Departure from the Dust

Migration, Policy Mitigation, and Aggregate Welfare

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Data and Dust Exposure

This paper investigates the economic impacts of dust storms through the lens of migration. We combine daily satellite observations with internal migration records in China.

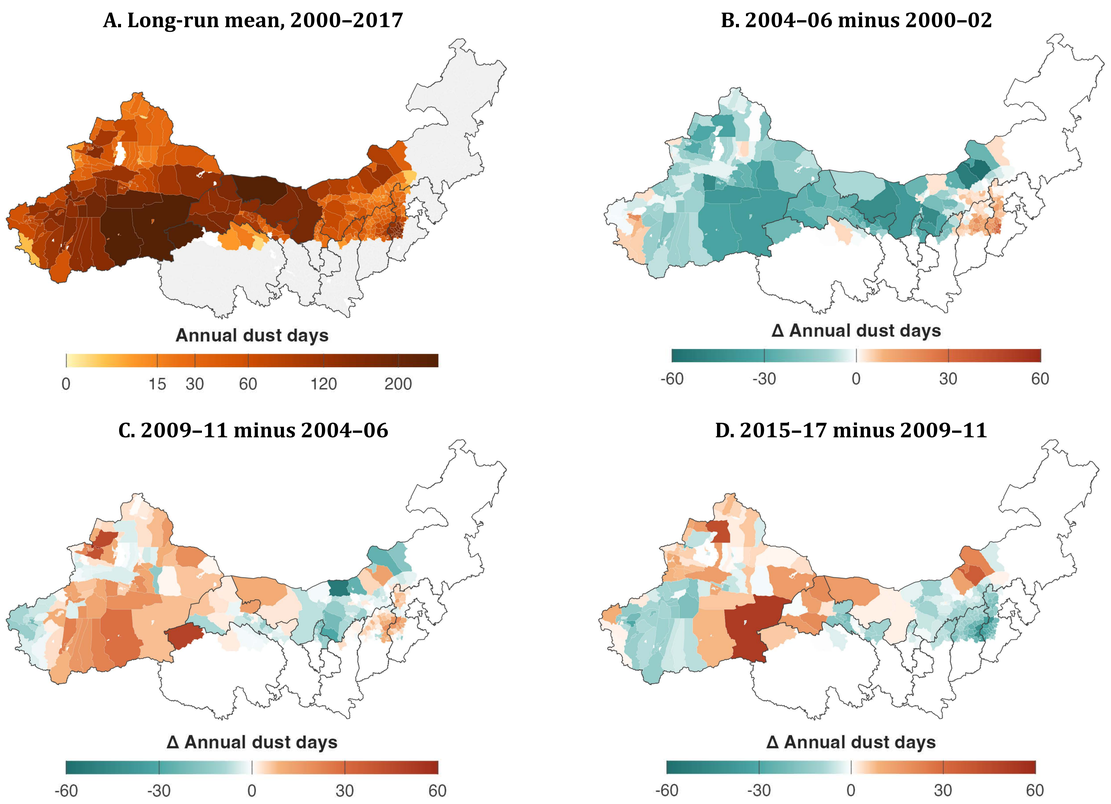


Figure 1. Spatial and temporal distribution of dust exposure. Panel A: mean annual dust days; B–D: changes in three-year means. Northern China; gray counties lie outside the mapped sample. Source: MODIS / CASEarth (Tao et al., 2021).

Productivity and Amenity Channels

Productivity losses

Dust exposure lowers agricultural and industrial productivity. The estimates below link migration responses to declining economic opportunities.

	Agriculture	Manufacturing
Dust share	−1.959**	−0.512**
	(0.913)	(0.204)
Unit fixed effects	Household	Firm
Observations	72,098	819,008
Sample period	2009–2015	2000–2007

Outcome: $\ln(1 + \text{TFP})$, where TFP is total factor productivity. Both regressions include year fixed effects, province-specific trends, and unit- and county-level controls. County-clustered standard errors in parentheses. $^{**}p < 0.05$.

Amenity losses

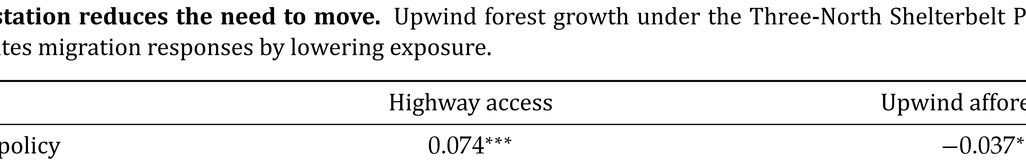
Dust exposure raises lung disease and lowers cognition among older adults. Household income falls while health-related spending rises. The migration coefficient remains positive after controlling for $PM_{2.5}$: **0.174** (SE 0.029). Together, these findings suggest that deteriorating amenities also contribute to migration.

Migration Outcomes and Identification

Data. The 2005 and 2015 mini-censuses and 2010 Census yield **35,955 county–year observations (2001–2015)**, covering ages 15–60. The outcome M_{it} is annual recorded out-migrants divided by 100; exposure D_{it} is dust days divided by 365.

Our baseline exploits within-county variation, controlling for county and year fixed effects, province-specific trends, and geographic, weather, and economic conditions.

Instrument: transport from upwind desert counties



$$IV_{it} = \sum_{m=1}^{12} \sum_{\substack{j \in \text{Desert} \\ j \neq i}} w(d_{ij}) \times \text{DustStorm}_{jmt} \times \text{WindAlign}_{ijmt} \times \text{DesertShare}_{j}.$$

DustStorm_{jmt}: monthly dust days in source county j; DesertShare_j: its desert-area share; $w(d_{ij})$: distance-decay weight. WindAlign_{ijmt} combines target wind speed and alignment with the source-to-target bearing. The instrument excludes county i itself. Identification requires upwind outbreaks to affect migration through local dust, conditional on controls.

Outcome	First stage D_{it}	OLS M_{it}	2SLS M_{it}
IV_{it}	0.020***	—	—
	(0.003)		
Dust share	—	0.238***	0.599***
		(0.030)	(0.105)
First-stage F	47.421	—	—
Observations	35,955	35,955	35,955

Preferred specifications include all fixed effects, trends and controls listed above. County-clustered standard errors in parentheses. $^{***}p < 0.01$.

Dust exposure generates substantial out-migration. Responses are more pronounced among agricultural hukou holders and younger residents.

Adaptation and Mitigation

Road expansion facilitates adaptation. Highway access amplifies migration responses to dust by lowering mobility costs.

Afforestation reduces the need to move. Upwind forest growth under the Three-North Shelterbelt Program attenuates migration responses by lowering exposure.

	Highway access	Upwind afforestation
Dust × policy	0.074***	−0.037***
	(0.027)	(0.008)
Observations	33,975	35,955

Outcome: annual recorded out-migrants/100. County and year fixed effects, province-specific trends and controls are included. County-clustered standard errors in parentheses. $^{***}p < 0.01$. Interactions are with dust share. Policy measures have different units; coefficient magnitudes are not directly comparable.

From migration responses to welfare

The two policies act on different margins of the same relationship. Reduced-form estimates describe the migration margin; the spatial model below evaluates aggregate welfare and distributional consequences.

Quantitative Spatial Model

We translate the reduced-form evidence into general-equilibrium welfare effects using **2,678 counties**, agriculture and manufacturing, costly migration, and costly trade. Dust lowers sectoral productivity and residential amenities.

Migration shares and sectoral choices

$$q_{ij} \equiv \frac{\Phi_j B_j(D_j)}{\kappa_{ij} P_j}, \qquad \varpi_{ij} = \frac{q_{ij}^{\epsilon}}{\sum_n q_{in}^{\epsilon}}, \qquad \Phi_j = \left(\sum_{k \in \{A,M\}} v_{jk}^{\eta} \right)^{1/\eta}.$$

i is the origin, j the destination, and k the sector. v_{jk} is income including land rents, B_j amenity, κ_{ij} migration cost, and P_j the price index. ϖ_{ij} is the migration share; $\epsilon = 1.5$ and $\eta = 2.7$ govern location and sector choices.

Trade and local price indices

$$P_{jk} \propto \left[\sum_n T_{nk} (c_{nk} \tau_{nj})^{-\theta_k} \right]^{-1/\theta_k}, \qquad P_j = \prod_k P_{jk}^{\alpha_k}.$$

T_{nk} is the Fréchet productivity scale, c_{nk} the unit input cost, τ_{nj} the iceberg trade cost, θ_k the trade elasticity, and α_k the consumption share, with $\sum_k \alpha_k = 1$.

Welfare and the cost of dust

$$\mathcal{W}_i \propto \left(\sum_j q_{ij}^{\epsilon} \right)^{1/\epsilon}, \qquad \ell_i = \frac{L_i}{\sum_n L_n},$$

$$\text{EV}(\%) = 100 \left[\exp\left\{ \sum_i \ell_i \log \frac{\mathcal{W}_i^{\text{dust}}}{\mathcal{W}_i^{\text{no dust}}} \right\} - 1 \right].$$

$\mathcal{W}_i$ is expected welfare for origin-i workers, L_i their population, and EV is equivalent variation. Counterfactuals re-solve wages, prices and population to clear labor and goods markets.

Policy implication. Reducing exposure delivers larger simulated welfare gains. Targeting infrastructure also matters: equalizing migration-cost reductions to the average for non-dust county pairs raises gains in high-dust counties from **1.04% to 1.72%**.

Welfare costs and migration as adaptation

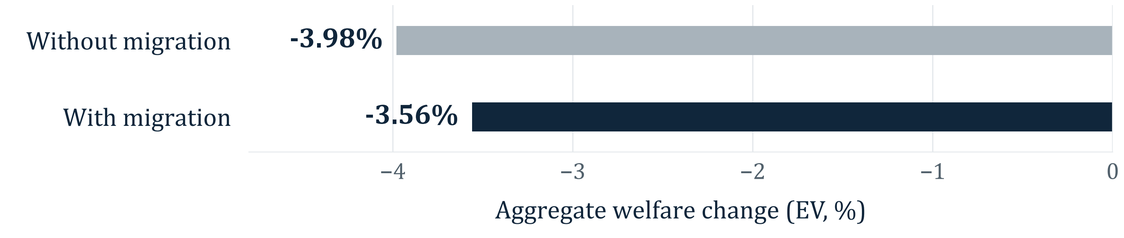


Figure 2. Aggregate welfare losses: 2010 dust versus no dust. The no-migration scenario sets $\kappa_{ij} = \infty$ for $i \neq j$ and re-solves both equilibria.
Migration offsets **0.42 percentage points**, or **10.6%** of the loss without migration. The amenity channel accounts for the dominant share of the welfare cost.

Policy gains and spatial heterogeneity

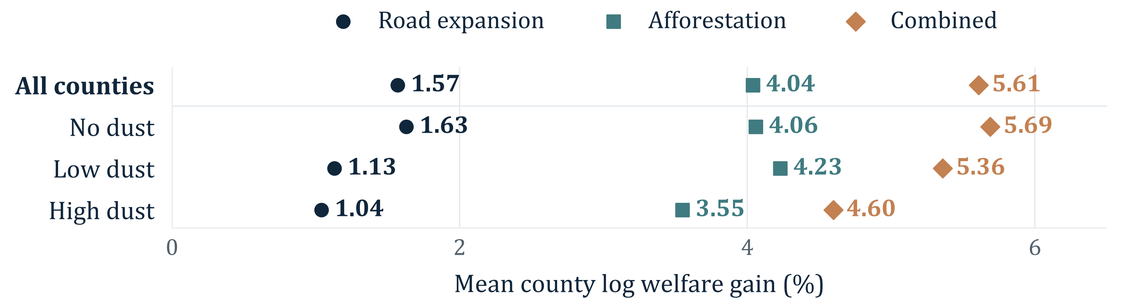


Figure 3. Welfare gains and heterogeneity, 2010. Unweighted means of county log welfare changes; distinct from aggregate EV. High/low dust groups split at the median positive 2010 dust share.
Roads: 2010 versus 2000 network, holding dust fixed. **Afforestation:** observed dust versus a counterfactual without program-induced dust reduction, holding migration costs fixed. **Combined:** joint implementation.