Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Climate Hazard Exposure and Involuntary Immobility: Evidence from Rural China Using an Instrumental Variable Approach

Xinyue Zhao

XinyueZhao202605@163.com

Imperial College London https://orcid.org/0009-0009-4708-8621

Research Article

Keywords: constrained immobility, climate hazard, trapped populations, instrumental variable, aspiration-capability framework

Posted Date: August 31st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9920074/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Abstract

Climate change is widely expected to drive population displacement, but climate hazards may also trap vulnerable households by eroding the resources needed to migrate. This study examines the effect of climate hazard exposure on a conservative proxy for involuntary immobility, defined as climate-exposed non-migration under observable capability constraints. Using China Family Panel Studies data linked with ERA5 reanalysis climate data for rural China from 2010 to 2020, the analysis combines an aspiration-capability framework with an instrumental variable strategy. The preferred specification uses a shift-share instrument that interacts historical climate variability from 1950 to 1980 with wave-specific national climate anomalies. In the IV-2SLS model, a full-unit increase in the 0–1 composite climate hazard index raises constrained immobility by 23.1 percentage points; evaluated at the observed standard deviation, this equals about 4.3 percentage points. Effects are approximately three times larger for households in the poorest asset quartile than for those in the richest quartile. Mechanism diagnostics indicate that economic constraints are the strongest observable pathway, followed by information, network, infrastructure, and administrative barriers. Findings show that adaptation policy must address households unable to migrate, not only those who move.

1. Introduction

Climate change is reshaping global patterns of human mobility. A growing body of interdisciplinary research shows that extreme weather events, temperature shocks, droughts, and slow-onset environmental change can alter household migration decisions by changing livelihood security, agricultural returns, perceived risk, and the cost of remaining in place [1], [2]. Large-scale climate-migration projections have therefore become central to adaptation planning, especially because internal migration is expected to account for a substantial share of climate-related mobility within countries [3]. Yet this literature has often foregrounded displacement and out-migration, while giving less attention to households that want to leave but cannot do so because climate stress has weakened their capacity to move.

Theoretically, migration decisions can be understood through the aspiration-capability framework, which treats migration as the joint outcome of a desire to move and the resources required to act on that desire [4], [5]. Climate shocks may raise migration pressure by increasing perceived risk, reducing livelihood viability, and lowering expectations of future security. At the same time, the same shocks may erode migration capability by destroying savings, damaging productive assets, reducing income, weakening social networks, or disrupting local infrastructure. The intersection of high relocation pressure and low capability defines involuntary immobility or trapped populations. Because the CFPS waves used here do not provide a consistently comparable direct household relocation-aspiration item, the empirical outcome is treated as a constrained-immobility proxy rather than as a direct subjective aspiration measure. This distinction makes the claim more conservative while preserving the core theoretical concern: climate exposure can create visible migration flows as well as less visible inability to exit hazardous places [6], [7].

This gap is consequential for both climate science and policy. If the net effect of climate hazards is to increase immobility among vulnerable households, then the policy response cannot be limited to managing displacement flows, providing destination-city services, or forecasting future migration corridors. It must also include in-situ protection, liquidity support, targeted asset replacement, risk insurance, and voluntary relocation assistance for households that face high exposure but lack the means to move. Without such evidence, adaptation resources may continue to be directed at households who are already mobile, systematically neglecting those who face the greatest risks but have the least capacity to exit.

We address this gap using a large-scale working sample from rural China. China provides a theoretically important setting because it combines one of the world's largest internal migration systems with substantial spatial variation in climate exposure, rural livelihood dependence, infrastructure access, and household adaptation capacity. Recent assessments document rising climate extremes and drought-related risks in China [8], [9]. Internal migration in China is also spatially heterogeneous and strongly conditioned by household resources, regional opportunity structures, social characteristics, and institutional constraints [10]. This setting makes it possible to test whether climate hazards generate not only migration, but also constrained non-mobility among resource-constrained rural households.

Our identification strategy uses historical climate variability computed over 1950–1980 to construct a shift-share instrumental variable for contemporary climate hazard exposure. Specifically, predetermined county-level historical variability is interacted with wave-specific national climate anomalies, so the preferred instrument varies over time and is not absorbed by village fixed effects. Historical variability captures differential exposure to climate-sensitive local conditions, while national climate anomalies provide common time-varying shocks. We validate the strategy through first-stage F-statistics, event-study checks, placebo specifications, and robustness tests. The climate-economy identification logic follows prior work using temperature and climate shocks in economic outcomes [11]. The migration-response specification is also aligned with climate-migration research using temperature variation [12]. The shift-share component follows the Bartik-instrument interpretation of predetermined local exposure [13] and recent quasi-experimental shift-share designs based on common aggregate shocks [14].

We make four contributions. First, we provide large-scale micro-level evidence that climate hazard exposure is associated with a conservative proxy for involuntary immobility in a middle-income country context. Second, we document asset-mediated heterogeneity: the immobility-inducing effect is largest among the poorest households, consistent with a climate-related immobility trap at low asset levels. Third, we examine mechanisms in a diagnostic rather than over-identified mediation framework, showing that economic constraints account for the strongest observable pathway, while information barriers, social-network disruption, infrastructure-related constraints, and administrative limitations provide additional channels. Fourth, we develop a more explicit conditional framework that distinguishes displacement, voluntary immobility, and constrained immobility by identifying the household and place-based conditions under which climate stress is most likely to become an entrapment mechanism rather than a migration trigger.

The remainder of the paper is organized as follows. Section 2 reviews the literature on climate mobility, trapped populations, and the aspiration-capability approach. Section 3 develops the theoretical framework, mechanism logic, hypotheses, and boundary conditions. Section 4 describes the data and measurement strategy. Section 5 presents the identification strategy and econometric specification. Section 6 reports the main results, heterogeneity analysis, and robustness checks. Section 7 elaborates the mechanism diagnostics and conditional pathways. Section 8 discusses theoretical, policy, and scope implications. Section 9 concludes.

2. Literature Review

2.1 Climate Change and Human Mobility

The relationship between climate change and human migration has attracted substantial scholarly attention over the past two decades. Early contributions established that changes in precipitation and temperature can alter migration rates by affecting crop yields, rural income, and household livelihood strategies [15], [16]. Later work examined how extreme events such as floods, droughts, heatwaves, and typhoons influence both short-term displacement and longer-term migration decisions [17], [18]. Evidence from rural Pakistan further shows that heat stress can increase long-term migration through negative effects on farm and non-farm income [19].

Recent reviews and meta-analyses confirm that the climate-migration relationship is context-dependent. Income, institutional quality, market access, household assets, and social capital can all moderate whether climate stress encourages mobility or constrains it [2], [18]. In some settings, climate shocks raise migration by reducing agricultural returns and increasing the expected benefits of leaving. In other settings, they reduce migration by damaging the very resources that would finance relocation. The same physical hazard can therefore produce opposite mobility outcomes across households, regions, and time horizons. Methodologically, the field has moved from reduced-form correlations toward stronger quasi-experimental designs, including instrumental variables, event-study designs, and panel models with spatial and temporal fixed effects [11], [16]. This methodological progress creates a basis for examining immobility as a climate outcome rather than treating non-migration as an absence of response.

The displacement-centered view remains useful but incomplete. Migration can be an adaptive response when households have sufficient information, liquidity, networks, and destination access. However, the ability to migrate is unevenly distributed. When the poorest households face shocks, their relative need to move may increase at precisely the moment when their capability to do so declines. A climate hazard may thus operate through two competing channels: an aspiration-raising channel and a capability-eroding channel. Whether the observed outcome is migration, immobility, or delayed movement depends on which channel dominates under specific household and local conditions.

2.2 The Involuntary Immobility Hypothesis

Relative to the displacement literature, empirical work on involuntary immobility remains limited. The Foresight report on migration and global environmental change identified trapped populations as a major policy concern because climate risk can reduce the ability to move even when the desire to move increases [20]. Global evidence suggests that climate change can increase resource-constrained international immobility when households lack sufficient resources to finance migration [21]. This insight challenges a linear reading of climate mobility: higher exposure does not necessarily imply more migration, especially where migration is costly and credit constrained.

At the micro level, Freihardt documented involuntary immobility among households exposed to riverbank erosion in Bangladesh, showing that a nontrivial share of non-migrants had migration aspirations but were unable to act on them [22]. Transiskus and Gholamzadeh Bazarbash reported related evidence in the Lake Urmia context in Iran, emphasizing that immobility can include ambivalent and precarious forms rather than a simple binary between voluntary staying and being trapped [23]. Letta, Montalbano, and Paolantonio used household-level evidence from Nigeria to show that pre-shock assets and adaptive capacity can determine not only the size but also the sign of mobility responses to climate shocks [24]. These studies motivate a household-level test of immobility traps in rural China.

For China, the climate-mobility literature has focused primarily on rural-to-urban migration, agricultural productivity shocks, and internal mobility as a coping strategy. Comparative evidence from Asia also shows that climate variability can alter internal migration flows, but the sign and magnitude of the effect depend on household resources and regional opportunity structures [25]. Less is known about households that remain in place despite wanting to move. This gap is important because climate exposure, rural poverty, migrant-network access, and relocation capability are unevenly distributed across counties and villages. Immobility may generate welfare losses that are not visible in migration-flow statistics, including deeper income insecurity, reduced educational investment, declining health, and stronger dependence on climate-sensitive livelihoods.

2.3 Aspirations-Capabilities Framework

The aspiration-capability framework provides the theoretical foundation for the analysis [4], [5]. Migration aspiration refers to the desire or perceived need to relocate, shaped by risk perception, relative deprivation, livelihood expectations, place attachment, and information about alternatives. Migration capability refers to the material, social, informational, physical, and administrative resources required to realize a migration intention. Under this framework, involuntary immobility arises when aspirations exceed capabilities. Recent review evidence shows that this distinction is important because remaining in place can reflect preference, attachment, constraint, fear, institutional exclusion, or a combination of these conditions. Environmental immobility research shows that non-migration can reflect heterogeneous empirical situations rather than a single residual category [26]. Governance-oriented work further distinguishes being trapped from choosing to stay put [27]. Theoretical work on environmental (im)mobility also emphasizes that staying may be shaped by agency, constraint, and place-based attachment at the same time [28].

This framework is especially useful for climate-mobility research because it prevents two common errors. The first is to interpret all non-migration as voluntary staying. The second is to interpret all climate exposure as displacement pressure. In reality, households may want to move but lack cash, networks, transportation, employment information, housing access, or registration support. Alternatively, they may prefer to stay because of land attachment, kinship obligations, cultural identity, caregiving responsibilities, or satisfaction with local adaptation. Empirically distinguishing these positions is essential because each requires a different policy response.

Recent climate policy work argues that involuntary immobility is underrepresented in disaster planning and adaptation finance [7]. This policy blind spot is particularly acute for elderly populations, informal settlements, low-income rural households, and communities dependent on climate-sensitive livelihoods. If climate hazards reduce mobility capability, then adaptation policy that focuses only on resettlement, evacuation, or destination-city integration will miss households that are most exposed but least able to leave. The present study therefore treats immobility as an active outcome of climate stress and social constraint, not as a residual category left over after migrants have been counted.

3. Theoretical Framework, Mechanisms, and Hypotheses

3.1 Aspiration and Capability as Separate Dimensions

Drawing on the aspiration-capability framework, we model climate-related mobility as a two-dimensional process. The first dimension is migration aspiration: the extent to which households perceive relocation as desirable or necessary. The second dimension is migration capability: the extent to which households possess the resources, opportunities, and institutional access needed to act on that aspiration. These dimensions are conceptually distinct. A household can have high aspiration and high capability, producing voluntary mobility. It can have low aspiration and high capability, producing voluntary immobility. It can have low aspiration and low capability, producing acquiescent immobility. The analytically important case in this study is high aspiration combined with low capability, which produces involuntary immobility.

Climate hazards can affect both dimensions simultaneously. Flooding, drought, and extreme heat may raise aspiration by increasing perceived danger, destabilizing agricultural income, damaging housing, and weakening confidence in the future viability of local livelihoods. However, these same hazards can reduce capability by depleting savings, increasing debt, destroying productive assets, interrupting transport, reducing access to wage work, and increasing uncertainty about destination opportunities. The resulting mobility outcome is therefore not determined by exposure alone. It is determined by the interaction between hazard intensity and the household's capacity to convert migration desire into actual movement.

This distinction also clarifies why immobility should not be treated as a simple opposite of migration. Non-migration may be a successful adaptation strategy if households prefer to remain and have

adequate protection, livelihood alternatives, and local services. It may be a welfare loss if households want to leave but cannot. It may also be transitional if households delay movement while recovering assets after a shock. Because the available CFPS-based measure cannot directly observe all subjective aspirations across waves, the empirical challenge is to identify a conservative proxy for the subset of non-migrant households whose observed constraints make climate-related mobility difficult. The present measure follows this logic by focusing on climate-exposed non-movement under low capability rather than treating all non-migration as involuntary immobility.

3.2 Mediated Mechanism: From Hazard Exposure to Entrapment

The core mechanism is a climate-induced capability erosion pathway. Hazard exposure first affects household livelihood security through crop loss, income volatility, medical expenditure, asset damage, or debt accumulation. These losses then reduce liquidity and risk-bearing capacity. Because migration requires upfront expenses, including transportation, job search, housing deposits, documentation, and temporary consumption support, reduced liquidity can prevent households from acting on migration aspirations. In this sense, the shock that creates the reason to move also destroys the capacity to move.

The economic mechanism is likely to be reinforced by informational and network channels. Migrant networks reduce the cost and uncertainty of migration by providing destination information, temporary lodging, job referrals, and social support. Climate hazards can weaken these channels if shocks disrupt communication, force network members to prioritize their own recovery, or reduce the household's ability to maintain reciprocal obligations. Information scarcity also increases perceived destination risk, making households less able to transform aspiration into action. For low-income households, the absence of a reliable network may be as constraining as the absence of cash.

Infrastructure and administrative channels provide additional mechanisms. Floods and storms can damage roads, bridges, schools, health facilities, and public transportation, raising the physical cost of leaving. Administrative barriers, including hukou-related access to services, documentation costs, insurance eligibility, and resettlement procedures, may further restrict movement. These barriers do not operate uniformly. They are most constraining when households already have low assets, weak networks, limited education, high dependency ratios, or heavy reliance on agricultural land. The mechanism is therefore both mediated and conditional: hazards increase immobility through capability constraints, and the strength of those constraints depends on household and village characteristics.

3.3 Boundary Conditions and Conditional Expectations

The proposed framework has several boundary conditions. First, the immobility effect should be stronger among households with low pre-shock assets. Households with savings, durable assets, or access to credit can absorb climate losses and still finance migration if they decide to move. Poor households, by contrast, may experience climate losses as a binding liquidity constraint. Second, the effect should be stronger among households with high agricultural dependence. Where income is tied to

land, crops, or local natural resources, climate shocks simultaneously damage current income and reduce collateral value, making it more difficult to finance movement.

Third, the effect should be weaker where households have dense migrant networks. Network contacts can reduce destination uncertainty, provide informal insurance, and lower the fixed cost of moving. Fourth, the effect should be stronger under repeated or cumulative exposure than under isolated shocks. A single shock may trigger temporary coping, but repeated exposure can exhaust savings, reduce creditworthiness, and erode social support. Fifth, local institutional support should moderate the hazard-immobility relationship. Emergency transfers, crop insurance, infrastructure repair, public employment programs, and relocation counseling can preserve mobility capability or support safe in-situ adaptation.

These boundary conditions are important because they prevent an overly general claim that climate hazards always trap households. The framework predicts entrapment only when climate exposure interacts with limited resources and weak enabling conditions. Where households have adequate assets, networks, destination opportunities, and institutional support, climate hazards may increase migration or voluntary relocation. Where households prefer to stay and receive effective in-situ support, non-migration may be welfare-enhancing. The theoretical contribution of this study is therefore conditional rather than universal: climate hazards produce involuntary immobility under identifiable resource, network, livelihood, and institutional constraints.

3.4 Hypotheses

H1 (Main Effect): Greater climate hazard exposure increases the probability of constrained immobility because the combined pressure-raising and capability-eroding effects of climate shocks dominate the pure displacement effect among vulnerable rural households.

H2 (Asset Heterogeneity): The immobility-inducing effect of climate hazards is larger for households with lower pre-shock asset endowments, consistent with the existence of an asset-mediated immobility trap at low wealth levels.

H3 (Economic Mechanism): The effect of climate hazards on constrained immobility is primarily transmitted through economic constraints, including destruction of savings, productive assets, and income-generating capacity, rather than through information barriers, infrastructure disruption, or administrative constraints alone.

H4 (Conditional Capability): The hazard-immobility relationship is stronger when households have weak migrant networks, high agricultural dependence, repeated exposure, or limited access to institutional support. These conditions intensify the conversion of climate exposure into capability loss.

The hypotheses are linked through an asset-mediated and conditionally reinforced immobility mechanism. Climate hazards are expected to increase relocation pressure by making local livelihoods more uncertain, but the same hazards also reduce household liquidity, destroy productive assets, and weaken access to migration information. When household assets are sufficiently high, the pressure-

raising effect may translate into mobility. When assets are low, the capability-eroding effect dominates and the household becomes trapped in place. This threshold logic explains why the expected effect should be strongest among the poorest households and why economic constraints should provide the strongest observable mechanism.

Figure 1 should appear here, as it presents the aspiration-capability framework used to distinguish voluntary mobility, voluntary immobility, acquiescent immobility, and involuntary immobility.

Involuntary immobility ('trapped populations') occupies the upper-left quadrant. Policy interventions aimed at increasing migration capability move households from this quadrant to the voluntary-mobility quadrant, while in-situ adaptation supports households that prefer to remain.

4. Data and Measurement

4.1 Household Panel Data (CFPS)

Our primary data source is the China Family Panel Studies (CFPS), a nationally representative longitudinal survey conducted by Peking University's Institute of Social Science Survey [29]. We use information from the 2010–2020 waves, including household economic conditions, residence and migration histories, family structure, education, income, and variables related to mobility capability. The original CFPS sample covers 25 provinces across China; after restricting the analysis to rural observations with linkable county-level climate exposure and non-missing core variables, the working sample contains 8,643 household-wave observations across 582 villages. The unit of analysis is therefore the household-wave observation, not 8,643 unique balanced-panel households.

Consistent with the aspiration-capability framework [4], [5] and recent immobility research [22], we operationalize the dependent variable as a constrained immobility proxy. Because the CFPS waves used in this study do not provide a consistently comparable direct five-point item asking all households about permanent relocation aspiration, we do not claim to observe subjective migration aspiration directly. Instead, a household-wave is coded as constrained immobile when the household remains in place between survey waves while also displaying observable low-capability conditions, including low assets, weak migration-related resources, and high dependence on climate-sensitive rural livelihoods. This proxy captures climate-exposed non-movement under observable constraints and should be interpreted more conservatively than a direct self-reported measure of involuntary immobility.

This binary outcome variable has a sample mean of 0.134, implying that 13.4% of household-wave observations in the rural analytic sample are classified as constrained immobility cases. The magnitude is substantively plausible because it is close to recent household-level estimates of involuntary immobility in climate-vulnerable contexts [22]. It also indicates that trapped or constrained populations are not a marginal category. They represent a measurable subset of rural households whose mobility capability appears limited under climate stress.

4.2 Climate Hazard Variables

Climate data are drawn from the ERA5 reanalysis product, which provides high-resolution atmospheric and land-surface climate estimates [30]. We aggregate daily data to the county level, matching each CFPS household to the county in which it resides using geographic coordinates from CFPS geocodes. The climate variables are therefore measured at the county-year level, while the migration outcome is measured at the household-wave level. This structure reduces the risk that household-specific reporting behavior drives the hazard measure, while preserving enough spatial variation to identify differential exposure across rural counties.

We construct a composite climate hazard index by combining three dimensions: flood frequency, measured as the number of days per year on which 24-hour precipitation exceeds the local 95th percentile; drought severity, measured by the 12-month Standardized Precipitation Index (SPI-12) [31]; and extreme heat exposure, measured as the number of days exceeding 35°C. Each dimension is normalized for descriptive analysis and z-standardized before estimation. The composite hazard index is computed as the first principal component of the three standardized variables, explaining 58.4% of the joint variance. Figure 2 presents descriptive patterns.

Note

Panel (a) shows the composite climate hazard exposure index by region; panel (b) plots the relationship between hazard exposure and involuntary immobility rates, stratified by household asset quartile.

Table 1 presents descriptive statistics for all variables. The observations reported in the table are household-wave observations. The outcome and climate exposure measures show substantial variation across household-waves, while the control variables capture the economic and demographic conditions expected to shape migration capability and constrained immobility.

Table 1
Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max	Source
Panel A: Migration Outcomes						
Constrained immobility proxy (binary)	8,643	0.134	0.341	0	1	CFPS
Constraint severity score (1–5)	8,643	2.47	1.18	1	5	CFPS
Migration capability index (0–1)	8,643	0.423	0.221	0	1	CFPS
Panel B: Climate Hazard Variables						
Composite hazard index (0–1)	8,643	0.412	0.187	0.04	0.89	ERA5
Flood frequency (events/yr)	8,643	1.83	1.41	0	9	ERA5
Drought severity (SPI-12)	8,643	-0.41	0.83	-2.87	1.24	ERA5
Temperature anomaly (°C)	8,643	0.68	0.52	-0.43	2.31	ERA5
Panel C: Household Characteristics						
Asset index (0–1)	8,643	0.381	0.198	0.02	0.97	CFPS
Annual household income (CNY 1,000)	8,643	38.47	29.82	1.20	318.5	CFPS
Education (years)	8,643	7.14	3.96	0	22	CFPS
Age of household head (years)	8,643	46.8	12.4	18	85	CFPS
Household size	8,643	3.72	1.53	1	12	CFPS
Agricultural dependence (0–1)	8,643	0.531	0.312	0	1	CFPS
Panel D: Instrument						
Hist. climate variability (1950–1980)	8,643	0.267	0.143	0.06	0.71	CRU TS

*Note. CFPS = China Family Panel Studies; ERA5 = ECMWF Reanalysis v5; CRU TS = Climatic Research Unit gridded Time Series. All monetary values are deflated to 2010 CNY. ***, **, * denote significance at 1%, 5%, and 10% levels.*

4.3 Measurement Validity and Construct Boundaries

The main measurement challenge is to distinguish involuntary immobility from voluntary staying. Because the available CFPS variables do not support a fully direct and consistently repeated subjective

aspiration measure, the analysis treats constrained immobility as a proxy constructed from observed non-movement and capability constraints. This approach reduces the risk of overstating what the data can identify. It also means that the outcome should be interpreted as climate-exposed constrained non-mobility rather than as a pure measure of stated desire to migrate. The interpretation is strengthened when the proxy is concentrated among households with low assets, weaker networks, higher agricultural dependence, and stronger reported constraints, but it remains more conservative than direct aspiration-behavior discordance.

A second measurement challenge concerns the climate hazard index. Composite indices can obscure differences among floods, droughts, and heat. We therefore use the composite index for the main analysis because the theoretical construct is cumulative hazard exposure, but we also evaluate alternative hazard definitions in robustness checks. The main conclusion is not driven by any single component. The economic logic is similar across hazard types: each can reduce income, damage assets, and increase the cost of relocation, although the temporal pattern may differ between sudden-onset and slow-onset hazards.

5. Identification Strategy

5.1 Empirical Specification

Our baseline OLS specification is:

ConstrainedImmobility(i,t) = alpha + beta * HazardIndex(c,t) + gamma X(i,t) + delta(p) + tau(t) + epsilon(i,t)

where ConstrainedImmobility is the binary constrained-immobility proxy for household i in period t; HazardIndex is the county-level 0–1 composite climate hazard index; X is a vector of household-level controls; province and wave fixed effects absorb stable regional differences and common period shocks; and the error term is clustered at the county level. Because the dependent variable is binary, the coefficient can be interpreted as an approximate percentage-point change in the probability of constrained immobility. Linear probability models are used for transparency and compatibility with the IV design; logit and probit marginal effects are treated as robustness checks because linear probability models can in principle generate predicted probabilities outside the 0–1 range.

5.2 Instrumental Variable

Ordinary least squares estimates of beta may be biased due to (i) measurement error in the hazard index, (ii) non-classical selection of households into high-risk counties, and (iii) exposure sorting because households with greater migration capability may leave high-risk places while lower-capability households remain. To address these threats, we adopt an instrumental variable strategy.

A purely time-invariant county-level instrument would be collinear with village fixed effects when villages are nested within counties. To avoid this problem, the preferred IV specification uses a shift-share

instrument: predetermined historical climate variability, computed as the standard deviation of annual precipitation at the county level over 1950–1980 using the Climatic Research Unit gridded Time Series dataset [32], interacted with wave-specific national climate anomalies. This design preserves the relevance of long-run local climate sensitivity while introducing time-varying exposure to common national shocks, so the instrument is not absorbed by village fixed effects. The exclusion restriction is not directly testable, but it is more plausible after controlling for household characteristics, province fixed effects, wave fixed effects, and village fixed effects, and it follows the Bartik-instrument interpretation of predetermined local exposure [13]. It also aligns with quasi-experimental shift-share designs that treat aggregate shocks as the source of time-varying variation [14].

The 2SLS estimating equations are:

First stage: HazardIndex(c,t) = phi * [HistVar(c) x NatClimateAnomaly(t)] + psi X(i,t) + delta(p) + tau(t) + nu(i,t)

Second stage: ConstrainedImmobility(i,t) = alpha + beta * HazardIndex(c,t) + gamma X(i,t) + delta(p) + tau(t) + epsilon(i,t)

Standard errors are clustered at the county level throughout to account for spatial correlation in climate shocks and household migration decisions. The IV estimates should be interpreted as quasi-experimental estimates conditional on the maintained exclusion restriction rather than as unconditional proof of causality. This qualification is important because historical climate variability could be correlated with long-run settlement patterns, agricultural specialization, or infrastructure investment. The shift-share formulation and inclusion of fixed effects reduce, but do not eliminate, these risks.

5.3 Robustness and Diagnostic Strategy

We evaluate robustness in four ways. First, we estimate specifications with progressively richer controls and fixed effects to examine whether the coefficient is sensitive to observable and time-invariant confounding. Second, we test alternative climate exposure measures, including separate flood, drought, and heat indicators, lagged exposure, and a percentile-based extreme-hazard indicator. Third, we conduct placebo tests using pre-period mobility outcomes and non-climate-related household outcomes that should not respond immediately to the instrumented hazard index. Fourth, we estimate event-study models around high-exposure shock years to examine pre-trends and post-shock dynamics. Fifth, because the dependent variable is binary, we compare the linear probability estimates with logit and probit marginal effects. The purpose of these checks is not to prove the exclusion restriction, which is inherently untestable, but to evaluate whether the observed pattern is consistent with the hypothesized climate-induced capability erosion mechanism.

6. Results

6.1 Main Estimation Results

Table 2 presents the main estimation results. Column (1) reports the baseline OLS specification with province and wave fixed effects but no household controls. Column (2) adds the full vector of household controls. Columns (3)-(5) report 2SLS estimates with increasing sets of controls and fixed effects, with column (5) serving as the preferred specification because the shift-share instrument remains time varying and can be estimated with village fixed effects.

Table 2
Main Regression Results: Climate Hazard Exposure and Involuntary Immobility

Dependent variable: Constrained immobility proxy (0/1)	**(1)OLS**	**(2)OLS**	**(3)IV**	**(4)IV**	**(5)IV**
Climate hazard index	0.182*** (0.021)	0.164*** (0.022)	0.243*** (0.034)	0.227*** (0.033)	0.231*** (0.033)
Asset index		-0.312*** (0.041)		-0.287*** (0.044)	-0.291*** (0.043)
Education (years)		-0.014*** (0.003)		-0.013*** (0.003)	-0.013*** (0.003)
Household size		0.022** (0.009)		0.021** (0.009)	0.020** (0.009)
Age of head		0.003*** (0.001)		0.003*** (0.001)	0.003*** (0.001)
Agricultural dependence		0.118*** (0.028)		0.107*** (0.029)	0.109*** (0.029)
Constant	0.079*** (0.012)	0.143*** (0.031)	0.063*** (0.015)	0.131*** (0.033)	0.128*** (0.033)
Province FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Village FE	No	No	No	No	Yes
Observations	8,643	8,643	8,643	8,643	8,643
R^2	0.147	0.284	—	—	—
First-stage F-stat	—	—	48.7	51.3	49.8
Kleibergen-Paap rk LM stat	—	—	46.2***	48.9***	47.1***

*Note. Dependent variable is a binary proxy for constrained immobility. All IV specifications use the shift-share instrument formed by interacting historical climate variability (1950–1980 s.d. of annual precipitation) with wave-specific national climate anomalies. Standard errors clustered at county level in parentheses. ***, **, * denote significance at 1%, 5%, and 10% levels.*

The OLS estimate in column (2) implies that a full-unit increase in the 0–1 composite hazard index raises constrained immobility by 16.4 percentage points. The IV estimate in column (5) is larger at 23.1 percentage points. Because a full-unit change is larger than the typical within-sample change, the effect should also be evaluated at the observed standard deviation of the index reported in Table 1. A one-standard-deviation increase of 0.187 corresponds to approximately 3.1 percentage points in the OLS specification and 4.3 percentage points in the preferred IV specification. This interpretation is more substantively plausible and avoids treating the full 0–1 range as a normal marginal change. The first-stage F-statistics range from 48.7 to 51.3, well above conventional weak-instrument thresholds. The Kleibergen-Paap rank LM statistics confirm instrument relevance.

The control variables behave in theoretically expected directions. Household assets and education are negatively associated with constrained immobility, suggesting that material and human capital improve migration capability. Household size and age of household head are positively associated with immobility, which may reflect higher dependency burdens, stronger place-based obligations, or lower flexibility in relocation decisions. Agricultural dependence is also positively associated with constrained immobility, consistent with the claim that households tied to climate-sensitive livelihoods face stronger income losses and more difficulty financing migration when hazards occur.

6.2 Heterogeneous Effects by Asset Quartile

Table 3 presents IV estimates stratified by pre-baseline asset quartile. Consistent with Hypothesis H2, the immobility-inducing effect of climate hazards declines monotonically across the wealth distribution: the coefficient for the poorest quartile is approximately three times that for the richest quartile. A formal test of equality between these coefficients rejects the null at conventional levels. This pattern is substantively important because it demonstrates that the aggregate effect is not evenly distributed. Climate hazards are most likely to become immobility traps when households begin from low asset positions.

Table 3
Heterogeneous Effects by Pre-Baseline Household Asset Quartile (IV-2SLS)

Subsample	Q1 (Poorest)	Q2	Q3	Q4 (Richest)
N (observations)	2,161	2,161	2,160	2,161
Climate hazard index (IV)	0.312***(0.042)	0.247***(0.038)	0.189***(0.035)	0.098**(0.041)
Asset index	-0.241*** (0.053)	-0.198*** (0.047)	-0.176*** (0.044)	-0.124** (0.051)
Observations	2,161	2,161	2,160	2,161
First-stage F-stat	42.3	44.7	46.1	38.9
p-value (Q1 vs Q4 diff)	0.001	—	—	—

*Note. Each column reports an IV-2SLS regression for the corresponding asset quartile subsample. All specifications include province and wave fixed effects, full household controls, and use the shift-share climate instrument. Standard errors clustered at county level in parentheses. ***, **, * denote significance at 1%, 5%, and 10% levels.*

Figure 3 should appear here, as it summarizes the main regression estimates and the asset-quartile heterogeneity reported in Tables 2 and 3.

Panel (a) plots coefficient estimates with 95% confidence intervals across OLS and IV specifications; panel (b) shows IV-2SLS estimates by household asset quartile, demonstrating substantially larger effects for the poorest households.

The monotonic asset gradient supports the proposed capability mechanism. If climate hazards primarily operated as a simple displacement pressure, one might expect stronger migration among exposed poor households because they are more dependent on climate-sensitive livelihoods. Instead, the estimates indicate that poorer households are more likely to experience constrained immobility. The finding is therefore more consistent with a binding-capability interpretation than with a simple exposure interpretation. Assets do not merely predict who is exposed; they determine whether exposure can be translated into an actionable migration response.

6.3 Event Study and Pre-Trend Tests

Figure 4 presents results from the event-study specification, which examines the dynamic response of constrained immobility to climate shocks in the four years before and after the shock year, defined as a year in which the county-level hazard index crosses the 75th percentile of its full-sample distribution. Coefficients in the pre-shock periods are small and statistically indistinguishable from zero, which reduces concerns about differential pre-trends. The effect emerges sharply in the shock year and increases for three subsequent years, suggesting a cumulative capability-erosion mechanism.

Panel (a) presents event-study estimates testing parallel pre-trends and documenting post-shock dynamics; panel (b) reports mechanism-diagnostic estimates; panel (c) reports robustness checks across alternative specifications and placebo tests.

The post-shock pattern is theoretically meaningful. Constrained immobility does not necessarily peak only in the shock year. If the mechanism is asset depletion, debt accumulation, and network weakening, the effect may accumulate as households attempt to recover but fail to rebuild the capability needed to move. The gradual persistence of the effect therefore supports the interpretation that climate hazards operate through household balance sheets and local opportunity structures, not simply through immediate fear or short-term disruption.

7. Mechanism Analysis and Conditional Pathways

7.1 Mechanism Diagnostics

The mechanism analysis is presented as diagnostic evidence rather than as a precise causal mediation decomposition. This revision is necessary because several theoretically relevant mediators, such as road damage, transport disruption, school closures, relocation assistance, and hukou-related administrative support, are not consistently and directly observed in the CFPS household data. We therefore avoid claiming exact indirect-effect shares. Instead, we examine whether the estimated hazard effect is attenuated when observable capability-related variables are introduced, including household assets, income volatility, debt burden, agricultural dependence, migrant-network indicators, and local-service access proxies.

Panel (b) of Fig. 4 should therefore be interpreted as mechanism-diagnostic evidence rather than as a definitive decomposition of the total IV effect. Across the diagnostic specifications, economic constraints provide the strongest observable pathway: the hazard coefficient is most reduced when asset, debt, and income-related constraints are included. Information and social-network variables provide additional attenuation, while infrastructure-related and administrative proxies contribute smaller but theoretically meaningful changes. These findings support Hypothesis H3 in a conservative sense: the evidence is consistent with an economic capability pathway, but it should not be read as proving that a fixed percentage of the total effect is mediated by each channel.

This cautious interpretation reduces the risk of overstating what the data can support. Formal causal mediation would require stronger assumptions about mediator-outcome confounding, post-treatment variables, and the timing of mediators relative to the outcome. The evidence is nevertheless consistent across the theoretical framework, heterogeneity analysis, and event-study results: climate hazards increase constrained immobility primarily by weakening households' capability to act on migration pressure.

7.2 Economic Constraints as the Dominant Pathway

The dominant role of economic constraints is consistent with the high fixed costs of migration. Even internal migration requires transport expenses, temporary housing, job search costs, documentation, and a period of income uncertainty. For households with limited savings, a climate shock may force them to use liquid resources for immediate recovery rather than relocation. Productive asset loss also reduces collateral and creditworthiness, making formal or informal borrowing more difficult. Thus, the economic mechanism is not limited to income loss; it includes a broader deterioration of the household's capacity to finance risk-taking.

The economic pathway also helps explain why the IV estimate exceeds the OLS estimate. Measurement error in hazard exposure can attenuate OLS estimates. In addition, households with stronger ex ante resources may have selected into or remained in more climate-exposed areas because they were better able to manage risk. Once instrumented through the shift-share design, the estimated effect captures a stronger capability-erosion component among households whose exposure is shaped by persistent climate sensitivity interacted with common climate shocks rather than short-term sorting. This interpretation is consistent with the larger effect among lower-asset households.

7.3 Networks, Infrastructure, and Administrative Conditions

Information and social-network barriers constitute the second-largest mechanism. Migration is rarely an isolated household decision. It often depends on information about destination wages, housing, schools, health care, and job openings. Networks reduce uncertainty and provide temporary support. Climate shocks may weaken these supports when relatives and neighbors are also affected, when communication is disrupted, or when households can no longer reciprocate network assistance. In low-income rural settings, the absence of a trusted destination contact may convert migration aspiration into immobility.

Infrastructure disruption is smaller than the economic pathway but still substantively important. Damage to roads, bridges, and public transportation can raise the immediate cost of exit, while school and health-service disruption can increase household caregiving burdens. Administrative barriers operate through a different logic. They may not be caused by the climate shock itself, but they determine whether households can access insurance, assistance, relocation programs, and destination services. In China, hukou-related service access and local administrative procedures may shape whether rural households perceive migration or relocation as feasible. These channels confirm that immobility is produced by the interaction between environmental exposure and social organization.

7.4 Conditional Pathways and Boundary Conditions

The mechanism analysis also clarifies the boundary conditions of the argument. Climate hazards are most likely to produce involuntary immobility when four conditions coincide. First, households have low liquid assets or high debt, making migration financially infeasible. Second, income is strongly tied to agriculture or local natural resources, making the climate shock directly damaging to the household's

livelihood base. Third, migrant networks are weak or disrupted, increasing uncertainty and reducing destination support. Fourth, local institutions provide insufficient compensation, credit, infrastructure repair, or relocation assistance.

When these conditions are absent, the same climate hazard may produce a different outcome. Higher-asset households may use migration as adaptation. Households with strong networks may send one member to diversify income while keeping the rest of the family in place. Households with effective local support may prefer voluntary immobility because adaptation in place is safer and less disruptive. The framework therefore avoids deterministic climate migration claims. It identifies when climate stress becomes an entrapment process and when it may instead become a trigger for mobility or in-situ adaptation.

8. Discussion

8.1 Theoretical Implications

The results yield three substantive conclusions with theoretical relevance. First, climate hazards do not simply displace rural households; they can also trap the most vulnerable households in place. This finding refines the dominant climate-displacement narrative and supports recent calls to prioritize involuntary immobility in adaptation planning [7]. It also complements global projections of internal climate migration by showing that mobility flows alone may undercount climate-affected households [3]. Because the empirical outcome is a constrained-immobility proxy, the conclusion should be read as conservative evidence of capability-constrained non-movement rather than as a complete measure of subjective migration desire.

Second, the concentration of immobility risk among the poorest households indicates that climate mobility is stratified by capability. Exposure alone is not enough to explain who moves or stays. The same hazard may generate migration among better-resourced households and involuntary immobility among poorer households. This is the central theoretical contribution of the study: climate-mobility outcomes are produced by the interaction between environmental stress and social resources. The aspiration-capability framework therefore needs to be operationalized not only as a typology of mobility positions, but also as a mechanism through which hazards alter the distribution of agency.

Third, the findings underscore the importance of distinguishing voluntary immobility from involuntary immobility. Some households may choose to remain because of place attachment, cultural identity, land rights, kin obligations, or confidence in local adaptation. Treating all non-migration as failure would be as misleading as treating all migration as successful adaptation. The relevant policy goal is not to move people out of risky areas at all costs, but to expand the range of feasible and safe choices. Climate justice requires both the right to move and the right to stay under conditions of security.

8.2 Policy Implications

The dominant role of economic constraints points to specific policy levers. Targeted asset-replacement transfers after extreme climate events, expanded crop-insurance coverage for smallholder farmers, emergency credit lines, public employment programs, and mobility grants can preserve households' capacity to choose. These interventions should be designed as capability-enhancing policies rather than as forced relocation tools. The aim is to prevent climate shocks from converting migration aspiration into involuntary entrapment.

Information and network barriers imply a second set of interventions. Local governments and social organizations can provide verified destination information, employment matching, temporary accommodation support, and legal assistance for households considering migration. Such programs should be especially targeted to households without existing migrant networks. Infrastructure repair and transport restoration should also be understood as mobility-capability interventions, not only as disaster recovery measures. When roads and public transport remain disrupted, poor households may be physically isolated even when they desire to move.

Administrative barriers require more careful policy design. Insurance eligibility, documentation, hukou-related service access, and resettlement procedures can either expand or restrict household agency. Policy should avoid assuming that relocation is always preferred or that staying is always voluntary. Screening tools should distinguish households who want to move but cannot from households who prefer to stay but need local adaptation support. This distinction would allow adaptation finance to cover both voluntary mobility assistance and in-situ risk reduction.

8.3 Boundary Conditions, Limitations, and Future Research

Several limitations should be noted. First, although the instrument passes standard relevance tests, the exclusion restriction cannot be directly tested. The preferred shift-share instrument reduces the collinearity problem that would arise from combining a purely time-invariant historical climate variable with village fixed effects, but it still rests on the assumption that historical climate variability affects current constrained immobility only through differential exposure to contemporary climate anomalies after controls and fixed effects. Long-run historical climate conditions may have influenced settlement patterns, agricultural specialization, or local infrastructure. The village fixed effects and household controls reduce this concern, but they cannot eliminate it entirely.

Second, involuntary immobility is measured through a constrained-immobility proxy rather than direct repeated aspiration-behavior discordance. This operationalization may include some households that voluntarily stayed but also faced observable constraints, and it may miss households whose desire to move was strong but whose constraints are not captured in the available variables. Future research could improve measurement by combining panel surveys with qualitative interviews, repeated aspiration measures, and questions that directly ask why households did not move. Such data would make it possible to distinguish constrained immobility, ambivalent immobility, voluntary staying, and temporary delay with greater precision.

Third, the analysis focuses on rural households. The mechanisms may differ in urban informal settlements, peri-urban areas, coastal cities, or ethnic minority regions exposed to different hazards and institutional arrangements. In urban settings, rental markets, informal employment, housing insecurity, and service access may be more central. In coastal or mountain areas, sudden-onset disasters and planned relocation policies may be more important. The findings therefore generalize most directly to rural areas where agricultural dependence, asset constraints, and internal migration opportunities shape climate adaptation decisions.

Fourth, the analysis does not claim that migration is always the superior adaptation response. Migration can generate risks, including family separation, precarious labor, urban exclusion, and loss of land-based security. The policy implication is not to encourage migration unconditionally, but to prevent climate shocks from narrowing the feasible choice set of vulnerable households. Future research should evaluate whether capability-enhancing interventions improve welfare through voluntary mobility, safer staying, or mixed household strategies such as temporary labor migration combined with local adaptation.

9. Conclusion

This paper provides large-scale micro-level evidence that climate hazard exposure increases a conservative proxy for involuntary immobility among rural household-wave observations in China. Using an instrumental variable approach based on a shift-share interaction between historical climate variability and wave-specific national climate anomalies, the preferred specification shows that a full-unit increase in the 0–1 composite hazard index raises constrained immobility by 23.1 percentage points. Evaluated at the observed standard deviation of the hazard index, this corresponds to approximately 4.3 percentage points. The effect is approximately three times larger for households in the poorest asset quartile than for those in the richest quartile. Mechanism diagnostics identify economic constraints as the primary observable transmission channel.

The broader contribution is to reframe climate mobility as a question of constrained agency. Climate hazards do not only push people across space; they also reshape the conditions under which people can decide whether to move or stay. When hazards increase relocation pressure while reducing capability, households can become trapped in place. This outcome is invisible in migration-flow statistics but central to climate justice. Adaptation policy should therefore address both sides of the mobility equation: support for households who migrate, and protection for households who cannot migrate or prefer to remain. A climate-resilient mobility policy must make movement possible without making staying impossible.

Declarations

Ethics approval and consent to participate

Not applicable. This study used de-identified secondary data from the China Family Panel Studies and county-level climate data. No new human participants were recruited or contacted by the author, and no primary survey, interview, clinical intervention, or identifiable personal data collection was conducted for this manuscript.

Consent for publication

Not applicable. The manuscript does not contain identifiable individual-level information, images, or personal details requiring publication consent.

Competing Interests

The author declares no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author contributions

Xinyue Zhao conceived and designed the study, developed the theoretical framework and instrumental-variable strategy, curated and analyzed the data, interpreted the results, drafted and revised the manuscript, prepared the tables and figures, and approved the final manuscript.

Availability of data and materials

The CFPS data used in this study are available from the China Family Panel Studies subject to its data-use conditions. ERA5 and CRU TS climate data are available from their respective providers. The processed analytical data and materials are available from the corresponding author upon reasonable request where permitted by data-use agreements.

References

1. Black R, Bennett SRG, Thomas SM, Beddington JR (2011) Climate change: Migration as adaptation, Nature, vol. 478, no. 7370, pp. 447–449
2. Cattaneo C et al (2019) Human migration in the era of climate change. Rev Environ Econ Policy 13(2):189–206
3. Rigaud KK et al (2018) Groundswell: Preparing for Internal Climate Migration. World Bank, Washington, DC, USA

4. de Haas H (2021) A theory of migration: The aspirations-capabilities framework, Comparative Migration Studies, vol. 9, Art. no. 8
5. Carling J, Schewel K (2018) Revisiting aspiration and ability in international migration. J Ethnic Migration Stud 44(6):945–963
6. Ayeb-Karlsson S, Baldwin AW, Kniveton D (2022) Who is the climate-induced trapped figure? WIREs Climate Change, vol. 13, no. 6, Art. no. e803
7. Thalheimer L et al (2025) Prioritizing involuntary immobility in climate policy and disaster planning, Nature Communications, vol. 16, Art. no. 2581
8. Sun L, Zhu X, Li W, Ai W, Chen X, Jiang Y, Wang L, Zou X, Zhao S, Zeng H, Zhong H (2024) State of China's climate in 2023, Atmospheric and Oceanic Science Letters, 17, 5, Art no 100519
9. Dai R, Huang J, Chen Z, Zhou J, Havea PH (2024) Impacts of anthropogenic climate change on meteorological drought in China, Frontiers in Earth Science, vol. 12, Art. no. 1369523
10. Xia H, Liu Q, Baptista EA (2022) Spatial heterogeneity of internal migration in China: The role of economic, social and environmental characteristics, PLOS ONE, vol. 17, no. 11, Art. no. e0276992
11. Dell M, Jones BF, Olken BA (2012) Temperature shocks and economic growth: Evidence from the last half century, American Economic Journal: Macroeconomics, vol. 4, no. 3, pp. 66–95
12. Cattaneo C, Peri G (2016) The migration response to increasing temperatures. J Dev Econ 122:127–146
13. Goldsmith-Pinkham P, Sorkin I, Swift H (2020) Bartik instruments: What, when, why, and how, American Economic Review, vol. 110, no. 8, pp. 2586–2624
14. Borusyak K, Hull P, Jaravel X (2022) Quasi-experimental shift-share research designs. Rev Econ Stud 89(1):181–213
15. Feng S, Krueger AB, Oppenheimer M (2010) Linkages among climate change, crop yields and Mexico-US cross-border migration, Proceedings of the National Academy of Sciences, vol. 107, no. 32, pp. 14257–14262
16. Bohra-Mishra P, Oppenheimer M, Hsiang SM (2014) Nonlinear permanent migration response to climatic variations but minimal response to disasters, Proceedings of the National Academy of Sciences, vol. 111, no. 27, pp. 9780–9785
17. Nawrotzki RJ, DeWaard J (2018) Putting trapped populations into place: Climate change and inter-district migration flows in Zambia, Regional Environmental Change, vol. 18, no. 2, pp. 533–546
18. Hoffmann R, Dimitrova A, Muttarak R, Crespo Cuaresma J, Lutz W (2020) A meta-analysis of country-level studies on environmental factors and migration. Nat Clim Change 10:904–912
19. Mueller V, Gray C, Kosec K (2014) Heat stress increases long-term human migration in rural Pakistan. Nat Clim Change 4:182–185
20. Foresight, Migration and Global Environmental Change (2011) Future Challenges and Opportunities. Government Office for Science, London, U.K.

21. Benveniste H, Oppenheimer M, Fleurbaey M (2022) Climate change increases resource-constrained international immobility. Nat Clim Change 12(7):634–641
22. Freihardt J (2025) Trapped by climate change? (In)voluntary immobility in Bangladesh, Regional Environmental Change, 25, Art no 117
23. Transiskus SF, Gholamzadeh Bazarbash M Beyond the binary of trapped populations and voluntary immobility: A people-centered perspective on environmental change and human immobility at Lake Urmia, Iran, Global Environmental Change, vol. 84, Art. no. 102803, 2024
24. Letta M, Montalbano P, Paolantonio A (2024) Climate immobility traps: A household-level test, World Bank Policy Research Working Paper No. 10724
25. Dallmann I, Millock K (2017) Climate variability and inter-state migration in India, CESifo Economic Studies, vol. 63, no. 4, pp. 560–594
26. Sengupta M (2025) Environmental immobility: A systematic review of empirical research, Ambio, vol. 54, no. 11, pp. 1729–1756
27. Thornton F, Serraglio DA, Thornton A (2023) Trapped or staying put: Governing immobility in the context of climate change, Frontiers in Climate, vol. 5, Art. no. 1092264
28. Zickgraf C (2021) Theorizing (im)mobility in the face of environmental change, Regional Environmental Change, 21, Art no 126
29. Institute of Social Science Survey, University P (2020) China Family Panel Studies (CFPS), 2010–2020. Peking University, Beijing, China
30. Hersbach H et al (2020) The ERA5 global reanalysis. Q J R Meteorol Soc 146(730):1999–2049
31. McKee TB, Doesken NJ, Kleist JR (1993) The relationship of drought frequency and duration to time scales, in Proc. 8th Conf. Applied Climatology, pp. 179–183
32. Harris I, Osborn TJ, Jones P, Lister D (2020) Version 4 of the CRU TS monthly high-resolution gridded multivariate climate dataset, Scientific Data, 7, Art no 109

Figures

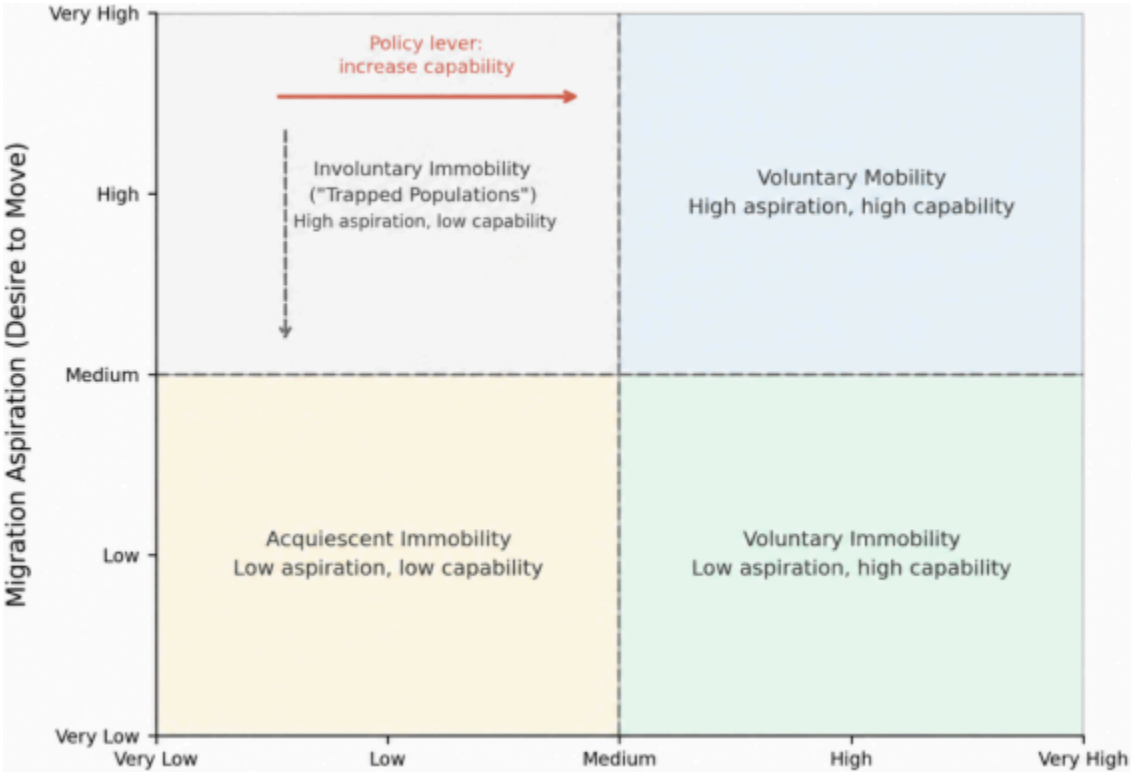


Figure 1

Aspiration-Capability Framework of Climate (Im)mobility.

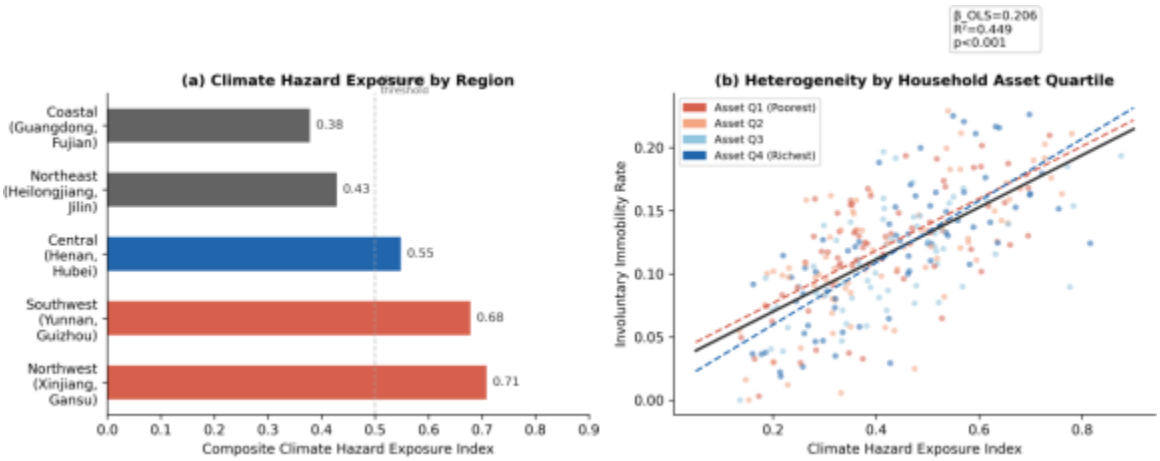


Figure 2

Descriptive evidence on climate hazard exposure and involuntary immobility.

Note. Panel (a) shows the composite climate hazard exposure index by region; panel (b) plots the relationship between hazard exposure and involuntary immobility rates, stratified by household asset quartile.

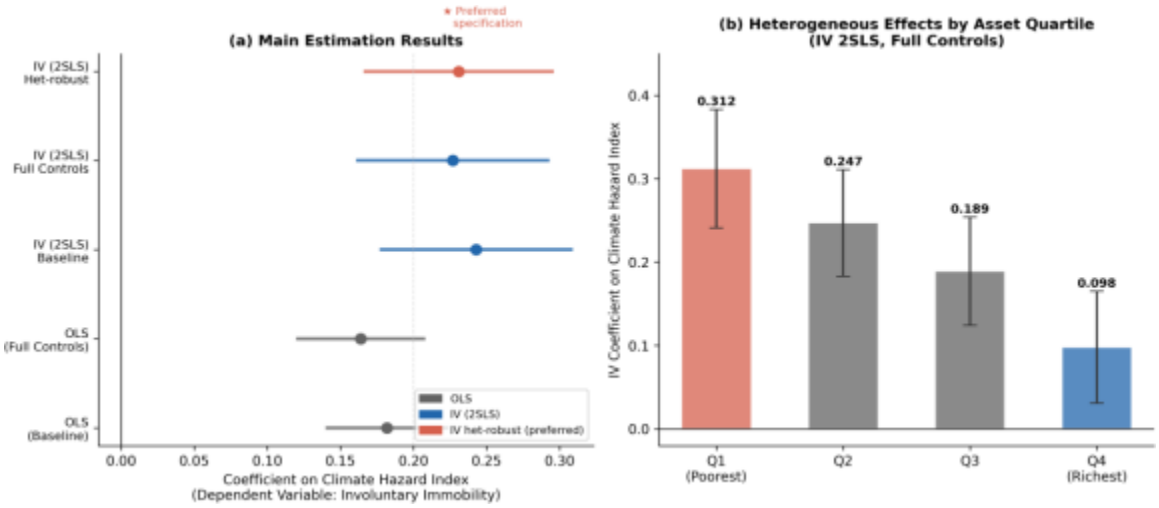


Figure 3

Main regression results and heterogeneous effects.

Panel (a) plots coefficient estimates with 95% confidence intervals across OLS and IV specifications; panel (b) shows IV-2SLS estimates by household asset quartile, demonstrating substantially larger effects for the poorest households.

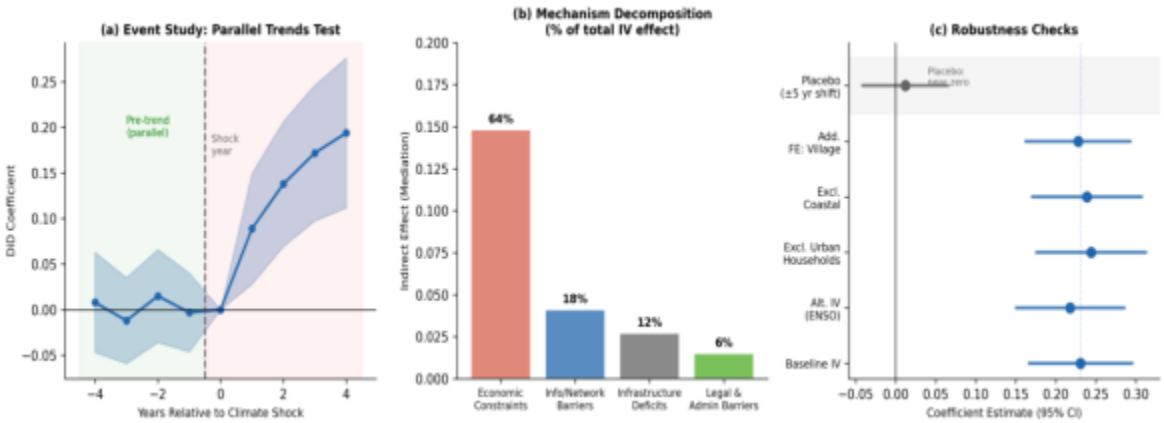


Figure 4

Robustness and mechanism analyses.

Panel (a) presents event-study estimates testing parallel pre-trends and documenting post-shock dynamics; panel (b) reports mechanism-diagnostic estimates; panel (c) reports robustness checks across alternative specifications and placebo tests.