P-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wave=5								
ASQ:SE	81.544	81.883	84.013	77.893	74.760	0.831	0.000***	0.174
	(45.832)	(47.06)	(46.239)	(40.238)	(39.382)			
Self-regulation	26.956	27.021	27.874	23.926	25.135	0.692	0.002***	0.166
	(18.089)	(17.926)	(18.634)	(16.371)	(17.706)			
Adaptive functioning	7.475	7.815	7.201	7.314	6.635	0.011**	0.043**	0.592
	(9.234)	(9.586)	(9.322)	(8.217)	(7.366)			
Affect	10.331	10.247	11.029	10.455	8.948	0.478	0.000***	0.01***
	(7.677)	(7.564)	(7.694)	(8.19)	(7.834)			
Compliance	5.488	5.510	6.046	5.165	4.073	0.951	0.000***	0.000***
	(6.017)	(5.964)	(6.274)	(5.161)	(5.58)			
Communication	6.894	6.863	7.305	6.653	6.073	0.670	0.011**	0.986
	(7.367)	(7.155)	(7.254)	(6.532)	(8.642)			
Autonomy	10.619	10.417	10.523	12.355	11.344	0.258	0.000***	0.007***
	(6.622)	(6.616)	(6.539)	(6.425)	(6.809)			
Interactions	10.944	11.282	10.778	10.744	9.854	0.027**	0.020**	0.594
	(10.442)	(10.596)	(10.417)	(10.521)	(9.691)			
N	800	288	351	38	123			

Note. ASQ:SE questionnaire does not include Compliance and Autonomy in wave 1

4.3. Main Results

Table 5 reports the main regression results. For FLBC, paternal migration increases ASQ:SE scores by 0.171 ($p < 0.01$), indicating a deterioration in children's socio-emotional outcomes. For MLBC, maternal migration has the largest effect (0.478, $p < 0.05$), significantly affecting self-regulation and adaptive functioning. For BLBC, the effects are also significant (0.406, $p < 0.01$), with impacts across multiple dimensions.

The magnitude of the estimated effects follows a clear and consistent pattern, with maternal migration exerting the largest impact, followed by joint parental migration, and

paternal migration showing relatively smaller effects.

Table 5. Effect of parental migration on early childhood non-cognitive development outcomes

Group	ASQ:SE score	Self-regulation	Adaptive functioning	Affect	Compliance	Communication	Autonomy	Interactions
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) FLBC	0.171***	0.159**	0.062	0.105	-0.077	0.132**	0.052	0.060
	(0.060)	(0.062)	(0.069)	(0.068)	(0.117)	(0.065)	(0.137)	(0.075)
N	3122	3122	3122	3122	2248	3122	2248	3122
(2) MLBC	0.478**	0.299*	0.397***	0.025	-0.211	0.110	0.373	0.468*
	(0.187)	(0.161)	(0.143)	(0.182)	(0.192)	(0.186)	(0.265)	(0.241)
N	1598	1598	1598	1598	1156	1598	1156	1598
(3) BLBC	0.406***	0.323***	0.205*	0.212*	-0.036	0.233*	0.215	0.348**
	(0.108)	(0.115)	(0.118)	(0.125)	(0.233)	(0.138)	(0.311)	(0.136)
N	1989	1989	1989	1989	1443	1989	1443	1989

Note. All standard errors account for clustering at the village level.
**p < .10, **p < .05, *** p < .01*

4.4. Parallel Trend Test

Table 6. Tests for parallel pre-trends.

Group	ASQ:SE score	Self-regulation	Adaptive functioning	Affect	Compliance	Communication	Autonomy	Interactions
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) $FLBC_{i-1}$	0.034	-0.011	-0.087	0.000	0.111	0.036	0.022	0.174
	(0.101)	(0.101)	(0.105)	(0.108)	(0.142)	(0.118)	(0.149)	(0.110)
(2) $FLBC_i$	0.196***	0.156**	0.061	0.105	0.054	0.135*	0.088	0.106
	(0.066)	(0.067)	(0.080)	(0.068)	(0.131)	(0.081)	(0.167)	(0.087)
N	3116	3116	3116	3116	2241	3116	2241	3116
(3) $MLBC_{i-1}$	0.087	-0.042	0.054	0.600*	-0.027	0.120	0.517	-0.234
	(0.204)	(0.256)	(0.274)	(0.328)	(0.280)	(0.320)	(0.347)	(0.176)
(4) $MLBC_i$	0.723***	0.595***	0.467**	0.338	-0.082	0.274	0.631*	0.391
	(0.231)	(0.221)	(0.198)	(0.292)	(0.236)	(0.291)	(0.320)	(0.269)
N	1595	1595	1595	1595	1152	1595	1152	1595
(5) $BLBC_{i-1}$	-0.184	-0.189	0.152	0.306	-0.344	-0.620***	-0.711	-0.044
	(0.218)	(0.245)	(0.295)	(0.265)	(0.303)	(0.183)	(0.295)	(0.274)
(6) $BLBC_i$	0.499***	0.318**	0.338**	0.432***	-0.152	0.120	0.055	0.386**
	(0.125)	(0.140)	(0.132)	(0.125)	(0.270)	(0.141)	(0.312)	(0.152)
N	1987	1987	1987	1987	1439	1987	1439	1987

Note. $FLBC_i$ *means the period of first paternal migration,* $FLBC_{i-1}$*means the period before first paternal migration, other variables are as above.*
All standard errors account for clustering at the village level.
**p < .10, **p < .05, *** p < .01*

Table 6 presents the parallel trend tests. Most pre-treatment coefficients are statistically

insignificant, supporting the validity of the parallel trends assumption. Although a few coefficients are significant, their magnitude is relatively small and does not undermine the overall identification strategy.

4.5. Robustness Checks

Tables 7 and 8 report robustness checks using the CSDID approach. Across all groups, the average treatment effects (ATE) after migration are significantly positive, confirming the negative impact of migration on child health.

Table 7. Robustness check using CSDID model.

Group	ASQ:SE score	Self-regulation	Adaptive functioning	Affect	Compliance	Communication	Autonomy	Interactions
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) ATE before migration (FLBC)	-0.043	0.131	-0.099	-0.039	-0.289	0.069	-0.096	-0.220
	(0.113)	(0.112)	(0.140)	(0.116)	(0.352)	(0.126)	(0.173)	(0.133)
(2) ATE after migration (FLBC)	0.179**	0.142*	0.061	0.030	0.093	0.140*	0.237	0.073
	(0.069)	(0.073)	(0.080)	(0.075)	(0.212)	(0.083)	(0.237)	(0.085)
N	2462	2462	2462	2462	1051	2462	1051	2462
(3) ATE before migration (MLBC)	0.159	0.480***	0.036	-0.422	-1.547	0.442	-0.011	-0.234
	(0.188)	(0.177)	(0.266)	(0.265)	(3.858)	(0.274)	(0.468)	(0.197)
(4) ATE after migration (MLBC)	0.719***	0.429**	0.518*	0.102	-2.402	0.096	1.599**	0.878**
	(0.215)	(0.207)	(0.291)	(0.300)	(1.442)	(0.278)	(0.696)	(0.342)
N	1518	1518	1518	1518	961	1518	961	1518
(5) ATE before migration (BLBC)	0.095	-0.050	-0.008	0.155	1.088*	0.348	-0.244	0.156
	(0.218)	(0.266)	(0.270)	(0.242)	(0.622)	(0.341)	(0.604)	(0.321)
(6) ATE after migration (BLBC)	0.534***	0.480***	0.362**	0.304**	-0.882	0.142	0.821	0.239
	(0.127)	(0.142)	(0.150)	(0.154)	(2.794)	(0.180)	(3.399)	(0.159)
N	1709	1709	1709	1709	963	1709	963	1709

Note. The table uses wave1-wave4 data because wave5 has 2 years and it means 4 times than other waves' interval time, this is not allowed.
All standard errors account for clustering at the village level.
**p < .10, **p < .05, *** p < .01*

Figures 3–10 illustrate the dynamic treatment effects across different groups over time. Overall, the estimated patterns are highly consistent with the baseline regression results, providing strong visual support for the empirical findings. In particular, the figures reveal that

the negative impacts emerge shortly after the onset of treatment and persist throughout subsequent periods, indicating that the effects are both immediate and sustained. Moreover, there is no clear evidence of attenuation over time, suggesting that these adverse effects may have long-lasting implications for children's socio-emotional health.

Table 8. Robustness check using CSDID model.

Group	ASQ:SE score	Self-regulation	Adaptive functioning	Affect	Compliance	Communication	Autonomy	Interactions
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(7) ATE before migration (FLBC)	-0.052	0.114	-0.296	-0.335	#	0.102	#	0.138
	(0.182)	(0.184)	(0.193)	(0.240)	#	(0.200)	#	(0.192)
(8) ATE after migration (FLBC)	0.193**	0.186**	0.032	0.133	-0.043	0.197**	-0.074	-0.044
	(0.085)	(0.083)	(0.093)	(0.092)	(0.210)	(0.094)	(0.209)	(0.094)
N	1745	1745	1745	1745	662	1745	662	1745
(9) ATE before migration (MLBC)	-0.147	-0.112	0.334	-0.649	#	0.261	#	-0.185
	(0.364)	(0.429)	(0.522)	(0.430)	#	(0.410)	#	(0.367)
(10) ATE after migration (MLBC)	0.558***	0.399*	0.368**	-0.020	0.113	0.122	-0.110	0.531**
	(0.202)	(0.206)	(0.172)	(0.197)	(0.431)	(0.263)	(0.426)	(0.240)
N	930	930	930	930	570	930	570	930
(11) ATE before migration (BLBC)	-1.480	-0.497	-3.569	-1.034	#	-0.034	#	-0.174
	(1.125)	(1.484)	(2.789)	(1.950)	#	(1.628)	#	(1.308)
(12) ATE after migration (BLBC)	0.400***	0.406***	0.268*	0.105	-0.901*	0.255*	0.346	0.182
	(0.122)	(0.130)	(0.145)	(0.150)	(0.546)	(0.151)	(0.690)	(0.155)
N	1098	1098	1098	1098	570	1098	570	1098

Note. The table uses wave1/wave4/wave5 data because their interval time are all same.
All standard errors account for clustering at the village level.
**p < .10, **p < .05, *** p < .01*

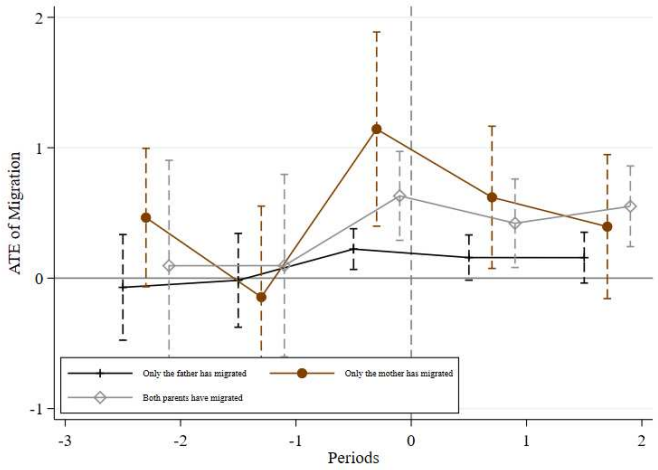
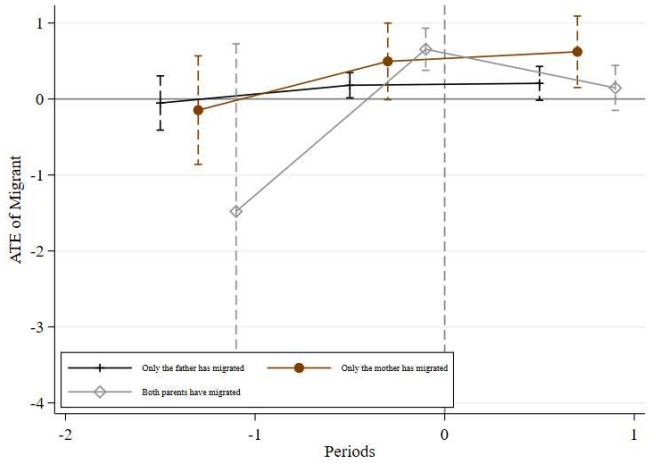
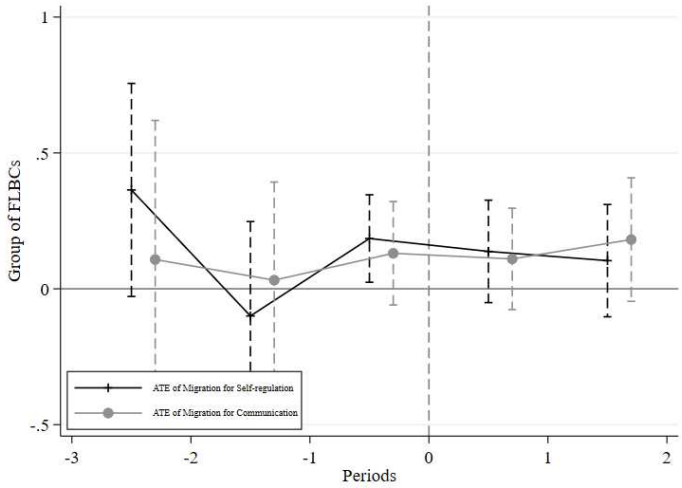


Fig.3. The ATE for non-cognitive development of children by parental migration.



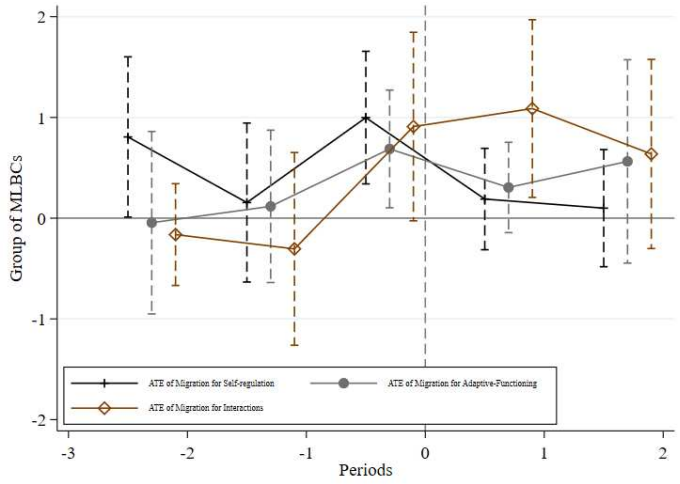
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281 **Fig.4.** The ATE for non-cognitive development of children by parental migration.



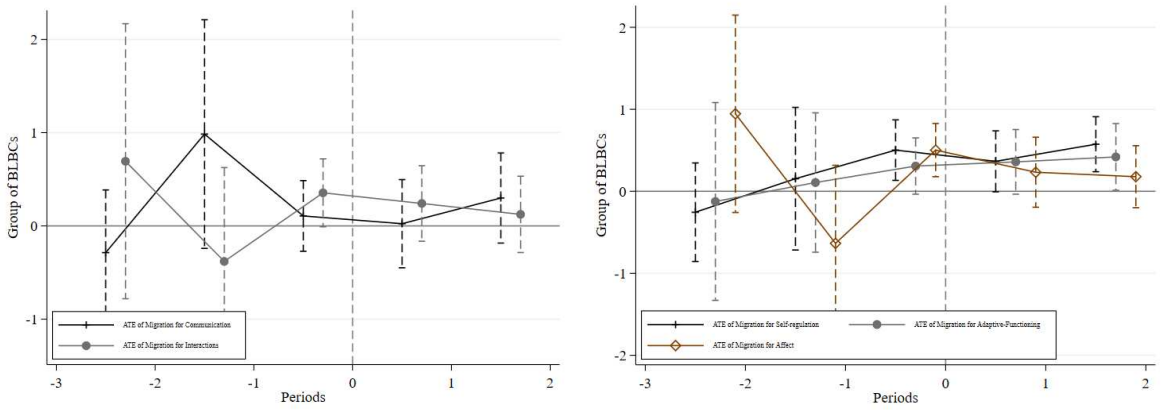
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283 **Fig.5.** The ATE for different non-cognitive development of FLBC**s** by parental migration.



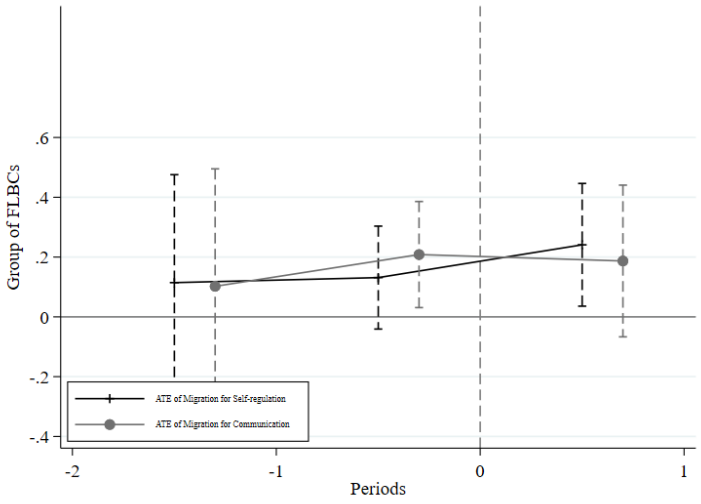
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285 **Fig.6.** The ATE for different non-cognitive development of MLBC**s** by parental migration.



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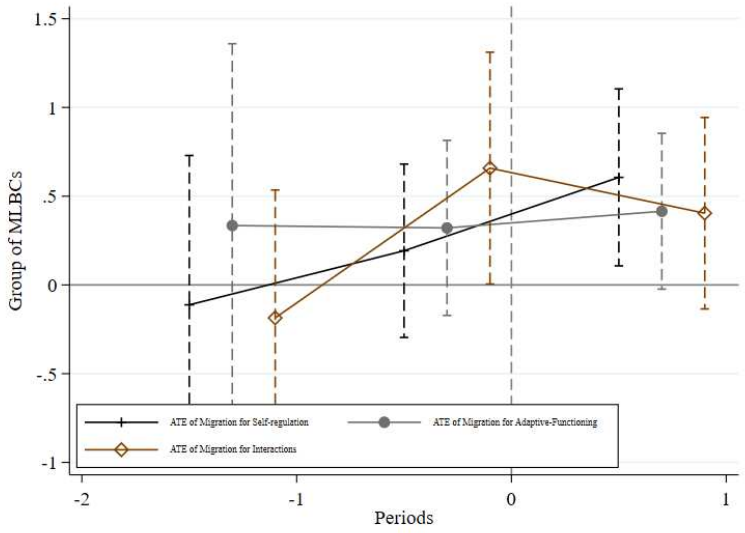
287 **Fig.7.** The ATE for different non-cognitive development of BLBC**s** by parental migration.



288

289 **Fig.8.** The ATE for different non-cognitive development of FLBC**s** by parental migration.

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291

Fig.9. The ATE for different non-cognitive development of MLBC**s** by parental migration.

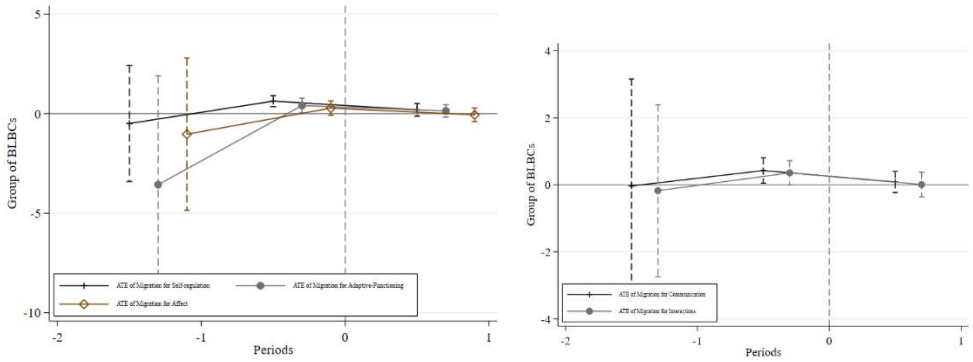


Fig.10. The ATE for different non-cognitive development of BLBC**s** by parental migration.

5. Mechanism Analysis

To better understand the mechanisms through which parental migration affects children's socio-emotional health, Table 9 presents the estimated associations between different types of parental migration and caregiving practices. The results reveal distinct patterns across paternal migration, maternal migration, and joint parental migration, providing important insights into the underlying pathways.

Table 9. Associations between parental migration and parenting practices of primary caregivers

	Watch TV	Kiss child	Used	Told	Told stories	Sang to	Spank	Spending
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	-1.119**	-0.344**	-0.035	0.018	-0.568	-0.184	0.213	0.210
Migration	(0.516)	(0.143)	(0.040)	(0.026)	(1.104)	(0.716)	(0.189)	(0.173)
N	1533	3122	2782	2782	911	910	908	910
(2)	-2.692***	0.324	-0.252**	-0.114*	-0.442	-3.638**	0.403	-0.034
Migration	(0.971)	(0.461)	(0.100)	(0.059)	(0.294)	(1.490)	(0.403)	(0.652)
N	801	1598	1440	1440	484	484	484	484
(3)	-1.154	0.061	-0.157*	-0.053	-2.278*	-0.141	0.541***	0.456*
Migration	(1.698)	(0.287)	(0.082)	(0.044)	(1.264)	(1.222)	(0.197)	(0.231)
N	981	1989	1779	1779	589	589	588	588

Note. All standard errors account for clustering at the village level.
**p < .10, **p < .05, *** p < .01*

5.1 Paternal migration (FLBC)

For children whose fathers migrate, the results show a significant reduction in the

amount of time spent in parent–child interaction. Specifically, paternal migration reduces the time caregivers spend watching television with children by approximately 1.119 hours per day ($p < 0.05$), and significantly decreases the frequency of affectionate behaviors such as kissing ($p < 0.05$).

These findings provide strong evidence that the observed effects operate primarily through changes in caregiving time allocation. In rural households, the absence of fathers often increases the workload and psychological burden of remaining caregivers, typically mothers, thereby reducing both the quantity and emotional quality of interactions with children.

Importantly, however, paternal migration does not significantly affect indicators related to interaction quality, such as storytelling or playing with toys. This suggests that while the quantity of caregiving time declines, the quality of interactions remains relatively stable.

These findings suggest that paternal migration primarily reduces caregiving time, while having limited effects on the quality of structured developmental interactions.

5.2 Maternal migration (MLBC)

The effects of maternal migration are substantially stronger and more comprehensive. As shown in Table 9, maternal migration significantly reduces caregiving time by approximately 2.692 hours per day ($p < 0.01$), which is more than twice the magnitude observed for paternal migration.

More importantly, maternal migration is also associated with significant declines in multiple indicators of interaction quality. The probability of caregivers playing with toys

decreases by 25.2% ($p < 0.05$), while the likelihood of storytelling declines ($p < 0.10$), and the frequency of singing to children decreases significantly ($p < 0.05$). These activities are widely recognized as critical forms of health-related developmental stimulation during early childhood.

This pattern indicates that maternal migration simultaneously affects both the quantity and quality of caregiving inputs. Given that mothers typically serve as primary caregivers in rural households, their absence leads not only to reduced time investment but also to a substantial deterioration in emotionally responsive and cognitively stimulating interactions.

Therefore, the negative effects of maternal migration on children's socio-emotional health are driven by a dual mechanism: (1) A sharp decline in caregiving time; (2) A significant reduction in interaction quality. This dual pathway provides a clear explanation for why maternal migration has the largest adverse impact among all migration types.

5.3 Joint parental migration (BLBC)

For children whose both parents migrate, the mechanism differs from that of single-parent migration. The results show that joint migration does not significantly reduce total caregiving time, suggesting that substitute caregivers (typically grandparents) partially compensate for the absence of parents in terms of time allocation.

However, joint parental migration is associated with significant declines in indicators of interaction quality. The likelihood of playing with toys decreases ($p < 0.10$), and the frequency of storytelling declines significantly ($p < 0.10$). At the same time, the probability of using physical punishment (spanking) increases significantly ($p < 0.01$), indicating a shift

toward less supportive and potentially harsher caregiving practices.

These findings suggest that while substitute caregivers are able to maintain the quantity of care, they are unable to replicate the quality of parental interactions, particularly in terms of emotional responsiveness and health-related developmental stimulation.

Thus, the primary mechanism underlying joint parental migration appears to be a deterioration in interaction quality driven by caregiver substitution.

5.4 Summary of mechanisms

Overall, the mechanism analysis reveals clear heterogeneity across migration types:

(1) Paternal migration mainly operates through a reduction in caregiving time;

(2) Maternal migration operates through both reduced caregiving time and lower interaction quality;

(3) Joint parental migration primarily affects interaction quality through caregiver substitution.

These findings highlight the importance of distinguishing between different types of parental migration and underscore the critical role of caregiving quality in shaping early childhood socio-emotional health.

6. Discussion

The findings highlight the central role of caregiving environments in shaping early socio-emotional health. Maternal migration appears particularly disruptive, likely because mothers typically serve as primary caregivers in early childhood. Their absence affects both the quantity and quality of interactions that are essential for emotional and social

development. In contrast, paternal migration has more limited effects, reflecting differences in caregiving roles within households. For children experiencing joint parental migration, substitute caregivers can maintain basic care but often provide lower-quality health-related developmental stimulation. From a public health perspective, these findings highlight how early-life family environments contribute to health inequalities[13–15, 74]. Children exposed to parental migration may experience disadvantages in socio-emotional health that accumulate over time and affect long-term well-being, including mental health and social functioning.

Our results are broadly consistent with previous studies documenting adverse health outcomes among left-behind children[29–34, 46–49, 75–77], but they extend prior research in several important ways. First, by focusing on preschool-aged children, this study sheds light on a critical developmental stage that has received relatively limited attention. Second, by distinguishing between paternal, maternal, and joint parental migration, we uncover substantial heterogeneity that is often obscured in studies treating left-behind children as a homogeneous group[44, 45]. Third, the use of longitudinal data allows us to track dynamic changes over time and better account for unobserved individual heterogeneity.

The findings also contribute to the broader literature on non-cognitive skill formation. Early socio-emotional skills are shaped by caregiving environments, parental investments, and daily interaction patterns[10, 11, 56, 57]. Our results suggest that parental migration disrupts these inputs in ways that are consequential for early-life health development. These findings highlight the importance of caregiving environments in shaping early socio-

391 emotional health.

392 The heterogeneity across migration types can be understood in light of differences in
393 caregiving roles within households. Mothers typically serve as primary caregivers in early
394 childhood, and their absence may therefore disrupt both routine caregiving and emotional
395 bonding. This interpretation is consistent with attachment theory, which emphasizes the
396 importance of stable and responsive caregiver–child relationships for emotional regulation
397 and social development[61, 62]. It is also in line with previous studies showing that maternal
398 absence tends to have stronger health consequences because of mothers' central role in early
399 caregiving[65, 66]. In contrast, fathers are generally less involved in daily caregiving
400 activities, which may explain the relatively smaller effects observed for paternal migration.
401 For children experiencing joint parental migration, substitute caregivers can maintain basic
402 care but often lack the capacity to provide high-quality health-related developmental
403 stimulation, which may explain the stronger interaction-quality channel identified in our
404 mechanism analysis[53, 63, 64].

405 More broadly, these findings are consistent with the view that parental migration
406 involves a trade-off between improved household income and reduced parental caregiving
407 inputs[53–55]. Although migration may alleviate poverty and relax budget constraints[78,
408 79], these gains do not fully offset the developmental costs associated with parental absence
409 during early childhood. This trade-off appears especially important for socio-emotional
410 outcomes, which depend heavily on stable routines, emotional support, and responsive
411 interactions[10, 11, 56, 57]. This trade-off has important implications for population health,

as improvements in household economic conditions may not fully compensate for the adverse effects of reduced parental care on early-life health outcomes.

Several limitations should be acknowledged. Although the longitudinal design and empirical strategies employed in this study help mitigate potential biases, residual confounding may remain due to unobserved time-varying factors. In addition, the findings are based on rural China and may not be directly generalizable to other institutional or cultural contexts. Future research could explore similar questions in other settings and examine whether the effects identified here persist into later childhood and adolescence.

Despite these limitations, this study provides comprehensive evidence on the health consequences of parental migration and highlights the central role of caregiving environments in shaping early socio-emotional outcomes.

7. Public health implications

The findings suggest that interventions should focus on improving caregiving environments for left-behind children. Expanding access to early-life health development services and community-based childcare may help compensate for reduced parental presence.

Improving the quality of caregiver–child interactions is also critical. Training programs for substitute caregivers, particularly grandparents, may enhance their ability to provide responsive and developmentally appropriate care.

In addition, policies that facilitate parent–child co-residence or provide childcare support in migrant-receiving areas may help reduce prolonged separation during early childhood.

These findings suggest the need for integrated public health strategies that address both

family environments and child health services. Expanding access to early childhood health programs, improving caregiver support systems, and reducing prolonged parent–child separation may help mitigate health inequalities associated with parental migration.

8. Conclusion

This study provides comprehensive longitudinal evidence that parental migration is associated with significant disadvantages in socio-emotional health during early childhood. The findings show a clear pattern of heterogeneity across migration types, with maternal migration exerting the largest negative impact, followed by joint parental migration, and paternal migration having relatively smaller effects.

This study contributes to the literature in several important ways. First, it provides new evidence on preschool-aged children, a group that has been largely overlooked in previous research on left-behind children[35, 46–49, 80–82]. Second, it highlights the importance of distinguishing between different parental migration patterns, revealing substantial heterogeneity in both the magnitude and mechanisms of the effects[44, 45]. Third, by combining longitudinal analysis with mechanism identification, the study offers a more comprehensive understanding of how parental migration influences early-life health development.

From a policy perspective, the findings underscore the importance of strengthening caregiving environments for left-behind children. Expanding early-life health development programs, improving the quality of substitute caregiving through targeted training, and promoting policies that reduce prolonged parent–child separation may help mitigate the

negative consequences of parental migration.

More broadly, the results suggest that improvements in household income through migration may come at the cost of reduced health-related investments in early childhood. Addressing this trade-off is essential for promoting long-term human capital formation and reducing inequality in health outcomes. Meanwhile, the findings highlight the importance of early-life interventions in reducing health inequalities and improving long-term population health outcomes.

Future research could further explore the long-term impacts of parental migration and evaluate the effectiveness of policy interventions.

Declarations

Ethics approval and consent to participate

The procedure for the study received ethical approval from the Stanford University Institutional Review Board (IRB; Protocol ID 25734) and from the Sichuan University Ethical Review Board (Protocol ID 2013005–01).

Written informed consent was obtained from the legal guardians of all participants before data collection. All procedures were performed in accordance with the Declaration of Helsinki and relevant guidelines and regulations for research involving human participants.

Consent for publication

Everyone who participated in the research consented to the authors' use of the data.

Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due to authorization restrictions for the project but are available from the corresponding author on reasonable request.

Competing interests

The authors declare no competing interests.

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Authors' contributions

YD conceived and designed the study, and he performed the statistical analysis. Meanwhile, YD also conducted the literature search and wrote the main manuscript. All authors provided critical feedback and commented on the manuscript. All authors approved the final version of the manuscript for submission.

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