Online Appendix

Segmented Labor Markets and Structural Transformation

Marius Hees

Department of Economics, Erasmus University Rotterdam

September 12, 2026

This Online Appendix provides supplementary material for the paper: additional data-construction detail (OA-1), measurement and harmonization detail (OA-2), numerical implementation and diagnostics (OA-3), calibration search ranges (OA-4), complete robustness results (OA-5), complete counterfactual decompositions (OA-6), and complete climate and conflict scenario results (OA-7). The material required to evaluate the paper's claims is contained in the paper and its print appendices; this document provides additional detail and complete supporting results. References to sections and appendices refer to the main manuscript.

Contents

OA-1 Data Construction Details

This Online Appendix provides supplementary construction detail for four components of the spatial dataset summarized in Appendix A of the paper: agricultural outcomes, travel times, demographics, and measured amenities. The discussion here focuses on measurement choices, harmonization, validation, and gap filling that are useful for interpreting the quantitative inputs. Definitions of the spatial framework, urban labor-market measures, prices, migration variables, and the final model geography are given in Appendix A of the paper.

OA-1.1 Agricultural data construction

The agricultural data combine Agricultural Sample Survey records, household surveys, remotely sensed climate and vegetation measures, and static geographic characteristics. The resulting panel contains agricultural outcomes and covariates for 547 AgSS-covered woredas over 2000–2020. These 547 woredas differ from the 555 rural locations in the model geography because several model locations split a common parent woreda and therefore share the corresponding agricultural survey information.

The construction proceeds in four substantive steps. I first harmonize historical administrative units to a common geography. I then harmonize crop production, area, household income, and crop-price measures across survey waves. Third, I merge rainfall, vegetation, temperature, terrain, and land-cover data. Finally, I use the observed survey years to estimate a prediction model that fills missing woreda-year agricultural outcomes.

OA-1.1.1 Administrative concordance

Ethiopian administrative boundaries change frequently through splits, mergers, renaming, and regional reorganization. Agricultural Sample Survey records therefore cannot be linked across years using raw administrative identifiers alone. I map survey observations to a common 2007 woreda geography before constructing the panel.

The concordance uses a sequence of increasingly permissive matches:

1. exact matches on administrative codes;
2. matches through an external administrative crosswalk;
3. explicit treatment of the Sidama reorganization;
4. zone-level concordance where a unique woreda-level match is unavailable; and
5. nearest-centroid assignment for the small residual set of unmatched units.

The procedure produces a concordance for all 904 units in the 2007 geographic reference grid. Agricultural analysis is subsequently restricted to the 547 unique woredas covered by the harmonized AgSS sample.

OA-1.1.2 AgSS crop production and unit harmonization

Eleven usable Agricultural Sample Survey waves span 2003–2022. The survey covers the Meher cropping season and reports harvested area and production at the woreda-by-crop level. Administrative identifiers, crop identifiers, harvested-area variables, and production variables are harmonized across questionnaire formats before aggregation.

Production units. A consequential measurement issue is the production-unit encoding in the early survey waves. Several early files do not express raw production in the later quintal convention. Applying a common conversion factor to all waves would therefore generate order-of-magnitude errors in measured yields.

The wave-specific conversion is

Table OA1: AgSS production-unit conversion

Survey wave	Conversion to kilograms	Basis
2003	$\times 10$	Dual raw and converted production fields
2004	$\times 10$	Dual raw and converted production fields
2005–2006	$\times 100$	Quintal reporting
2007	$\times 10$	Validation against published yield levels
2008	$\times 10$	Validation against published yield levels
2009–2022	$\times 100$	Quintal reporting

Notes: The table reports the factor used to convert raw AgSS production quantities into kilograms. The early-wave conversion is validated using waves containing both raw and converted production fields and by comparing implied national cereal yields with published CSA and FAOSTAT series.

With these conversions, aggregate cereal yields rise from approximately 1,250 kg/ha in 2003 to approximately 2,790 kg/ha in 2017 and are generally within about 5% of the corresponding published benchmarks. Applying the quintal conversion to the early waves instead would imply cereal yields around 12,000–15,000 kg/ha, which is inconsistent with the published Ethiopian series.

OA-1.1.3 ESS household income and crop prices

The 2011, 2013, and 2015 Ethiopia Socioeconomic Survey waves provide complementary household-level information on agricultural and non-agricultural income. The 2018/19 wave additionally contributes to the spatial price-index construction described in Appendix A of the paper.

Household income combines crop revenue, livestock income net of sales costs, agricultural wage income, and income from non-farm enterprises. Crop unit values are constructed from reported sales values and quantities and aggregated to the zone level. Twenty-one commonly observed food items account for approximately 99% of measured food expenditure in the harmonized basket.

Household GPS locations are assigned to the common administrative geography spatially. Harmonization also addresses two survey-specific issues: household identifiers are not globally unique in the 2013 files, and quantity-conversion codes differ across waves. Both are resolved before income and unit-value measures are aggregated.

OA-1.1.4 Climate and environmental inputs

Rainfall. Monthly CHIRPS v2.0 rainfall rasters (Funk et al., 2015) at approximately 0.05° resolution are aggregated to woreda-level area-weighted means. The resulting variables are

Table OA2: Rainfall variables

Variable	Definition
Kiremt rainfall	Total rainfall during June–September, in millimeters
Kiremt rainfall variability	Within-season coefficient of variation
Kiremt rainfall anomaly	Woreda-specific standardized anomaly relative to the 1981–2010 mean
Drought indicator	$\mathbf{1}[z < -1]$
Excess-rain indicator	$\mathbf{1}[z > 1]$
Belg rainfall	Total rainfall during February–May
Annual rainfall	Total rainfall during January–December

Notes: Variables are constructed from monthly CHIRPS v2.0 rainfall data and aggregated to area-weighted woreda means. The standardized anomaly compares each woreda-year Kiremt total with that woreda's own 1981–2010 rainfall distribution. The panel contains 547 woredas over 2000–2020.

For woreda i in year t, the standardized Kiremt rainfall anomaly is

$$z_{it} = \frac{R_{it} - \bar{R}_i}{\sigma_{R,i}}.$$

The construction therefore measures weather relative to local climatology rather than comparing rainfall levels across agro-ecological zones. Because CHIRPS records rainfall depth in millimeters, spatial aggregation uses the area-weighted mean of intersecting raster cells rather than their sum.

Vegetation. Monthly MODIS vegetation-index products are observed at native resolution of approximately 250 meters and aggregated to approximately one kilometer before spatial extraction. The principal vegetation measure is the seasonal NDVI change

$$\text{NDVI\_delta}_{i,t} = \text{NDVI}_{i,t}^{\textit{Aug-Sep}} - \text{NDVI}_{i,t}^{\textit{Apr-May}}. \tag{OA1}$$

Differencing peak-season vegetation from the pre-growing-season baseline reduces the contribution of persistent vegetation cover and isolates variation associated more closely with seasonal crop growth (Becker-Reshef et al., 2010). An analogous measure is constructed for Belg-growing areas.

Temperature. ERA5 reanalysis provides three temperature measures aggregated to the woreda level:

- growing degree days during Kiremt, using a base of 8°C and a cap of 30°C;
- harmful degree days above 30°C during Kiremt; and
- mean Kiremt temperature.

Temperature observations are unavailable for two years in the underlying 2000–2020 construction window.

Terrain and land cover. Static elevation, slope, and terrain ruggedness are constructed from the SRTM digital elevation model. Elevation provides a parsimonious measure of agro-ecological differences between Ethiopian highland and lowland locations. Cropland shares are obtained from ESA CCI land-cover data for the available benchmark years and are used in the classification of local agricultural production systems.

OA-1.1.5 Prediction of missing agricultural yields

AgSS does not observe every woreda in every year. I therefore estimate a prediction model on observed survey yields and use it to fill missing woreda-year outcomes. The procedure is designed to exploit persistent spatial productivity differences without mechanically interpolating observed yield levels into the prediction target.

Prediction architecture. The final specification combines gradient-boosted trees and random forests. Observed AgSS yield enters only as the dependent variable and is never included directly as a predictor. Spatial persistence is instead represented through a local productivity component constructed from relationships estimated outside the target observation.

The local component is obtained in three steps. First, within each zone I estimate

$$\log(\text{yield}_{i,t}) = \alpha_z + \beta_z^{\text{ndvi}}\text{NDVI\_delta}_{i,t} + \beta_z^{\text{rain}}\text{rain}_{i,t} + \beta_z^{\text{temp}}\text{temp}_{i,t} + u_{i,t}. \quad \text{(OA2)}$$

These regressions pool observations across survey years within approximately 80 zones. Second, I recover the mean residual for each observed woreda as a persistent local productivity component. Third, for a woreda without an observed local component, I construct that component from nearby observed woredas using distance and elevation similarity. Current-year climate and vegetation variables remain those of the target woreda-year.

The resulting predictor therefore transfers estimated local productivity and input-yield relationships rather than directly interpolating neighboring observed yields.

Out-of-sample validation. To evaluate temporal extrapolation, the years 2004, 2007, and 2015 are removed entirely from model training and used as held-out validation observations. Additional validation exercises vary the geographic and temporal structure of the holdout.

Table OA3: Out-of-sample performance of the agricultural yield model

Validation exercise	n	Log R^2	Level R^2
Complete-year holdout	1,918	0.339	0.261
Leave-year-out	—	0.022	—
Leave-block-out	—	0.386	0.243

Notes: The dependent variable is cereal-equivalent yield. The complete-year holdout removes 2004, 2007, and 2015 from training. Level predictions apply a Duan smearing correction when transforming predictions from logs. Dashes indicate statistics that were not calculated for the corresponding validation exercise.

The complete-year holdout produces a log-scale R^2 of 0.339 and a level R^2 of 0.261. The model therefore contains useful cross-sectional predictive information, but its temporal generalization is substantially weaker: the leave-year-out exercise produces a log R^2 of only 0.022. I therefore do not interpret the prediction model as accurately forecasting aggregate annual agricultural shocks. Its principal role is to construct spatially differentiated agricultural outcomes for woreda-years that are not directly observed.

Predictor contribution. The strongest predictor is the local productivity-transfer component described above. Vegetation measures provide the next-largest contributions, followed by within-season rainfall variability.

The final ensemble places weights of 0.512 on gradient boosting and 0.488 on the

Table OA4: Predictor importance in the agricultural yield model

Predictor	Mean |SHAP|
Local productivity transfer	0.242
Belg NDVI change	0.078
Main-season NDVI change	0.071
Kiremt rainfall variability	0.032

Notes: Mean absolute SHAP values for the leading predictors in the final yield-prediction ensemble. The local productivity-transfer variable is constructed from zone-level input-yield relationships and persistent woreda components and does not contain the target observation's realized yield.

random forest. Removing the local productivity-transfer component reduces validation R^2 by approximately 0.217. Removing the main-season NDVI-change variable instead modestly improves validation performance by approximately 0.023, indicating that this vegetation measure contributes little incremental out-of-sample predictive power conditional on the other inputs.

OA-1.1.6 Weather variation and agricultural yields

I estimate a set of weather-yield specifications to isolate the component of agricultural productivity associated with short-run variation in rainfall and temperature. Identification comes from within-woreda changes in weather after controlling for woreda and year fixed effects. Under the maintained assumption that these conditional weather shocks are orthogonal to other time-varying determinants of yields, the fitted weather component provides the exogenous variation used in the agricultural IV exercise.

I consider five specifications:

A. Quadratic rainfall:

$$\log(y_{it}) = \alpha_i + \beta_1 R_{it} + \beta_2 R_{it}^2 + \delta_t + \varepsilon_{it}.$$

B. Rainfall interacted with temperature.

C. Drought and excess-rain indicators:

$$\log(y_{it}) = \alpha_i + \beta_D \mathbf{1}[z_{it} < -1] + \beta_E \mathbf{1}[z_{it} > 1] + \delta_t + \varepsilon_{it}.$$

D. A piecewise-linear specification in rainfall quintiles.

E. Specification C augmented with within-season rainfall variability.

All specifications include woreda and year fixed effects. Table OA5 reports the corresponding relevance statistics and the principal weather coefficients.

Table OA5: Weather-yield specifications

Specification	Kleibergen–Paap F	Principal estimate	95% CI
A. Quadratic rainfall	16.87	+8.9% per SD rainfall	—
B. Rainfall × temperature	11.57	—	—
C. Drought and excess rainfall	23.93	−22% for drought	[−27%, −16%]
D. Piecewise rainfall	10.44	—	—
E. Drought bins and rainfall CV	11.52	—	—

Notes: Weather-yield regressions for log cereal-equivalent yield, with woreda and year fixed effects. The sample contains the harmonized agricultural panel for 547 woredas over 2000–2020. The Kleibergen–Paap statistic summarizes the relevance of the excluded weather variation used in the corresponding IV construction. The principal estimate reports the headline weather coefficient where applicable.

Specification C provides the strongest relevance statistic, with a Kleibergen–Paap F statistic of 23.93, and is the preferred specification. A drought year, defined as rainfall more than one standard deviation below the woreda-specific historical mean, is associated with approximately 22% lower cereal-equivalent yield. This magnitude lies within the range reported for Ethiopian agricultural responses to adverse rainfall shocks by Dercon and Christiaensen (2011). The estimated temperature effect is approximately −7.7% per additional degree Celsius but is imprecisely estimated ($p = 0.13$). I therefore use the weather specification primarily to isolate plausibly exogenous agricultural variation rather than to interpret each individual weather coefficient as a precisely estimated structural elasticity.

OA-1.1.7 Agricultural variable construction

Cereal-equivalent production. To aggregate heterogeneous crops into a common physical-output measure, I convert production to cereal-equivalent kilograms using caloric conversion factors:

$$Q^{ce}_{i,t} = \sum_{c} \theta_c q_{c,i,t}, \tag{OA3}$$

where $q_{c,i,t}$ is physical production of crop c and θ_c is its caloric content relative to teff, the reference crop. This follows the physical-productivity approach used by Gollin et al. (2014) to compare agricultural output across heterogeneous crop mixes.

Agricultural employment. Woreda-level agricultural employment is constructed using a shift-share procedure,

$$L^i_{ag,t} = N^i_t \cdot s^i_{ag,2007} \cdot \frac{s^{national}_{ag,t}}{s^{national}_{ag,2007}}, \tag{OA4}$$

where N^i_t is population, $s^i_{ag,2007}$ is the woreda agricultural-employment share in the 2007 Census, and $s^{national}_{ag,t}$ is the national agricultural-employment share. The construction preserves the spatial employment distribution observed in the census while allowing the national agricultural share to evolve with structural transformation.

Agricultural value added and rural earnings. National agricultural value added is allocated across woredas using their shares of cereal-equivalent production:

$$\omega_{i,t} = \frac{Q^{ce}_{i,t}}{\sum_{i'} Q^{ce}_{i',t}}.$$

The resulting agricultural value added per worker is

$$w^{i,t}_R = \frac{\omega_{i,t}\, \mathrm{VA}^{national}_{ag,t}}{L^i_{ag,t}}. \tag{OA5}$$

By construction, allocated woreda-level agricultural value added sums to the national agricultural total.

The national-accounts series is expressed in constant 2010/11 Ethiopian birr. I therefore do not apply an additional consumer-price deflator before constructing (OA5). As a validation check, applying an additional food-price deflator would imply a 2007 value conversion equivalent to approximately 2.7 birr per US dollar, far below the contemporaneous market exchange rate of roughly 9–10. Using the constant-price national-accounts series directly gives an implied conversion of approximately 9.8 birr per dollar.

Livestock adjustment for pastoral areas. National agricultural value added includes both crop and livestock production, whereas the allocation weight $\omega_{i,t}$ is constructed from crops. Without an adjustment, this procedure would assign very little agricultural activity to pastoral locations with low cropland shares despite substantial livestock production.

I therefore classify the 547 agricultural woredas using cropland shares:

- *Crop-dominant*: cropland share at least 0.30, 235 woredas;

- *Mixed*: cropland share between 0.10 and 0.30, 132 woredas;
- *Pastoral*: cropland share below 0.10, 180 woredas.

Livestock adjustments are based on year-specific crop and livestock value shares. The median adjustment factor is 1.19 in mixed areas and 1.35 in pastoral areas, compared with one in crop-dominant areas. The adjustment raises the median constructed agricultural earnings measure in pastoral woredas by approximately 35%.

OA-1.1.8 Sensitivity and data coverage

I evaluate the agricultural prediction procedure under seven specifications:

A. the baseline predictor set;

B. excluding the local productivity-transfer component;

C. excluding the seasonal NDVI change;

D. excluding temperature;

E. excluding rainfall;

F. climate variables only; and

G. NDVI variables only.

The constructed rural earnings series is substantially less sensitive to these prediction choices than the underlying yield estimates. This follows from the accounting structure in (OA5): national agricultural value added is externally anchored, while the prediction model primarily affects its spatial allocation through cereal-equivalent production shares. Across the principal alternative prediction specifications, the resulting rural earnings series is essentially unchanged in rank and level relative to the final specification.

The more important limitation concerns direct survey coverage. Of the 11,487 woreda-year observations in the 547-by-21 agricultural panel, 3,996, or 34.8%, are directly observed in AgSS data and 65.2% use predicted agricultural outcomes. In 11 of the 21 panel years, no woreda is directly observed in the harmonized AgSS sample. Agricultural productivity levels and year-specific spatial patterns in these years consequently rely heavily on the prediction procedure. This limitation is more consequential for analyses using imputed productivity and agricultural shocks than for the nationally anchored rural earnings measure.

OA-1.1.9 Agricultural productivity shock

The transitory agricultural productivity component entering the quantitative model combines the remotely sensed agricultural signal with additional information on Belg-season exposure. For woreda i in year t, the shock is

$$\zeta^{A}_{i,t} = B_{i,t} \left(\text{belg ratio}_{i,t}\right)^{0.30\, bf_i}, \qquad \text{(OA6)}$$

where $B_{i,t}$ is the baseline remotely sensed agricultural shock, belg ratio$_{i,t}$ measures the Belg-season vegetation signal relative to its anchor-year value, and bf_i is the long-run share of annual rainfall occurring during the Belg season.

The Belg adjustment is therefore strongest in locations where short-season rainfall is agriculturally important. The effective exponent $0.30\, bf_i$ has a mean of approximately 0.095 and a maximum of approximately 0.18. The resulting shock is normalized to the 2007 anchor and winsorized to the interval $[0.3, 3.0]$.

The hybrid specification has a correlation of 0.758 with AgSS yield observations, compared with 0.749 for the Belg-adjusted baseline component alone and 0.736 for the pure NDVI specification. It also reproduces pronounced adverse agricultural conditions during the 2002, 2009, and 2015 drought episodes. I use these comparisons to select among alternative shock constructions rather than as independent validation of the agricultural data system, since AgSS information also enters other parts of the agricultural measurement architecture.

OA-1.2 Travel-time matrix

The bilateral travel-time matrix links all 681 spatial units using least-cost paths over a gridded transport-friction surface. The surface combines the road network with terrain-adjusted off-road travel speeds and is calibrated against observed travel times between Addis Ababa and major regional cities.

OA-1.2.1 Friction surface

Road network. The road layer combines OpenStreetMap coverage from 2018 with supplementary federal-road information. Road classes are assigned baseline free-flow speeds before adjusting for local terrain.

Off-road travel. Off-road speed follows the Tobler hiking function (Tobler, 1993),

$$v = 6 \exp(-3.5\, |\tan(\text{slope}) + 0.05|)\,, \qquad \text{(OA7)}$$

Table OA6: Road-speed assumptions

Road class	Baseline speed (km/h)
Motorway	100
Trunk	80
Primary	60
Secondary	40
Tertiary	25
Track	10
Path or footway	4

Notes: Baseline speeds assigned before terrain adjustment. On-road speeds are subsequently reduced as slope increases, while off-road movement follows the Tobler walking-speed function described in the text.

with speed measured in kilometers per hour. The function reaches its maximum on slight downhill terrain and is bounded below at 0.5 km/h.

Terrain adjustment on roads. Baseline road speeds are adjusted according to

$$v_{\text{adjusted}} = v_{\text{base}} \exp(-0.07\,|\text{slope}^{\circ}|)\,. \tag{OA8}$$

For each raster cell, effective travel speed is the larger of the terrain-adjusted road speed and the corresponding walking speed. The resulting friction surface is expressed in minutes per meter,

$$f = \frac{60}{1000v}.$$

Least-cost travel times are then computed between the centroids of all 681 spatial units. The resulting matrix is symmetric and provides the bilateral travel-time input used in the spatial analysis.

OA-1.2.2 Travel-time calibration

Raw least-cost travel times are systematically faster than observed road journeys because they approximate free-flow movement and omit waiting, congestion, stops, and other transport frictions. I therefore apply a common multiplicative calibration factor based on observed travel times from Addis Ababa to four major cities.

The common calibration factor is 1.313. After applying it, the four calibration routes are reproduced within approximately 15%. Because the calibration relies on only four routes originating in Addis Ababa, it should be interpreted as a coarse national speed adjustment rather than a location-specific validation of the entire matrix.

Table OA7: Calibration of bilateral travel times

Destination	Observed (h)	Raw (h)	Calibrated (h)	Error
Hawassa	4.5	3.2	4.2	−7.5%
Dire Dawa	7.5	5.7	7.5	+0.6%
Bahir Dar	8.5	6.4	8.4	−0.6%
Jimma	5.5	4.8	6.3	+14.5%

Notes: Raw least-cost-path times and calibrated values compared with observed road travel times from Addis Ababa. The common calibration multiplier is 1.313, the median observed-to-model travel-time ratio across the four routes.

OA-1.2.3 Derived accessibility measures

The travel-time matrix enters the model directly through bilateral spatial frictions and also supports descriptive measures of domestic accessibility. For location i, I construct

$$\mathrm{DMA}_i = \sum_c \mathrm{pop}_c \exp(-\kappa_{MA} tt_{ic}), \tag{OA9}$$

where tt_{ic} is calibrated travel time from location i to destination c and $\kappa_{MA} = 0.01$. This decay parameter implies a half-life of approximately 69 minutes; a value of 0.005 is used as a sensitivity check.

I denote this object DMA_i to distinguish the descriptive domestic-accessibility measure from the structural world-gateway market-access shifter MA_j entering formal productivity in the quantitative model.

The median rural location is approximately 100 minutes from its nearest city and 502 minutes from Addis Ababa. The descriptive accessibility index is therefore highly spatially concentrated: Addis Ababa's value is approximately 26.3 times the rural median.

Limitations. Four limitations are relevant for interpretation. First, the road network largely reflects conditions around 2018 and therefore omits later infrastructure investment. Second, the friction surface does not model seasonal deterioration of unpaved roads. Third, road speeds approximate physical travel rather than household-specific public-transport access. Fourth, the common calibration multiplier is identified from only four Addis-origin routes. The matrix is consequently best interpreted as a harmonized measure of relative spatial accessibility rather than a precise door-to-door travel-time prediction.

OA-1.3 Demographic inputs

The demographic panel provides location-specific natural population growth used to distinguish demographic change from spatial reallocation. Population evolves according to

$$N_{t+1} = N_t + \text{births} - \text{deaths} + \text{net migration}. \tag{OA10}$$

The construction combines national demographic levels from UN World Population Prospects with regional and urban-rural variation from the Demographic and Health Surveys.

OA-1.3.1 Fertility and mortality

Regional fertility and birth rates. Regional total fertility rates from successive DHS waves are interpolated as step functions between survey dates. I map these regional fertility differences into crude birth rates using

$$\text{CBR}_r(t) = \text{CBR}^{UN}_{national}(t)\frac{\text{TFR}_r(t)}{\text{TFR}^{weighted}_{national}(t)}. \tag{OA11}$$

This construction preserves the national birth-rate path from UN WPP 2024 (UN DESA, 2024) while allowing regional fertility differences observed in the DHS to generate spatial variation in natural population growth. It should be interpreted as a proportional allocation rule rather than a full cohort-component demographic model.

Urban-rural fertility. Within each region, urban and rural fertility are separated using the national urban-rural TFR ratio. Let

$$r_t = \frac{\text{TFR}^{national}_{urban,t}}{\text{TFR}^{national}_{rural,t}}.$$

Then

$$\begin{aligned} \text{TFR}_{rural,r,t} &= \frac{\text{TFR}_{r,t}}{s_{urban,r,t} r_t + (1 - s_{urban,r,t})}, \\ \text{TFR}_{urban,r,t} &= r_t \text{TFR}_{rural,r,t}. \end{aligned} \tag{OA12}$$

The procedure preserves each region's overall fertility rate while imposing the national urban-rural fertility gradient within regions.

Mortality. Regional crude death rates are constructed as

$$\text{CDR}_{r,t} = \text{CDR}_{national,t}\left(\frac{\text{TFR}_{r,t}}{\text{TFR}_{national,t}}\right)^{0.3} \Big/ \mathcal{N}_t, \tag{OA13}$$

where $\mathcal{N}_t$ normalizes the population-weighted regional average to the national crude death rate. The elasticity of 0.3 provides a reduced-form mapping from regional demographic conditions into mortality differences.

Urban mortality is set below rural mortality using

$$\mathrm{CDR}_{urban} = 0.65\,\mathrm{CDR}_{rural}.$$

This ratio is motivated by the large urban-rural mortality gradient observed in DHS data. Because the underlying evidence is strongest for child mortality rather than the all-age crude death rate, I treat this mapping as a demographic approximation and examine the implications of alternative demographic paths in the robustness analysis.

OA-1.3.2 Validation

Table OA8: Demographic inputs and external benchmarks, 2007

Moment	Constructed value	External benchmark
National CBR	37.5	37.5 (UN WPP)
National CDR	9.3	9.3 (UN WPP)
Natural population growth	2.82%	approximately 2.6% (WDI)
Urban TFR	2.6	approximately 2.4–3.0 (DHS)
Rural TFR	5.9	approximately 5.5–6.5 (DHS)

Notes: Comparison of the constructed demographic panel with UN WPP, WDI, and DHS benchmarks for 2007. CBR and CDR are crude birth and death rates per 1,000 people; TFR is the total fertility rate. The national CBR and CDR coincide mechanically with the WPP aggregates because the regional construction is normalized to those national series.

The national CBR and CDR comparisons are accounting checks rather than independent validation because the construction is anchored to the corresponding UN aggregates. The urban and rural fertility rates provide a more informative check on the within-country decomposition and lie within the ranges implied by the DHS data.

OA-1.4 Measured amenity index

I construct a descriptive amenity index for all 681 spatial units using seven measures of environmental conditions, accessibility, and local services. This index is separate from the inverted amenity term used in the migration model.

OA-1.4.1 Components

Night lights. DMSP observations for 2000–2013 and VIIRS observations from 2012 onward are placed on a common scale using their overlap period. A log-log mapping between the two systems converts the older DMSP measurements into VIIRS-equivalent

Table OA9: Components of the measured amenity index

Component	Source	Temporal variation	Index direction
Night lights	DMSP and VIIRS	Annual	Positive
$PM_{2.5}$	Satellite-based estimates	Cross-section	Negative
Temperature stress	ERA5	Annual	Negative
Health-facility distance	OpenStreetMap	2018 snapshot	Negative
School distance	OpenStreetMap	2018 snapshot	Negative
Elevation	SRTM	Time invariant	Positive
Domestic accessibility	Travel-time matrix	Time invariant	Positive

Notes: Raw inputs to the measured amenity index. Negative-direction components are transformed so that higher normalized values uniformly correspond to the index's "higher amenity" convention. The signs are construction conventions for this descriptive index and should not be interpreted as separately estimated causal effects on household utility.

units. Where multiple DMSP satellites report a location-year, their harmonized values are averaged.

Service access. The 2018 OpenStreetMap snapshot contains 780 health facilities and 1,039 schools used in the index. For each spatial unit, I calculate straight-line distance from the unit centroid to the nearest observed health facility and school. Because these measures come from a single crowd-sourced snapshot, they are treated as time invariant and are likely measured with non-classical spatial error.

OA-1.4.2 Index construction

Time-varying components are normalized within year, while time-invariant components are normalized over the full spatial cross-section. Variables interpreted as disamenities are reversed so that larger transformed values consistently correspond to higher values of the composite index.

I report three aggregation methods:

1. an equal-weight mean of available normalized components, requiring at least four non-missing measures;
2. the first principal component, which explains 42.0% of total variation; and
3. a two-factor model with varimax rotation.

In the factor model, the first factor loads most strongly on service access and connectivity, with loadings of 0.872 for school proximity, 0.788 for health-facility proximity, and 0.740 for domestic accessibility. The second factor loads primarily on temperature stress

(0.812) and particulate pollution (0.618).

The three constructions are highly correlated. The correlation between the equal-weight and principal-component indices is 0.902, while the correlation between the principal-component and factor-based indices is 0.985. Under the equal-weight specification in 2010, the mean index is 0.757 in urban locations and 0.681 in rural locations.

OA-1.4.3 Relation to the structural amenity term

The measured amenity index is not imposed directly as the migration amenity in the quantitative model. Instead, the model contains a destination-specific amenity term $\hat{a}_j$ recovered from the anchor-year population distribution conditional on wages, prices, housing costs, migration frictions, and the remaining model fundamentals. The inversion therefore treats amenity as the residual destination fundamental required to reconcile the model with observed spatial population shares.

This distinction is deliberate. Several components of the measured index, particularly service-location measures from OpenStreetMap, are observed with substantial error and only at a single date. Directly imposing the composite index would therefore translate these measurement errors into the migration block. The inversion instead allows observed population patterns to discipline the destination-specific residual while the measured index remains a separate descriptive measure of spatial amenities.

After the 2025 re-inversion, the baseline forward simulation applies the common urban amenity adjustment described in Appendices D and E of the paper. Urban log amenities receive a linear adjustment of 0.006 per year and are re-centered across locations to preserve the amenity normalization. This adjustment does not alter relative amenities through an independently estimated location-specific trend and does not enter the paper's welfare measure directly. Alternative amenity-drift assumptions are examined in the robustness analysis.

The amenity inversion should not be interpreted as independently identifying the causal contribution of amenities to migration. Conditional on the model and its other calibrated fundamentals, it recovers the residual destination attractiveness required to match the anchor population distribution. The measured index provides a complementary description of observed spatial conditions but does not independently identify $\hat{a}_j$.

OA-2 Measurement and Harmonization

This Online Appendix summarizes the main harmonization steps linking the raw geographic, agricultural, labor, price, and demographic sources to the variables used in the quantitative model. Appendix A of the paper describes the principal data objects and their economic interpretation, while Online Appendix OA-1 provides additional detail on the agricultural, travel-time, demographic, and measured-amenity constructions. The purpose here is to make the remaining transformations transparent without reproducing the file-level architecture of the replication package.

The data construction has four broad components: urban delineation, microdata harmonization, model-variable construction, and price measurement. Table OA10 provides an overview.

Table OA10: Measurement and harmonization workflow

Component	Principal inputs	Main transformations
Urban geography	Census population, WorldPop, GHSL, OpenStreetMap	Population calibration, density-based urban cores, built-up peripheries, temporal boundary harmonization, fragmentation corrections, and city naming
Agricultural and household microdata	AgSS, ESS, CHIRPS, MODIS, ERA5, SRTM	Administrative concordance, unit harmonization, income construction, climate and vegetation extraction, and agricultural outcome construction
Urban labor markets	UEUS, informal-sector surveys, national accounts	Wave harmonization, employment-status classification, wage construction, city-to-survey geography mapping, and formal-informal labor-market measures
Model-ready spatial variables	Harmonized microdata and geospatial inputs	Agricultural employment and productivity, travel times, demographics, amenities, migration moments, and aggregation to the model geography
Prices	CPI series, household expenditure and unit values, rents, transport costs	Temporal deflation, spatial food-price indices, and composite local price indices

Notes: The table describes the substantive transformations underlying the model inputs. Implementation detail is provided separately with the replication materials.

OA-2.1 Urban geography

The urban geography is constructed from a combination of census-calibrated population surfaces and remotely sensed built-up land. The objective is to define urban labor markets consistently across space while avoiding reliance on administrative city boundaries that differ in coverage and economic meaning.

The construction begins by scaling the 2007 population raster to reproduce Census woreda totals. Contiguous high-density cells identify candidate urban cores. The final delineation uses a density threshold of approximately 1,250 persons per square kilometer together with a built-up periphery derived from GHSL. OpenStreetMap place information and Census settlements provide city names and location checks.

Several adjustments address geographic cases in which a mechanical density rule does not correspond cleanly to an economically meaningful city. Polycentric urban areas are consolidated where nearby dense cores form a common labor market. Voronoi allocation is used where competing urban cores would otherwise claim overlapping hinterlands. A small number of locations, including Hawassa, Sodo, Dessie, and Kombolcha, require additional boundary review because dense neighboring settlements and administrative geography produce ambiguous automated delineations.

The resulting framework contains 126 urban locations. Boundaries are constructed consistently over the historical panel, while the quantitative equilibrium uses the spatial aggregation described in Appendix A of the paper.

OA-2.2 Microdata harmonization

OA-2.2.1 Agricultural surveys

Agricultural Sample Survey records are first mapped to a common administrative geography using the woreda concordance described in Online Appendix OA-1. Crop area and production variables are then harmonized across questionnaire waves, including the wave-specific production-unit conversions documented there.

Household information from the Ethiopia Socioeconomic Survey provides agricultural income components, crop unit values, and expenditure information. Climate and environmental inputs are spatially aggregated to the same woreda geography before they are combined with agricultural outcomes.

The resulting harmonized agricultural records support the construction of cereal-equivalent output, agricultural employment, agricultural value added per worker, the agricultural productivity panel, and the transitory productivity shock ζ^A.

OA-2.2.2 Urban employment surveys

The Urban Employment and Unemployment Survey is harmonized across eleven waves. Harmonization standardizes demographic characteristics, labor-force status, employment type, earnings, survey weights, and geographic identifiers before constructing the urban labor-market variables.

The principal distinction for the model is between private informal employment, private formal employment, and government employment. Informal and formal status are constructed using the employment definitions documented in Appendix A of the paper. Government workers are subsequently separated from private formal employment because government employment follows its own transition rule in the quantitative model.

Wage construction additionally harmonizes reported earnings periods and applies the common temporal price basis. Diagnostic comparisons with informal-sector survey evidence are used to assess the relative wage levels of employment groups and the stability of the resulting formal-informal differential.

City-level labor-market measures require a second geographic harmonization because UEUS information is available at a coarser survey geography than the 126-city spatial framework. Cities are therefore assigned to the corresponding survey zone. Of the 126 delineated cities, 124 can be mapped directly to the survey geography; cities sharing a survey zone inherit the same survey-based employment-composition measure where finer information is unavailable.

This geographic limitation is important for interpretation. Cross-city variation in model fundamentals can occur at the city level, but survey-based informality and wage inputs need not contain independent variation across every delineated city.

OA-2.3 Construction of model-ready variables

The harmonized sources are converted into a common set of spatial variables before model calibration.

Agricultural employment and productivity. Agricultural employment combines the 2007 Census spatial distribution with annual population and national agricultural-employment trends. National agricultural value added is allocated spatially using the agricultural production measures described in Online Appendix OA-1. The resulting value-added-per-worker measure provides the rural earnings input.

Urban labor-market mapping. Urban employment shares and wage measures are mapped from the harmonized survey geography to the model cities. Private formal, private informal, and government employment are kept distinct once the model-ready panel is assembled.

Travel times. Bilateral travel times between all 681 underlying spatial units are calculated from the friction surface described in Online Appendix OA-1. These travel times support both the structural bilateral frictions and descriptive domestic-accessibility measures.

Demographics. Location-level natural population growth combines national demographic paths with regional and urban-rural variation as described in Online Appendix OA-1.

Amenities. The measured amenity index combines environmental, accessibility, and service measures. It is retained as a descriptive data product and is distinct from the destination amenity inverted within the migration model.

Migration moments. Migration measures are harmonized across the available labor-force and household surveys. These data provide the origin-destination and migrant-tenure moments used to discipline the migration and formalization components of the model. Because survey coverage and migration-tenure information differ across sources, the role of each dataset is stated separately in Appendix A and Appendix E of the paper.

OA-2.4 Price measurement

All monetary variables are converted to a common constant-price basis before spatial comparison. The price construction has two conceptually separate components.

Temporal deflation. Nominal survey earnings and expenditure measures are expressed in constant 2010/11 birr using the common CPI series, with Ethiopian fiscal-year timing aligned to the corresponding survey period. National-accounts series already reported in constant 2010/11 birr are not deflated a second time.

Spatial prices. Relative local purchasing power is measured using household unit values and complementary non-food cost information. The food component is constructed as a Törnqvist index from comparable consumption items observed across locations. A broader spatial price index augments food prices with housing and transport costs to better approximate the consumption costs relevant for migration and real-income comparisons.

The distinction between temporal and spatial adjustment is maintained throughout. Temporal deflation places monetary observations from different years in a common unit, while the spatial index captures differences in the purchasing power of that common unit across locations.

OA-2.5 Replication materials

The executable implementation of the transformations described above and in Online Appendix OA-1 is provided separately with the replication materials.

OA-3 Numerical Implementation and Diagnostics

This Online Appendix provides additional numerical diagnostics for the equilibrium solution and calibration procedures described in Appendix D of the paper. It reports the scale of the parameter searches, convergence performance, and numerical accuracy of accepted solutions. Implementation detail is provided separately with the replication materials.

OA-3.1 Scale of the calibration searches

Each within-period equilibrium contains 207 unknowns across the 121 model locations. As described in Appendix D of the paper, these consist of 78 agricultural prices and, for the 43 urban locations, 43 formal-goods prices, 43 informal-goods prices, and 43 urban rents.

The calibration proceeds sequentially in parameter selection while preserving the general-equilibrium structure within each stage. Static parameters and the trade specification are selected before the productivity and dynamic searches. Conditional on previously selected parameter blocks, candidate productivity and dynamic parameter vectors are evaluated by resolving the spatial equilibrium along the relevant simulated path.

Table OA11 reports the numerical scale of these searches.

Table OA11: Scale of the numerical calibration

Calibration stage	Reported evaluations	Converged evaluations
Static within-period calibration	432	423
Trade specification	495	495
Productivity-drift search	34,056	34,056
Dynamic calibration	1,763	—

Notes: "Reported evaluations" follows the accounting used in the calibration records. The three principal calibration blocks excluding the separately evaluated trade grid contain $432 + 34{,}056 + 1{,}763 = 36{,}251$ evaluations. Including the 495 trade-grid evaluations gives 36,746. The calibration records separately report complete convergence of the trade and productivity-drift searches and convergence of 423 of the 432 static configurations. A separate aggregate convergence count is not reported here for the dynamic search.

The number of parameter evaluations understates the number of within-period equilibrium solutions required by the dynamic stages. A candidate dynamic path requires the equilibrium to be resolved repeatedly as population, employment composition, housing, productivity, and other state variables evolve through time. The computational burden therefore reflects repeated solution of the full spatial equilibrium rather than independent evaluation of reduced-form calibration equations.

OA-3.2 Equilibrium solution

The default within-period solver uses fixed-point iteration with Anderson acceleration. Candidate solutions are warm-started from nearby parameter configurations or from the preceding point on a simulated transition whenever possible. If the default iteration fails to satisfy the convergence criterion, alternative numerical methods are used, including Newton-type and trust-region procedures and direct minimization of the squared equilibrium residuals.

The latter objective can be written as

$$\mathcal{L}(x) = \frac{1}{2}R(x)'R(x), \tag{OA14}$$

where x is the vector of equilibrium unknowns and $R(x)$ contains the agricultural, formal-goods, informal-goods, and housing-market residuals defined in Appendix D of the paper. Automatic differentiation is used where derivatives are required by the numerical solver.

This combination of warm starts, accelerated fixed-point iteration, and fallback optimization is particularly useful in the dynamic calibration because nearby parameter vectors typically imply nearby equilibrium allocations, while configurations close to nonlinear regime boundaries can require a more robust solver.

OA-3.3 Convergence and numerical accuracy

Nine of the 432 configurations in the static calibration do not satisfy the solver's convergence criterion and are excluded from parameter selection. The remaining 423 configurations converge, corresponding to a rate of approximately 98%. All 495 trade-grid evaluations and all 34,056 evaluations recorded in the productivity-drift search converge.

For accepted equilibria, the reported maximum absolute market-clearing residual is below

$$10^{-14}.$$

Because the equilibrium conditions are expressed as proportional or log market-clearing errors, this criterion implies that numerical market imbalance is negligible relative to the economically relevant differences across candidate parameter values and counterfactuals.

The productivity-drift search also remains numerically well behaved across the admissible grid: the recorded transition paths do not exhibit solver discontinuities that would alter selection of the preferred parameter combination. This is important because the forward calibration evaluates changes in equilibrium outcomes over a long transition rather than matching a single static cross-section.

OA-3.4 Numerical reproducibility

The reported calibration architecture is deterministic conditional on the underlying data, parameter grids, and numerical tolerances. The numerical evidence relevant for interpreting the model is the convergence record, the equilibrium accuracy of accepted solutions, and the sensitivity of the selected outcomes to alternative parameter configurations, reported here and in Online Appendices OA-4 and OA-5.

OA-4 Calibration Search Ranges

This Online Appendix reports the search ranges used for parameters selected numerically rather than fixed directly from external evidence. Appendix E of the paper describes the identifying moments and the partial-identification problem associated with the formalization hazard. The purpose here is narrower: to make transparent which search intervals are externally disciplined, which are determined by model-relevant empirical ranges, and which govern auxiliary shape or normalization choices.

The strength of external discipline differs substantially across parameters. Some search ranges are informed directly by empirical estimates or observed shares. Others correspond to model-specific parameters for which no direct empirical analog exists and are therefore searched over economically admissible regions. These distinctions matter for interpretation, particularly for the formalization parameters (θ, ψ_0).

Table OA12: Calibration search ranges and external discipline

Parameter	Search range	External or empirical discipline	Role in calibration
θ	$[2, 8]$	No direct external prior; aggregate formalization trajectory and additional micro evidence described in Appendix E of the paper	Formalization-hazard curvature; partially identified jointly with ψ_0
ψ_0	$[5, 12]$	No direct external analog	Saturation of the formalization hazard; trades off with θ along the calibration ridge
φ_c	Discrete grid	No direct external estimate	Location of the adaptive formalization brake
ζ_{brake}	Discrete grid	No direct external estimate	Governs the strength of the adaptive brake
$\underline{\lambda}$	Discrete grid	Positive lower bound required by the hazard specification	Minimum formalization hazard
ϑ	$[1.5, 3.0]$	Centered on migration-dispersion estimates in Bryan and Morten (2019)	Migration-choice dispersion; selected value 2.50
κ_{fixed}	Discrete grid	Level of observed bilateral migration	Fixed component of migration costs

continued on next page

Table OA12 continued

Parameter	Search range	External or empirical discipline	Role in calibration
κ_s	Discrete grid	No direct external estimate	Destination-size component of migration costs
ν	$[2, 12]$	No direct literature anchor used in the calibration	Curvature parameter selected from equilibrium fit; baseline value 8.0
s_x^A	Discrete grid	Agricultural trade shares of approximately 8–12% from ERCA/NBE	Agricultural export-cap parameter
κ_b	Discrete grid	Width of the observed trade-price band	Trade-band parameter
ff	Discrete grid	No separate external estimate	Scale term entering the trade-band specification
κ_{food}, κ_{cash}, κ_{formal}	Discrete grids	Sectoral trade-share and price-band moments	Sector-specific trade-scale parameters
g_R^{init}, g_R^{long}	Discrete grid	Agricultural productivity-growth evidence from the World Bank and Fuglie (2012)	Initial and long-run rural productivity growth
g_U^{init}, g_U^{long}	Discrete grid	No direct external target imposed	Initial and long-run urban productivity growth
k	$\{0.22, 0.30, 0.40\}$	Shape of the UN WPP demographic transition	Speed of convergence in the demographic transition
n_{min}^R, n_{min}^U	Discrete grids	Aggregate population path based on UN WPP	Long-run rural and urban natural-increase rates

Notes: The table reports search ranges for parameters selected numerically. Parameters fixed directly from external evidence, such as the formal-sector land share α_F, are reported in Appendix E of the paper and are not repeated here. "No direct external estimate" means that the parameter is specific to the model's functional form rather than that its value is unrestricted: the admissible range is constrained by equilibrium behavior and by the calibration moments described in Appendix E. The exact discrete search grids are included in the replication package.

OA-4.1 Formalization-hazard search region

The formalization parameters require separate discussion because the aggregate calibration does not identify θ and ψ_0 independently. As shown in Appendix E of the paper, combinations of higher curvature and weaker saturation can generate similar national formalization trajectories. The search intervals

$$\theta \in [2, 8], \qquad \psi_0 \in [5, 12]$$

are therefore broad enough to include both the low-curvature transition consistent with the projected formalization path and high-curvature configurations associated with weak current absorption.

The baseline value $\theta = 3.25$ should not be interpreted as a direct micro estimate of current absorptive capacity. It is the value embedded in the projection-consistent transition. Independent migration-tenure estimates place the curvature parameter higher, while a persistence benchmark based on the model's forward cross-city dispersion also points toward the higher-curvature region. These exercises motivate the current-capacity comparison around $\theta = 4.75$, but they do not convert the aggregate ridge into conventional point identification.

The remaining hazard parameters, including φ_c, ζ_{brake}, and $\underline{\lambda}$, primarily govern the shape and limiting behavior of the transition function. They have no direct empirical counterparts and are therefore searched over admissible ranges and subjected to the perturbation and functional-form exercises reported in Appendix F and Online Appendix OA-5.

OA-4.2 Productivity-growth ranges

The rural productivity-growth corridor is externally disciplined more strongly than its urban counterpart. The long-run rural rate is anchored to agricultural TFP evidence, while the higher initial rate allows for transitional catch-up. The baseline path begins at

$$g_R^{\text{init}} = 0.045$$

and converges toward

$$g_R^{\text{long}} = 0.020.$$

The initial value exceeds typical long-run estimates and should therefore be interpreted as a transitional growth rate rather than a maintained agricultural TFP forecast.

Urban productivity growth is selected primarily to produce a plausible forward equilibrium jointly with the remaining transition parameters. Appendix E of the paper reports the baseline values

$$g_U^{\text{init}} = 0.040, \qquad g_U^{\text{long}} = 0.025.$$

Sensitivity to these productivity paths is reported in Online Appendix OA-5.

OA-4.3 Demographic search ranges

The demographic parameters combine external projection discipline with model calibration. UN World Population Prospects provides the aggregate population trajectory and broad shape of the fertility transition, but the model-specific natural-increase floors and convergence parameter are selected so that the spatial demographic system reproduces that aggregate path.

These parameters should therefore not be described as independently estimated demographic primitives. They are transition parameters conditional on the WPP reference path. Alternative demographic trajectories are included in the robustness analysis.

OA-5 Complete Robustness Results

This Online Appendix reports the detailed robustness results summarized in Appendix F of the paper. The exercises are organized by robustness family and report the full distributional decomposition whenever it is available. Appendix F discusses the economically most important cases and provides a consolidated overview.

I report quantitative changes directly rather than assigning "stable" or "sensitive" labels based on a single outcome. This distinction matters because some specifications leave the population-weighted urban-to-rural NPV ratio nearly unchanged while substantially altering national welfare, GDP, urbanization, or employment composition.

OA-5.1 Sensitivity to the aggregate target paths

The first exercise asks how the preferred region of the (θ, ψ_0) parameter space changes when the aggregate forward targets are varied. For each of five target specifications, I re-evaluate the same 5×5 parameter grid. This produces 125 scored configurations in total.

Table OA13 reports two distinct objects. The endpoint columns describe the best-fitting parameter combination under each alternative target. The final two columns report where the baseline pair,

$$(\theta, \psi_0) = (3.25, 9.0),$$

ranks within that alternative 25-point grid and how much its calibration score exceeds the minimum score under that target.

Changing the urbanization target within the considered range has little effect on the location of the baseline pair in the grid. Changing the desired formalization path matters more. Under the slower informality decline, the baseline pair ranks ninth, with a score approximately 12.8% above the target-specific optimum. Under the faster decline it ranks tenth and its score is approximately 48.5% above the optimum.

This exercise therefore reinforces the interpretation in Appendix E of the paper. The baseline value $\theta = 3.25$ is tied to the projection-consistent formalization path rather than being a direct estimate of current absorptive capacity. Alternative assumptions about the speed of formalization move the preferred position within the θ–ψ_0 region more than comparable changes in the urbanization path.

Table OA13: Sensitivity to alternative forward targets

Target specification	Best-fit urban share, 2065	Best-fit φ_{2065}	Rank of baseline pair	Score gap
Baseline targets	23.34%	0.319	2/25	+2.2%
Lower urbanization path	23.34%	0.319	2/25	+2.4%
Higher urbanization path	23.34%	0.319	2/25	+2.0%
Slower decline in informality	23.42%	0.357	9/25	+12.8%
Faster decline in informality	23.29%	0.290	10/25	+48.5%

Notes: Each row re-evaluates a 5×5 grid over (θ, ψ_0) under a different aggregate target path. The urbanization and informality columns report the 2065 endpoints generated by that target's own best-fitting grid point. "Rank of baseline pair" reports the position of $(3.25, 9.0)$ among the 25 candidate points, and "Score gap" is its calibration loss relative to the minimum loss under that target. The simulated path at the baseline parameter pair is unchanged across rows; only the scoring target changes.

OA-5.2 Local parameter perturbations

I next vary individual model parameters one at a time around their baseline values while holding the remaining parameters fixed. Table OA14 reports the effects on the urban-rural NPV ratio, national welfare, the three worker-group values, and GDP.

Because the implemented perturbations are not literally symmetric percentage changes for every parameter, I report the exact parameter values rather than describing the entire exercise as a uniform $\pm 10\%$ perturbation.

Most local perturbations have modest effects on the relative urban-rural value measure and on aggregate outcomes. The largest changes in the NPV ratio arise from the discount factor, the agricultural Armington elasticity, the food retail wedge, and the migration-choice dispersion.

The discount-factor experiment should be interpreted separately. Changing β mechanically changes the capitalization of future flows through the lifetime-value calculation. The very large percentage changes in national and group welfare therefore primarily reflect the valuation convention rather than equally large changes in contemporaneous economic allocations. GDP is essentially unchanged in both β exercises. The urban-rural ratio moves much less because the same discounting change affects each group.

OA-5.3 The θ–ψ_0 ridge and alternative hazard form

Appendix E of the paper documents the partial identification of the formalization hazard. Aggregate calibration moments admit a ridge of (θ, ψ_0) combinations that generate similar national transition paths. The purpose of Table OA15 is to show how the principal welfare objects vary along that ridge and under a more substantial change in the hazard's functional form.

Table OA14: Local parameter perturbations: 2065 outcomes

Perturbation	Δ NPV ratio %	Δ national %	Δ rural %	Δ informal %	Δ formal %	Δ GDP %
$\beta : 0.95 \rightarrow 0.855$	-13.4	-67.6	-65.5	-70.2	-65.5	-0.1
$\beta : 0.95 \rightarrow 0.97$	+6.0	+70.9	+66.5	+76.7	+66.8	-0.1
$\eta_d : 1.30 \rightarrow 1.17$	+1.0	-1.0	-1.2	-0.2	-0.2	-1.1
$\eta_d : 1.30 \rightarrow 1.43$	-0.5	+0.7	+0.7	+0.2	+0.2	+0.6
$\eta_I : 0.050 \rightarrow 0.045$	-0.9	-1.0	-0.6	-1.5	+0.3	-1.0
$\eta_I : 0.050 \rightarrow 0.055$	+1.0	+1.0	+0.7	+1.6	-0.3	+1.0
$\eta_{tr} : 0.40 \rightarrow 0.36$	+0.2	+2.0	+1.9	+2.1	+2.5	+1.7
$\eta_{tr} : 0.40 \rightarrow 0.44$	-0.2	-2.0	-1.8	-2.0	-2.4	-1.6
$\kappa_{\text{fixed}} : 40 \rightarrow 36$	-0.0	-0.1	-0.1	-0.1	-0.1	-0.0
$\kappa_{\text{fixed}} : 40 \rightarrow 44$	-0.0	+0.1	+0.1	+0.1	+0.0	+0.0
$\underline{\lambda} : 0.010 \rightarrow 0.009$	-0.1	-0.0	+0.0	-0.1	+0.0	-0.0
$\underline{\lambda} : 0.010 \rightarrow 0.011$	+0.1	+0.0	-0.0	+0.1	+0.0	+0.0
$\nu : 8.0 \rightarrow 7.2$	+0.2	-0.1	-0.2	+0.0	+0.2	-0.1
$\nu : 8.0 \rightarrow 8.8$	-0.2	+0.1	+0.1	-0.0	-0.2	+0.1
$\omega_H : 0.35 \rightarrow 0.315$	+1.5	+1.3	+0.6	+2.1	+2.0	+0.7
$\omega_H : 0.35 \rightarrow 0.385$	-1.4	-1.3	-0.7	-2.1	-1.9	-0.7
$\varphi_c : 0.25 \rightarrow 0.225$	+0.2	+0.4	+0.3	+0.5	-0.2	+0.5
$\varphi_c : 0.25 \rightarrow 0.275$	-0.3	-0.4	-0.2	-0.6	+0.2	-0.5
$\psi_0 : 9.0 \rightarrow 8.1$	+0.4	+0.3	+0.1	+0.5	-0.1	+0.4
$\psi_0 : 9.0 \rightarrow 9.9$	-0.3	-0.3	-0.2	-0.5	+0.1	-0.4
$\psi_H : 0.30 \rightarrow 0.27$	-0.7	-0.5	-0.2	-0.9	-0.8	-0.2
$\psi_H : 0.30 \rightarrow 0.33$	+0.7	+0.5	+0.2	+0.9	+0.8	+0.2
$\sigma_A : 4.0 \rightarrow 3.6$	+3.3	-0.8	-2.4	+0.9	+0.8	-1.8
$\sigma_A : 4.0 \rightarrow 4.4$	-4.0	+1.0	+3.0	-1.2	-1.1	+2.5
$\tau_{\text{retail}} : 0.15 \rightarrow 0.135$	+3.3	-0.2	-1.7	+1.5	+1.5	-1.5
$\tau_{\text{retail}} : 0.15 \rightarrow 0.165$	-3.3	+0.3	+1.8	-1.5	-1.5	+1.7
$\theta : 3.25 \rightarrow 2.925$	+0.7	-0.1	-0.3	+0.3	+0.2	-0.3
$\theta : 3.25 \rightarrow 3.575$	-0.5	-0.1	+0.1	-0.2	-0.1	-0.0
$\vartheta : 2.50 \rightarrow 2.25$	+2.3	-1.6	-2.1	-0.1	+0.2	-2.0
$\vartheta : 2.50 \rightarrow 2.75$	-2.2	+1.2	+1.8	-0.4	-0.4	+1.9
$\zeta_{\text{brake}} : 4.0 \rightarrow 3.6$	-0.1	-0.1	-0.1	-0.1	+0.0	-0.1
$\zeta_{\text{brake}} : 4.0 \rightarrow 4.4$	+0.1	+0.1	+0.1	+0.1	-0.0	+0.1

Notes: The table reports terminal 2065 deviations from the baseline simulation, varying one parameter at a time and holding all remaining parameters fixed. The baseline population-weighted urban-to-rural NPV ratio is 2.606. "National," "rural," "informal," and "formal" refer to the population-weighted national welfare measure and the corresponding worker-group lifetime values. GDP is market-price output.

Across D1–D5, the NPV ratio moves by less than one percent and national and group values differ from baseline by at most approximately one percent. The paper's principal welfare comparisons are therefore quantitatively stable along the documented portion of the calibration ridge. This does not imply that θ and ψ_0 are point identified; it

Table OA15: Formalization-hazard robustness: 2065 welfare outcomes

Specification	θ	ψ_0	Δ NPV ratio %	Δ national %	Δ rural %	Δ informal %	Δ formal %
D1	2.0	12.0	+0.6	-1.0	-1.0	-0.7	+0.7
D2	2.5	10.5	+0.7	-0.6	-0.7	-0.2	+0.5
D3	3.0	9.5	+0.3	-0.2	-0.3	-0.1	+0.2
Baseline	3.25	9.0	0.0	0.0	0.0	0.0	0.0
D4	3.5	8.5	-0.3	+0.2	+0.3	+0.1	-0.2
D5	4.0	7.0	-0.3	+0.3	+0.3	+0.9	-0.6
D6, off ridge	5.0	5.0	+0.6	-8.1	-6.8	-2.7	+3.6
Logistic hazard	3.25	9.0	-3.7	-17.0	-12.1	-12.7	+4.5

Notes: The table reports terminal 2065 deviations from the baseline simulation. D1–D5 trace the (θ, ψ_0) substitution ridge along which higher curvature is offset by weaker saturation. D6 is a high-curvature configuration outside that region and generates a 2065 private informality share of 0.552. The final row replaces the baseline formalization hazard with a logistic specification evaluated at the reported baseline parameter values; its 2065 private informality share is 0.039.

instead shows that the welfare objects of interest are substantially less sensitive than the individual hazard parameters.

D6 illustrates why stability of the NPV ratio alone is not sufficient to evaluate robustness. Although the ratio is only 0.6% above baseline, national welfare falls by 8.1% and the economy enters a high-informality regime. The employment composition therefore changes materially even though the relative urban-rural value measure does not.

The alternative logistic hazard produces an even larger change in the employment transition. Private informality falls to 0.039 by 2065, while national welfare is 17.0% below the baseline specification and formal-worker value is 4.5% higher. This exercise shows that the precise long-run employment composition is sensitive to the functional form of the formalization hazard. The comparatively small 3.7% movement in the NPV ratio should not be interpreted as evidence that the full quantitative transition is invariant to functional form.

OA-5.4 Alternative structural specifications

Table OA16 replaces several components of the model rather than perturbing individual parameters locally.

Freezing the endogenous informal-demand weight has essentially no quantitative effect. The symmetric Armington alternative produces moderate changes in welfare and GDP.

Housing supply is much more consequential for aggregate levels than the urban-rural ratio alone suggests. Halving the housing-supply elasticity lowers national welfare by 42.2% and GDP by 56.0%, while increasing it by 50% raises national welfare by 80.9%

Table OA16: Alternative structural specifications: 2065 outcomes

Specification	Δ NPV ratio %	Δ national %	Δ rural %	Δ informal %	Δ formal %	Δ GDP %
Fixed informal-demand weight ω_I	-0.0	-0.0	-0.0	+0.0	-0.0	+0.0
Homothetic upper-tier CES	-85.5	-85.9	-77.2	-96.7	-95.9	+230.5
Symmetric Armington structure	+3.1	-5.4	-7.0	-3.7	-6.0	-3.5
Housing supply elasticity $b_1 \times 0.5$	+2.1	-42.2	-39.5	-37.9	-28.8	-56.0
Housing supply elasticity $b_1 \times 1.5$	-7.2	+80.9	+79.8	+66.9	+38.7	+151.0
Distance-only migration costs	+162.8	-69.6	-70.4	-27.0	-6.0	-50.1

Notes: Terminal 2065 deviations from the baseline specification. The two housing exercises halve or increase by 50% the short-run housing-supply elasticity. The distance-only migration specification removes the fixed and destination-size components of migration costs. Appendix F of the paper discusses the non-homothetic preference and migration-friction cases in more detail.

and GDP by 151.0%. Yet the NPV ratio moves by only $+2.1\%$ and -7.2%. Housing supply therefore has a large effect on the level of the simulated economy even though it has a smaller effect on relative urban-rural valuation.

The homothetic preference specification generates an especially large change in both welfare and output. Because this exercise changes the preference system itself, comparisons of welfare levels require additional caution: changing utility curvature and non-homotheticity can alter the cardinal scale of lifetime-value objects in addition to changing equilibrium allocations. The robust economic finding is that removing the estimated expenditure response profoundly changes the rural-urban incidence and equilibrium allocation, which is why Appendix F treats non-homotheticity as a load-bearing assumption.

Finally, the distance-only migration specification produces an urbanization rate of only approximately 7.1% by 2065 and large declines in output and national welfare. This specification removes the fixed and destination-size components required to reproduce the observed migration pattern. It is therefore best interpreted as an alternative migration structure rather than a locally plausible perturbation of the baseline model.

OA-5.5 Alternative parameter values from the literature

The next exercises replace selected baseline parameters with alternative values motivated by ranges used in the empirical or quantitative literature. These substitutions are deliberately wider than the local perturbations reported above and therefore provide a

Table OA17: Alternative parameter values: 2065 outcomes

Alternative value	Δ NPV ratio %	Δ national %	Δ rural %	Δ informal %	Δ formal %	Δ GDP %
α_A : 0.40 → 0.30	-7.7	+39.6	+41.4	+30.8	+29.9	+8.7
α_A : 0.40 → 0.50	+11.5	-33.4	-35.6	-28.2	-27.6	-8.8
η_{tr} : 0.40 → 0.50	-0.5	-4.8	-4.5	-4.9	-5.8	-3.9
σ_A : 4 → 5	-9.3	+2.4	+7.1	-2.8	-2.7	+6.1
σ_A : 4 → 8	-28.3	+9.7	+26.2	-9.4	-8.8	+24.4
β : 0.95 → 0.90	-8.9	-52.0	-50.0	-54.5	-50.0	+0.0
β : 0.95 → 0.96	+2.8	+26.5	+25.0	+28.4	+25.0	-0.1
β : 0.95 → 0.99	+15.0	+430.6	+398.2	+473.6	+401.0	-0.5
ϑ : 2.50 → 1.50	+12.3	-9.0	-11.0	-1.6	+1.4	-11.4
ϑ : 2.50 → 3.00	-4.0	+2.2	+3.2	-1.0	-0.9	+3.5
η_I : 0.05 → 0.10	+11.7	+13.5	+8.7	+21.2	-2.0	+13.1
s_x^A : 0.10 → 0.50	-30.4	+11.9	+28.7	-10.3	-10.0	+29.9

Notes: Terminal 2065 deviations from the baseline simulation, changing one parameter at a time and holding all remaining parameters fixed. The alternative values are motivated by ranges used in the corresponding empirical or quantitative literature. The baseline population-weighted urban-to-rural NPV ratio is 2.606. The welfare columns report national population-weighted lifetime value and the rural, informal, and formal worker-group values.

more demanding check on the quantitative conclusions.

Several substitutions generate economically large level effects. Changing the agricultural production share α_A materially shifts both welfare and GDP. Raising the agricultural trade elasticity to $\sigma_A = 8$ increases GDP by 24.4% and rural value by 26.2% while lowering the urban-rural NPV ratio by 28.3%. Raising the agricultural export cap to $s_x^A = 0.50$ generates similarly large changes.

The discount-factor substitutions again require separate interpretation. Moving β from 0.95 to 0.99 raises reported lifetime-value measures by several hundred percent while GDP changes by less than one percent. These changes primarily reflect the capitalization of future flows rather than comparable changes in contemporaneous equilibrium allocations. The NPV ratio is substantially less sensitive because discounting affects all worker groups simultaneously.

The low-dispersion value $\vartheta = 1.5$ generates a substantially different migration pattern and lowers GDP by 11.4%. In the baseline calibration, this value also implies a mean stay probability outside the range matched to Ethiopian migration data. I therefore treat it as a comparison with a lower-dispersion migration structure rather than as an empirically plausible local alternative.

Table OA18: Calibration-window checks: 2065 outcomes

Alternative calibration	Δ NPV ratio %	Δ national %	Δ rural %	Δ informal %	Δ formal %	Δ GDP %
2007 rather than 2014 anchor	+0.0	-0.0	-0.0	+0.0	+0.0	-0.0
Exclude Tigray from calibration loss	-0.0	+0.0	+0.0	-0.0	-0.0	+0.0

Notes: Terminal 2065 deviations from the baseline simulation. Reported values round to zero at the displayed precision. The Tigray exclusion does not alter the simulated forward state under the implemented calibration architecture and is therefore an accounting check rather than an independent perturbation of the equilibrium path.

OA-5.6 Calibration-window checks

I perform two checks on the temporal and geographic calibration choices. The first reconstructs the productivity fundamentals using 2007 rather than 2014 as the anchor year and simulates the corresponding forward path. The second excludes Tigray from the calibration loss.

Re-anchoring the productivity inversion in 2007 produces terminal outcomes that are numerically indistinguishable from those obtained from the 2014 anchor at the reported precision. This shows that the reported forward equilibrium is insensitive to this particular anchor-year choice.

The Tigray exclusion has a different interpretation. Under the implemented calibration architecture, Tigray enters the scoring objective but not the forward-simulation state used for this exercise. Removing it from the loss therefore leaves the selected path unchanged to numerical precision. This result verifies the implementation of the scoring convention but should not be interpreted as evidence that equilibrium outcomes would be insensitive to removing Tigray from the model itself.

OA-5.7 Productivity and demographic paths

The forward simulation necessarily relies on assumptions about long-run productivity and demographic change. I therefore vary the rural and urban productivity paths substantially and replace the baseline demographic trajectory with the UN WPP low- and high-population alternatives.

Long-run productivity assumptions are quantitatively important. Increasing the urban TFP path by 50% raises GDP by 130.2% and national welfare by 67.5%, while halving it lowers GDP by 56.1% and national welfare by 42.1%. Rural productivity growth also has substantial welfare effects, although its GDP response differs because higher agricultural productivity changes relative agricultural prices as well as physical output.

Table OA19: Productivity and demographic sensitivity: 2065 outcomes

Alternative path	Δ NPV ratio %	Δ national %	Δ rural %	Δ informal %	Δ formal %	Δ GDP %
Rural TFP growth ×1.5	+17.1	+33.4	+19.9	+40.4	+39.4	-3.8
Rural TFP growth ×0.5	-9.1	-32.6	-28.9	-35.5	-34.7	+2.0
Urban TFP path ×1.5	+8.8	+67.5	+61.0	+74.9	+76.3	+130.2
Urban TFP path ×0.5	-12.9	-42.1	-37.2	-45.2	-45.4	-56.1
WPP low-population path	+2.7	+0.0	-0.9	+1.8	+1.8	-7.0
WPP high-population path	-2.4	-0.2	+0.7	-1.7	-1.7	+7.2

Notes: Terminal 2065 deviations from the baseline simulation. Productivity exercises multiply the corresponding trend path by 0.5 or 1.5. Demographic exercises use the UN WPP 2024 low- and high-population variants.

These exercises should therefore be interpreted as alternative development paths rather than small parameter perturbations. They show that the levels of long-run GDP and welfare depend importantly on assumptions about productivity growth, even though the model continues to generate the core distinction between urbanization and employment formalization over the considered paths.

The alternative demographic trajectories have much smaller effects on lifetime-value measures. The WPP low- and high-population paths change GDP by approximately -7% and $+7\%$, respectively, but move national welfare by less than 0.2% at the terminal horizon. The different responses of GDP and welfare reflect the fact that population scale and per-worker lifetime value are distinct objects.

OA-5.8 Channel shutdowns

The next exercises remove major equilibrium channels rather than varying parameters locally. They are therefore mechanism decompositions, not conventional robustness checks. Their purpose is to establish which components materially shape the baseline transition.

Migration is quantitatively central to the spatial transition. Suppressing migration lowers GDP by 44.3% and national welfare by 27.6% and reduces the terminal urbanization rate to approximately 13.1%. At the same time, the urban-rural NPV ratio rises because the remaining urban workers become a more selected and scarce group. This illustrates why the ratio should not be read as an aggregate welfare statistic.

Housing congestion also matters materially. Removing it raises national welfare by 19.0% and GDP by 10.1%. Together with the large housing-elasticity responses reported above, this confirms that housing is quantitatively important for the level and

Table OA20: Channel shutdowns: 2065 outcomes

Channel removed	Δ NPV ratio %	Δ national %	Δ rural %	Δ informal %	Δ formal %	Δ GDP %
Endogenous formalization response	+4.0	-0.8	-1.9	+1.7	+0.8	-1.9
Housing congestion	+21.0	+19.0	+9.3	+33.0	+33.2	+10.1
Migration	+85.2	-27.6	-33.6	+21.6	+24.9	-44.3
Subsistence floor	+68.0	-15.1	-28.5	+20.3	+19.9	-30.7
International trade	-62.5	+6.2	+47.0	-45.2	-44.3	+52.2

Notes: Terminal 2065 deviations from the baseline specification. "Endogenous formalization response" removes the dependence of the formalization transition on the relevant endogenous state rather than eliminating all transitions into formal employment. "Housing congestion" removes the baseline housing-congestion channel. "Migration" suppresses spatial reallocation by making migration prohibitively costly. The trade exercise is the near-autarky specification discussed in Appendix F of the paper. These exercises deliberately alter major pieces of the model and should be interpreted as mechanism decompositions.

distribution of urban gains.

The subsistence and international-trade exercises generate especially large changes and are discussed in Appendix F of the paper. The trade shutdown is particularly instructive: national welfare rises by 6.2% even as informal and formal worker values fall by more than 44% and rural value rises by 47.0%. The result reflects a large redistribution through relative prices and should not be summarized by either GDP or the urban-rural NPV ratio alone.

OA-5.9 Amenity-drift sensitivity

The baseline forward simulation applies an urban log-amenity adjustment of 0.006 per year after the 2025 re-inversion. I vary this adjustment from zero to four times its baseline value. Amenities affect location choice but do not enter the paper's welfare measure directly, so welfare changes in this exercise arise through induced migration and the resulting equilibrium changes in wages, prices, housing, and employment composition.

Within the narrower range from 0.003 to 0.009 per year, the urban-rural NPV ratio changes by approximately seven percent in either direction and national welfare changes by less than three percent. The much larger 0.012–0.024 values are useful for tracing the strength of the amenity channel but should be read as bounding scenarios rather than nearby alternatives to the baseline path.

Setting the amenity adjustment to zero lowers terminal GDP by 10.6% and national welfare by 5.6%. The corresponding terminal urbanization rate is approximately 2.3 percentage points below baseline. The amenity adjustment therefore contributes non-

Table OA21: Amenity-drift sensitivity: 2065 outcomes

Annual urban amenity adjustment	Δ NPV ratio %	Δ national %	Δ rural %	Δ informal %	Δ formal %	Δ GDP %
0.000	+14.3	-5.6	-8.4	+4.7	+4.8	-10.6
0.003	+7.2	-2.8	-4.4	+2.4	+2.5	-5.5
0.006 (baseline)	0.0	0.0	0.0	0.0	0.0	0.0
0.009	-7.1	+2.9	+4.9	-2.5	-2.5	+6.0
0.012	-13.7	+5.7	+9.9	-5.1	-5.0	+12.1
0.018	-25.4	+11.2	+20.6	-9.9	-9.8	+24.9
0.024	-35.4	+16.5	+32.1	-14.6	-14.3	+38.3

Notes: Terminal 2065 deviations from the baseline simulation. The baseline annual log-amenity adjustment is 0.006. The values 0.003 and 0.009 correspond to one-half and one-and-a-half times that rate. Amenities affect migration choices but are excluded from the welfare metric itself.

trivially to the simulated urban transition, although most of the baseline movement is generated by the remaining demographic, productivity, migration, housing, and labor-market mechanisms.

Increasing the amenity adjustment has opposite effects across rural and urban worker groups. At the largest values, rural value rises while informal and formal urban values fall. Since amenities themselves are not valued directly in the welfare calculation, these differences capture the general-equilibrium incidence of stronger amenity-induced migration rather than a direct utility gain from living in cities.

OA-6 Complete Counterfactual Decompositions

This Online Appendix reports the complete instrument-level results underlying the counterfactual analysis in Sections 7 and 8 of the paper. Appendix G of the paper summarizes the principal mechanisms and incidence results. Here I provide the full formalization-capacity sweep and the output, welfare, wage, and spatial-incidence decompositions for the individual policy experiments.

All policy effects are measured relative to the zero-intervention baseline corresponding to the same formalization-capacity regime. Results are reported under both the projection-consistent regime, $\theta = 3.25$, and the current-capacity benchmark, $\theta = 4.75$. National welfare is the population-weighted lifetime value across worker groups. Rural Π^R, informal V^I, formal V^F, and the urban entrant NPV are reported separately where relevant. The fixed spatial incidence groups are defined in Appendix G of the paper and are held constant across experiments.

OA-6.1 Formalization-capacity sweep

Section 7 of the paper reports the principal effects of changing formalization capacity. Figure OA1 provides the corresponding transition paths in levels rather than deviations. The figure traces urbanization, employment composition, the formalization hazard, the formal-to-rural wage ratio, sectoral output, and sectoral real wages between 2015 and 2065.

The figure illustrates the central separation between urbanization and formalization. Urban population shares remain comparatively close across capacity regimes, while employment composition diverges substantially. The formalization hazard also evolves differently across the capacity scenarios because the size of the informal pool feeds back into the rate at which workers move into formal employment. The figure should be read as a numerical illustration of this nonlinear feedback rather than as establishing a sharp analytical threshold at a particular value of θ.

OA-6.2 Supply-side counterfactuals

The supply-side experiments raise productivity in formal, informal, or agricultural production. A fourth exercise raises formal and agricultural productivity jointly. The summary comparisons are reported in Appendix G of the paper; the tables below provide the complete worker-group and spatial decompositions.

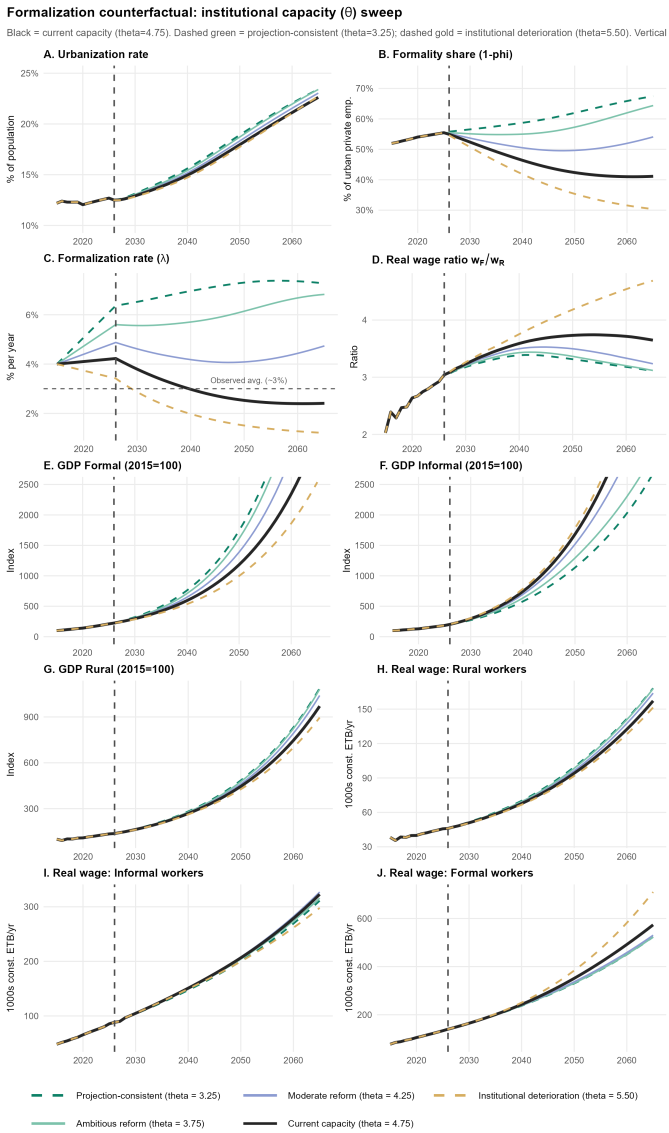

Figure OA1: Formalization-capacity sweep in levels

Notes: Model-implied transition paths under $\theta \in \{3.25, 3.75, 4.25, 4.75, 5.50\}$, with lower θ corresponding to greater formalization capacity. The capacity change in this transition experiment begins in 2026. The panels report the urbanization rate, the private formal employment share $1-\varphi$, the annual formalization hazard λ, the formal-to-rural real-wage ratio w_F/w_R, sectoral output in agriculture, informal production, and formal production, and the corresponding three sectoral real wages. Monetary quantities are expressed in constant 2010/11 birr. These are simulated model paths rather than comparisons with observed data. Source: author's computation.

OA-6.2.1 Formal-sector productivity

The formal-sector productivity experiment raises A_F by between 5 and 25%. Greater formal productivity raises formal labor demand and formal wages, but the employment response depends on whether workers can move through the informal queue. The decomposition at the reported 25% intervention shows larger national gains under $\theta = 3.25$ than under $\theta = 4.75$.

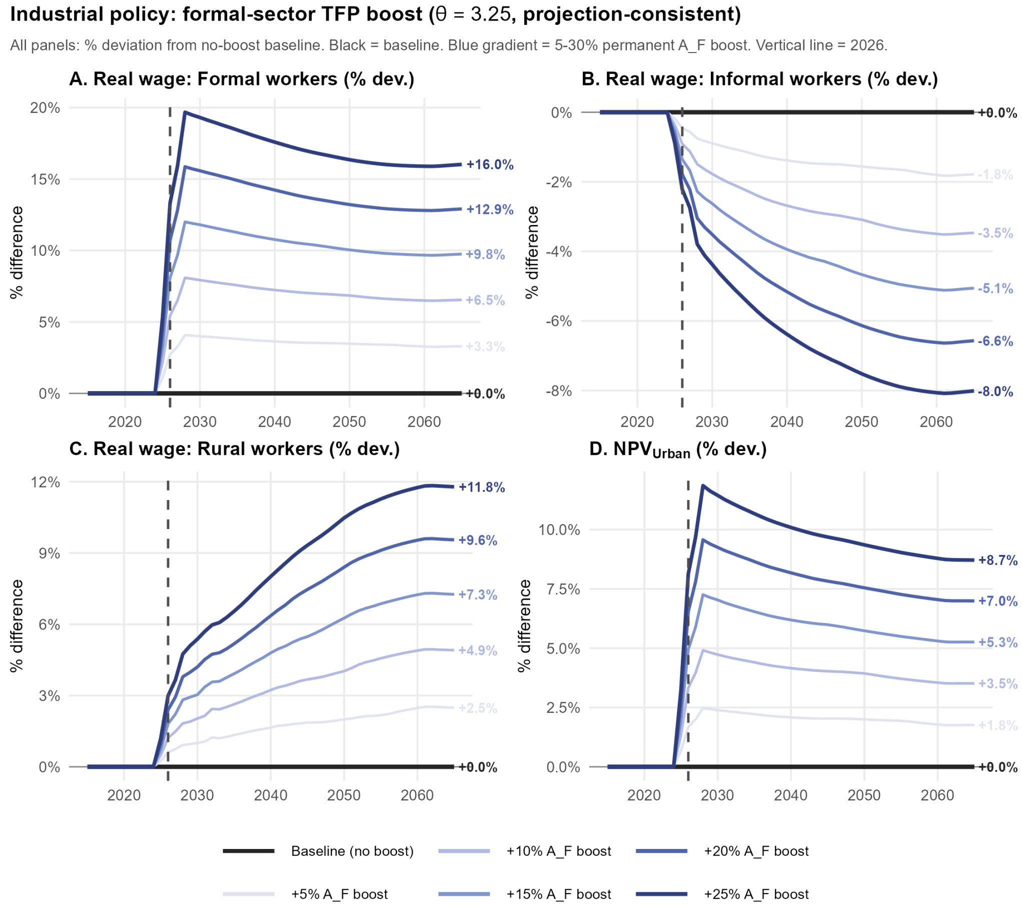

Figure OA2: Formal-sector productivity, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding regime baseline as formal-sector TFP rises from 5 to 25% above baseline. At the common 20% dose, formal real wages rise by 12.9%, informal real wages fall by 6.6%, rural real wages rise by 9.6%, and GDP rises by 16.7%. At the reported 25% intervention, urban entrant NPV rises by 8.7%. Source: author's computation.

Spatial variation in the proportional gain to formal-worker value is limited. At the reported 25% intervention, the increase in V^F is approximately 16% across all three urban-connectedness groups. The principal incidence margin is therefore employment status rather than a strong connectedness gradient among workers already in formal employment.

Table OA22 reports the full output and welfare decomposition for the formal-productivity experiment at the 2035 and 2065 horizons under both capacity regimes; Table OA23 reports the corresponding regional-incidence cuts across the fixed location groups.

The decline in informal wages despite higher aggregate output illustrates an important incidence mechanism. Formal productivity reallocates demand toward formal production. Workers who obtain formal positions benefit directly, while workers remaining in informal employment can face weaker contemporaneous labor demand. Their life-

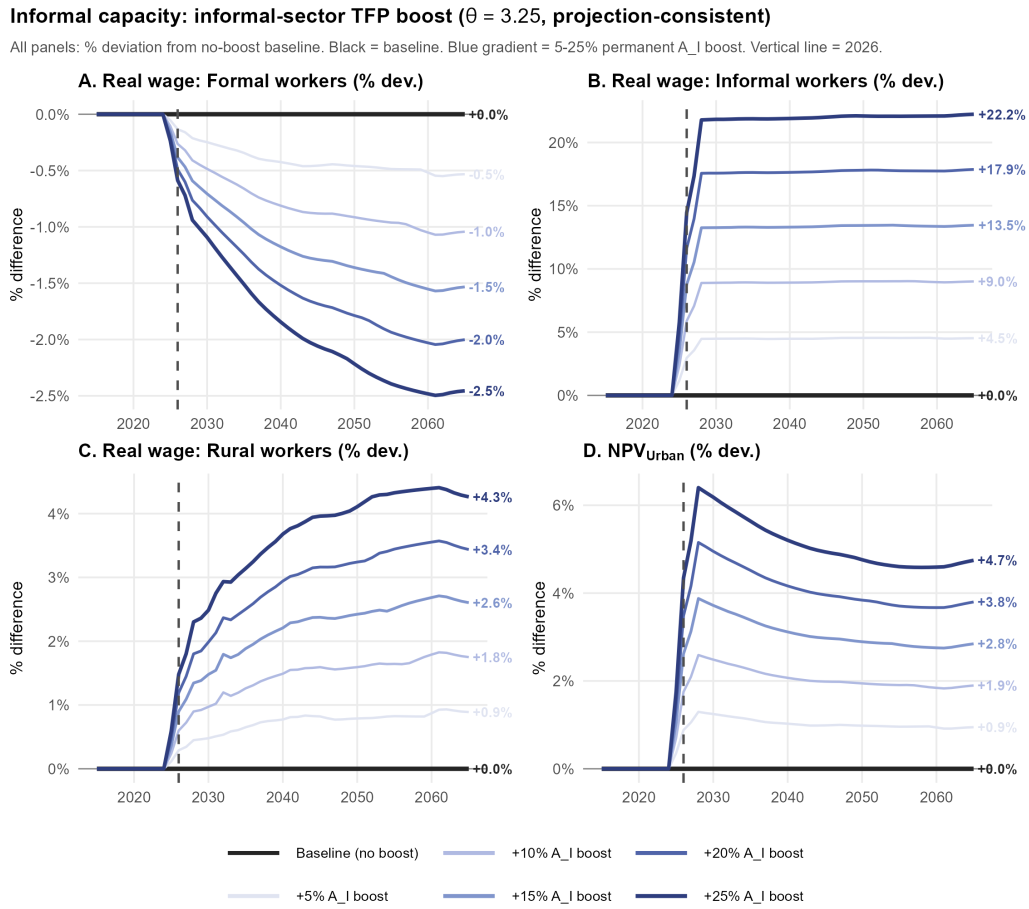

Figure OA3: Informal-sector productivity, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding regime baseline as informal-sector TFP rises from 5 to 25%. At the common 20% dose, the informal real wage rises by 17.9%, the formal real wage falls by 2.0%, the rural real wage rises by 3.4%, and GDP rises by 4.8%. At the reported 25% intervention, urban entrant NPV rises by 4.7% under $\theta = 3.25$. Source: author's computation.

time value may nevertheless increase because the formal job reached after successful transition becomes more valuable.

OA-6.2.2 Informal-sector productivity

The informal-sector productivity experiment raises A_I by between 5 and 25%. Unlike formal-sector productivity, it directly raises productivity in the sector containing workers who have not yet formalized.

The capacity interaction is primarily compositional. At the 25% dose, the decomposition reports a national welfare increase of 2.0% under $\theta = 3.25$ and 6.6% under $\theta = 4.75$. The mechanism need not be intrinsically more productive under weak formalization capacity. Rather, the informal sector contains approximately 46.5% of the relevant urban workforce under $\theta = 4.75$, compared with approximately 23.3% under $\theta = 3.25$, so a larger population is directly exposed to the productivity improvement.

Table OA24 reports the full output and welfare decomposition for the informal-productivity experiment at the 2035 and 2065 horizons under both capacity regimes; Table OA25 reports the corresponding regional-incidence cuts across the fixed location groups.

The experiment therefore illustrates why productivity support within the existing employment structure can remain valuable when formal absorption is weak. It improves earnings for workers who remain informal, but it does not itself remove the transition friction governing access to formal employment.

OA-6.2.3 Agricultural productivity

The agricultural development experiment raises rural TFP by between 5 and 30%. It operates both through rural productivity and through the equilibrium price of agricultural goods. Among the three sector-specific productivity experiments, it is the only one at the reported common dose that raises all three sectoral real wages.

The proportional rural welfare effect varies little across the market-access groups. At the reported 30% intervention, rural value rises by approximately 8.1–8.8% across the three terciles. The corresponding gains in birr remain smaller in initially poorer and less connected locations because they start from lower income levels. Similar percentage gains therefore do not imply convergence in welfare levels.

Table OA26 reports the full output and welfare decomposition for the agricultural-productivity experiment at the 2035 and 2065 horizons under both capacity regimes; Table OA27 reports the corresponding regional-incidence cuts across the fixed location groups.

The small market-price GDP response should therefore not be interpreted as an absence of economic gains. Greater agricultural supply lowers relative food prices and raises real purchasing power. The distinction between nominal market-price output and real household welfare is particularly important for this experiment.

OA-6.2.4 Joint formal and agricultural productivity

The combined experiment raises formal and agricultural productivity together. The purpose is to examine whether the food-price and rural-income effects of agricultural productivity can offset the adverse informal-wage incidence generated by formal-sector expansion.

In the simulated combinations, an agricultural productivity increase equal to approximately 0.6–0.85 times the formal-productivity increase is sufficient to offset the informal-wage loss under $\theta = 3.25$. Under $\theta = 4.75$, the corresponding ratio is approximately

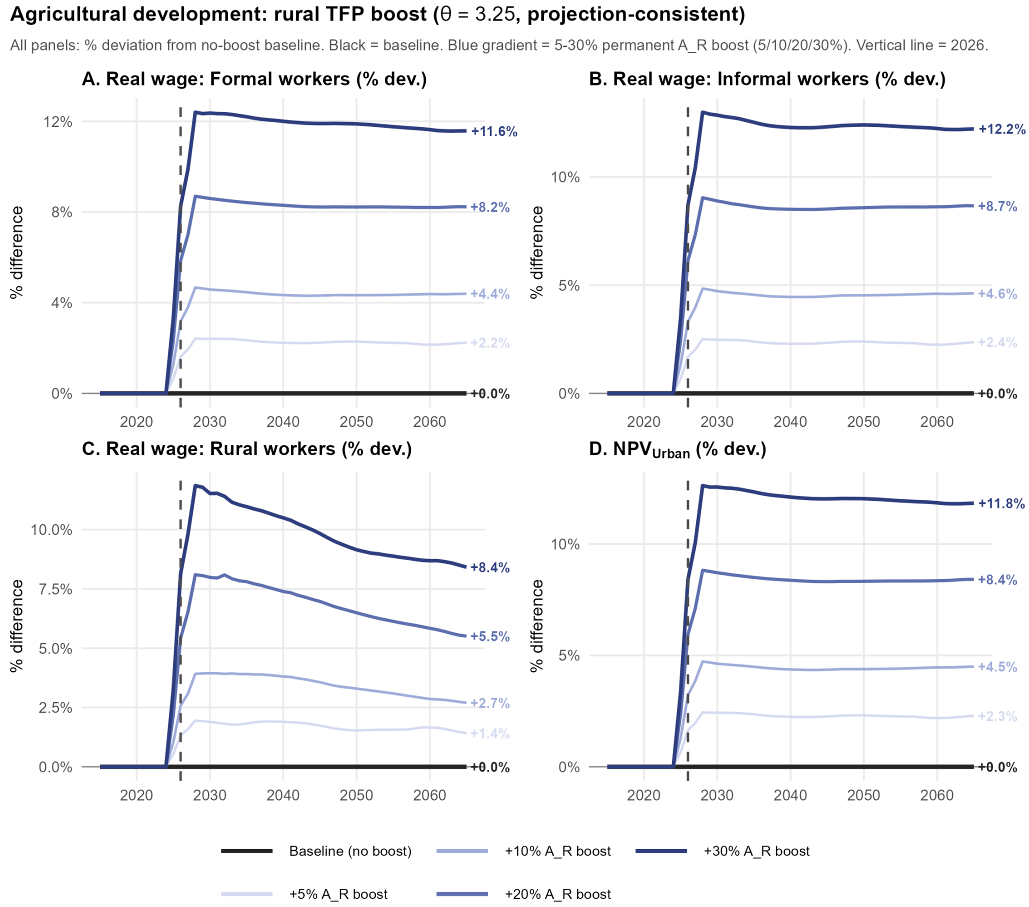

Figure OA4: Agricultural productivity, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding regime baseline as agricultural TFP rises from 5 to 30%. At the 30% dose, market-price GDP changes little and is slightly below baseline, while the urban entrant NPV rises by 11.8%. Formal, informal, and rural real wages rise by approximately 11.6%, 12.2%, and 8.4%, respectively. The GDP and welfare responses differ because higher agricultural productivity also lowers food prices. Source: author's computation.

0.4–0.55. These quantities refer specifically to the informal-wage offset and should not be interpreted as a general measure of distributional neutrality.

The combined experiment preserves the output and formal-employment effects of stronger formal productivity while using agricultural productivity to support food purchasing power and rural incomes. It therefore illustrates a complementarity between structural transformation and productivity growth in the sector supplying the principal subsistence good.

OA-6.3 Demand-side and demographic counterfactuals

These experiments operate through population growth, government employment, household purchasing power, or direct formal-employment support rather than sectoral TFP. Appendix G of the paper discusses the fiscal-comparability limitation: the reported

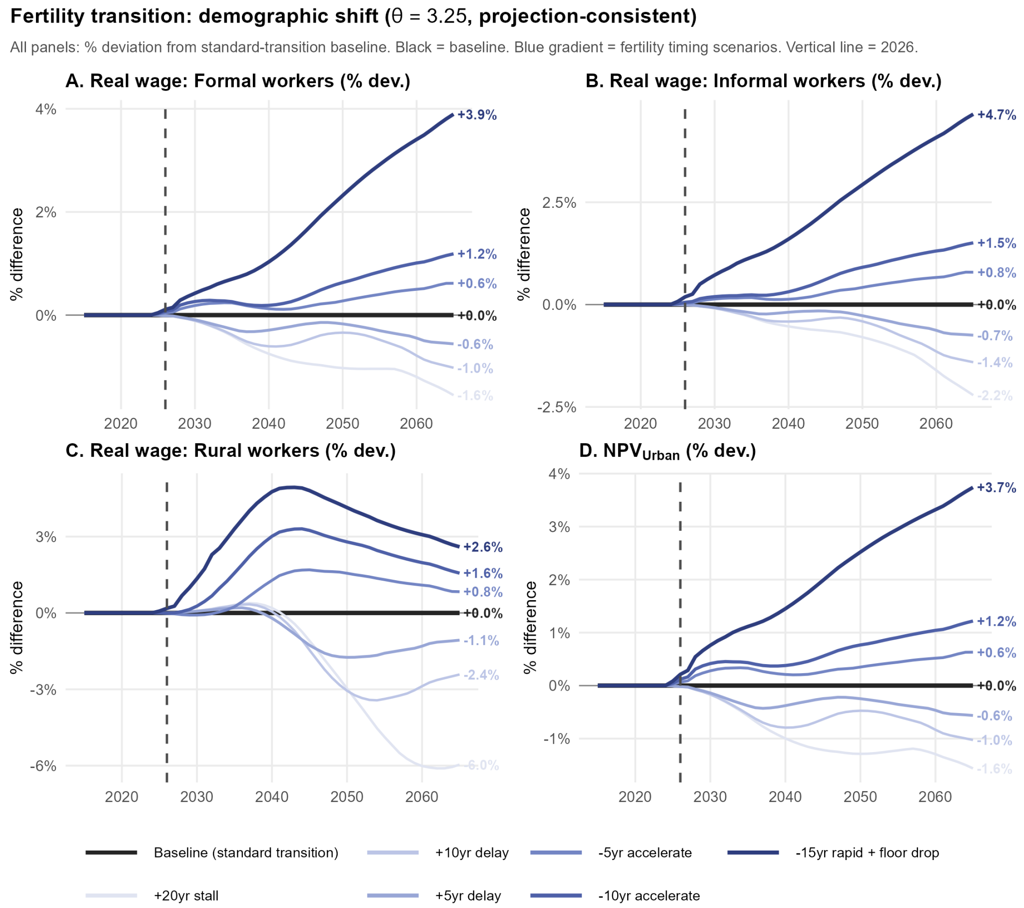

Figure OA5: Alternative fertility-transition paths, $\theta = 3.25$

Notes: Terminal 2065 deviations across alternative timings of the fertility transition, including accelerations and delays of up to 20 years and a faster movement toward the long-run fertility floor. Under the fastest reported transition, GDP is approximately 20.5% below baseline while urban entrant value and all three sectoral real wages are higher. These are alternative demographic paths rather than forecasts of a specific fertility intervention. Source: author's computation.

interventions are not normalized to a common public-resource cost.

OA-6.3.1 Fertility transition

The fertility exercise accelerates or delays the demographic transition relative to the baseline path. It should be interpreted as an alternative demographic scenario rather than as the effect of a single short-run policy instrument.

Faster fertility decline generates a pronounced divergence between aggregate output and per-worker welfare. A smaller future labor force lowers total GDP but raises land and other congestible resources per worker and reduces pressure on urban housing and the informal queue. The welfare effects are consequently positive in the reported accelerated-transition scenarios even though aggregate output is lower.

Table OA30 reports the full output and welfare decomposition for the fertility-dividend scenario at the 2035 and 2065 horizons under both capacity regimes; Table OA31 reports the corresponding regional-incidence cuts across the fixed location groups.

The gains from faster demographic transition can be larger when formal absorption is weak because slower labor-force growth reduces the rate at which new workers enter an already congested labor market. This mechanism does not make fertility decline a substitute for formalization capacity: it affects future labor-supply growth rather than directly moving the existing informal workforce into formal employment.

OA-6.3.2 Government employment

The government-employment experiments vary the scale of public hiring from a complete elimination of public hiring to a doubling relative to the baseline path. Government employment is treated separately from private formal employment in the model, so these exercises do not mechanically constitute private-sector formalization.

Expanding government employment produces one of the largest urbanization responses among the demand-side experiments. It attracts workers toward cities and increases the public employment share, while also altering the allocation of labor across private formal and informal activity. At the upper end of the experiment, the informal real wage falls, illustrating that public hiring can generate private labor-market crowding even when national lifetime value rises.

Table OA32 reports the full output and welfare decomposition for the doubling of public employment at the 2035 and 2065 horizons under both capacity regimes; Table OA33 reports the corresponding regional-incidence cuts across the fixed location groups.

The contrasting experiment eliminates public hiring entirely, so the government wage bill falls to zero; it is an elimination scenario rather than a freeze at current staffing levels. Table OA34 reports the full output and welfare decomposition for this elimination scenario at the 2035 and 2065 horizons under both capacity regimes; Table OA35 reports the corresponding regional-incidence cuts across the fixed location groups.

The expansion and elimination should be interpreted as public-employment scenarios rather than as estimates of the effect of a specific Ethiopian hiring reform. In particular, the aggregate welfare comparison depends on the model's treatment of public wages, labor reallocation, and the resource cost of public employment. The fiscal-cost comparisons discussed in Appendix G of the paper are therefore important for interpreting these large gross effects.

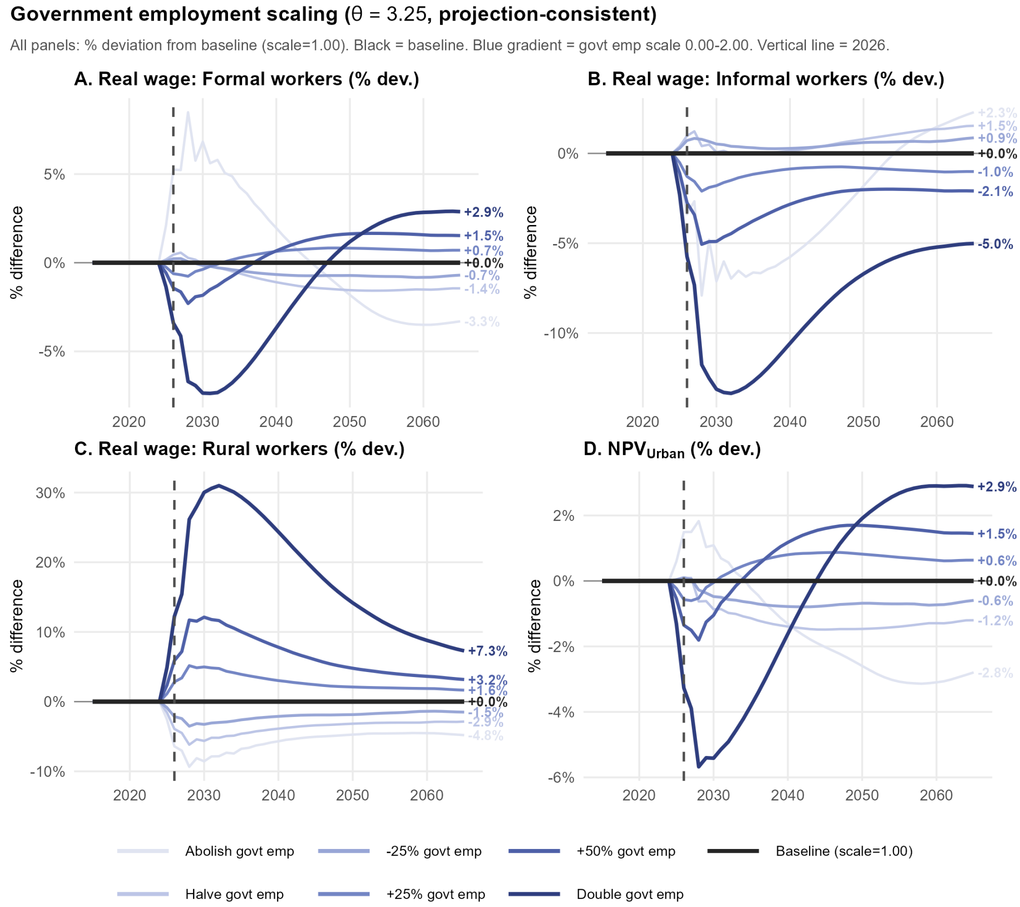

Figure OA6: Government employment, $\theta = 3.25$

Notes: Terminal 2065 deviations as government hiring ranges from complete elimination to twice the baseline scale. A 1.5-fold expansion raises GDP by approximately 5.1% and the urban share by 3.36 percentage points. At twice the baseline hiring scale, the urban share rises by approximately 8.43 percentage points and the informal real wage falls by approximately 5.0%. The government wage bill is accounted for separately from market-price GDP. Source: author's computation.

OA-6.3.3 Food support

The food-support experiment subsidizes part of the food expenditure of informal households. The subsidy rate ranges from 5 to 30% of eligible food expenditure. Because eligibility is tied to informal employment, the intervention reaches a larger share of the population when formalization capacity is weak.

At the largest dose, the effective purchasing power of informal earnings rises by approximately 16.9%. The corresponding market informal wage changes by only about -0.6%, indicating that most of the gain comes from the transfer itself rather than a large equilibrium wage response. The experiment is therefore useful as a benchmark for a narrowly targeted policy that supports workers remaining in informal employment without directly changing the formalization technology.

Table OA36 reports the full output and welfare decomposition for the food subsidy

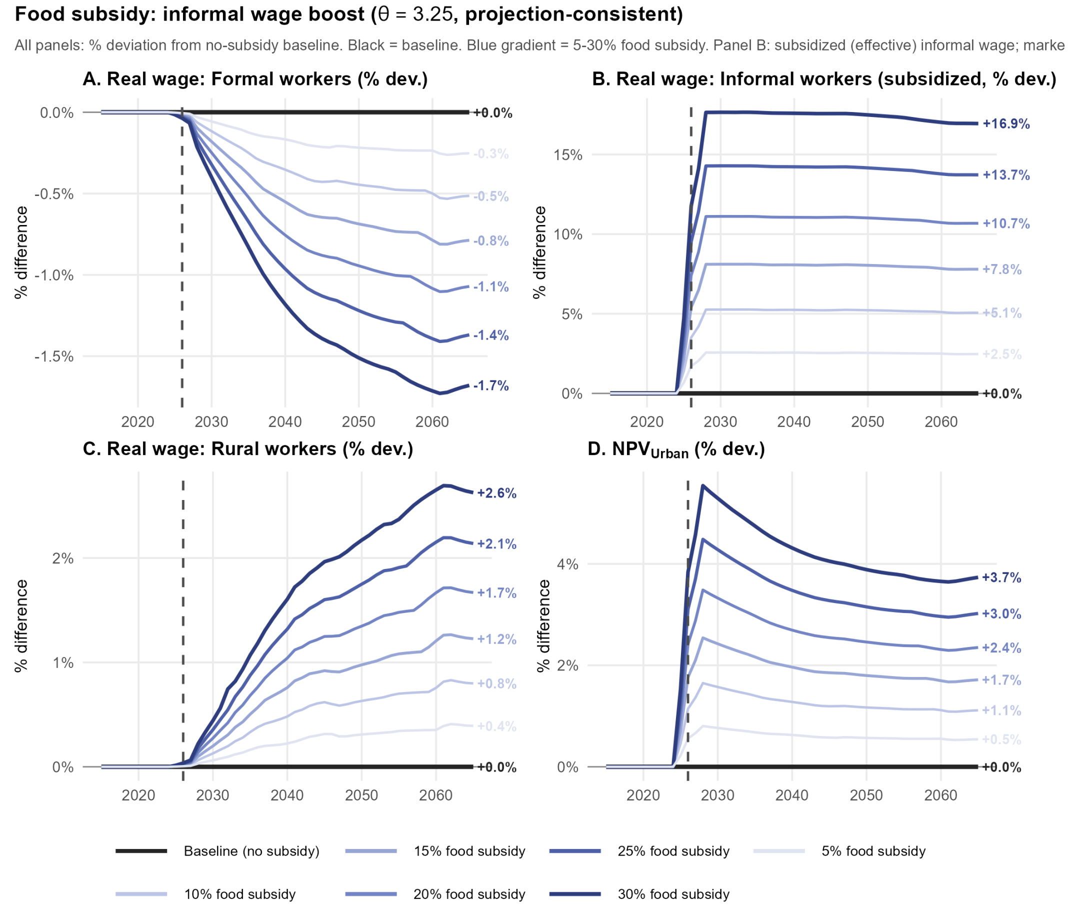

Figure OA7: Food support for informal households, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding capacity-regime baseline as the subsidy rises from 5 to 30% of eligible informal-household food expenditure. At the largest dose, the effective purchasing power associated with informal earnings rises by approximately 16.9%, while the underlying market informal wage changes by approximately -0.6%. Rural and formal real-wage effects are comparatively small. The urban entrant value rises by approximately 3.7% under $\theta = 3.25$ and 7.0% under $\theta = 4.75$. Source: author's computation.

at the 2035 and 2065 horizons under both capacity regimes; Table OA37 reports the corresponding regional-incidence cuts across the fixed location groups.

The stronger effect under $\theta = 4.75$ is primarily compositional. A larger informal workforce remains eligible for support when formal absorption is weak. Food assistance can therefore protect workers during a slow formalization transition, but it does not itself relax the capacity constraint governing movement into formal employment.

OA-6.3.4 Targeted formal-employment support

The targeted formal-employment experiment combines two interventions: stronger formal-sector productivity and a direct increase in the minimum formalization hazard. It should therefore be interpreted as a composite formal-employment scenario rather than as a single structural parameter change. The experiment approximates a package in

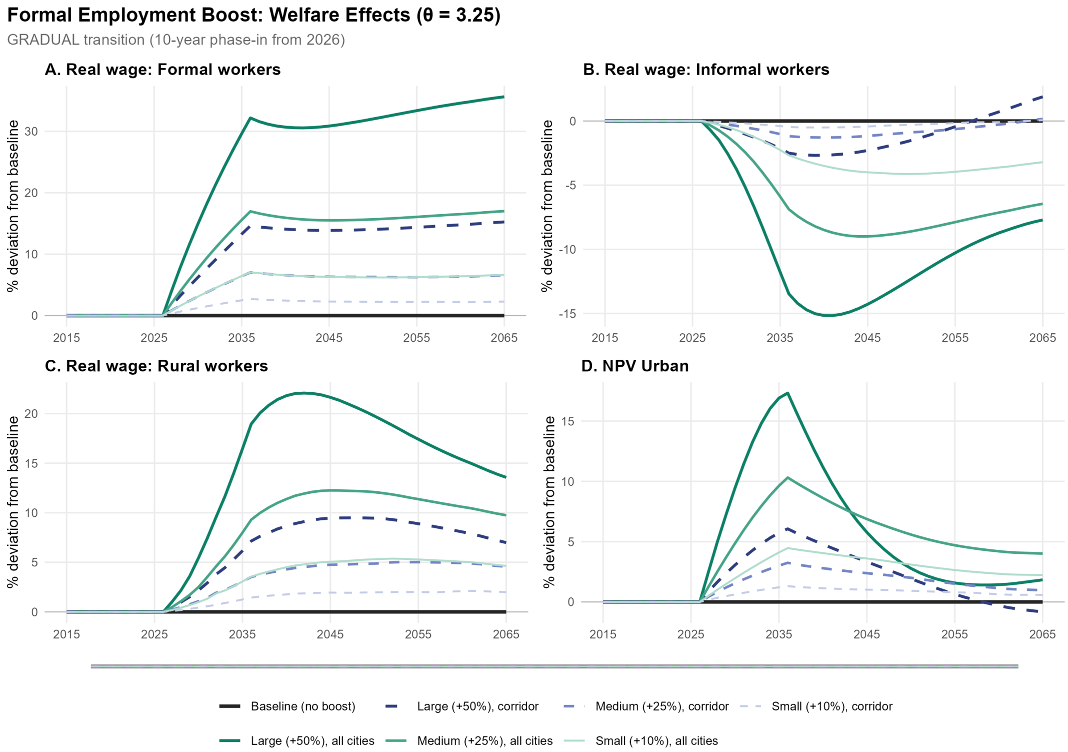

Figure OA8: Targeted formal-employment support, $\theta = 3.25$

Notes: Terminal 2065 deviations for a composite intervention that combines higher formal-sector productivity with an increase in the minimum formalization hazard. The figure compares broad implementation across cities with a targeted secondary-city corridor. Under the medium all-city specification, GDP rises by approximately 19.4% and the urban entrant value by 4.2% under $\theta = 3.25$. The corresponding urban entrant effect is approximately 10.2% under $\theta = 4.75$. The targeted corridor generates smaller aggregate effects but substantially limits the adverse informal-wage response. Source: author's computation.

which productive formal firms, infrastructure, and administrative or matching capacity expand together.

Because the intervention directly relaxes one component of the formalization constraint, its effect is mechanically larger where baseline absorption is weaker. This capacity interaction is informative about the mechanism, but it should not be interpreted as independent evidence that any particular real-world program would generate the same response.

Table OA38 reports the full output and welfare decomposition for the composite formal-employment boost at the 2035 and 2065 horizons under both capacity regimes; Table OA39 reports the corresponding regional-incidence cuts across the fixed location groups.

Broad implementation expands formal employment but can reduce informal wages as workers and expenditure are reallocated toward the formal sector. The corridor experiment illustrates the role of spatial targeting. Concentrating the intervention in selected cities preserves part of the formal-employment gain while limiting adverse spillovers to informal workers elsewhere.

The exercise should not be interpreted as identifying an optimal industrial-park design. It shows instead that an intervention affecting both formal labor demand and workers' access to formal jobs can have substantially different effects from a pure formal-productivity shock.

OA-6.4 Infrastructure and spatial-friction counterfactuals

The infrastructure experiments alter internal travel times, migration costs, international trade costs, or urban housing burdens. Roads and migration costs primarily induce spatial reallocation. Trade integration and housing support operate more strongly through purchasing power within existing locations. This distinction explains much of the difference in their distributional effects.

OA-6.4.1 Road connectivity

The road experiment reduces bilateral domestic travel times by between 5 and 25%. Better connectivity raises rural market access and facilitates movement toward cities, but the induced reallocation can also increase congestion in urban informal labor markets.

The incidence differs systematically across space. Under the largest road improvement, informal-worker value falls by approximately 7.2% in the smallest-city tercile and 4.3% in the largest-city tercile. Rural gains display the opposite accessibility gradient: the best-connected rural tercile gains approximately 15.9%, compared with about 19.6% in the middle and least-connected terciles. The pattern is consistent with diminishing returns to improvements in already high accessibility.

Table OA40 reports the full output and welfare decomposition for the travel-time reduction at the 2035 and 2065 horizons under both capacity regimes; Table OA41 reports the corresponding regional-incidence cuts across the fixed location groups.

Road improvements therefore illustrate the difference between aggregate gains and incidence. Better connectivity can raise output and rural welfare while making urban incumbents worse off through additional labor-market competition. The effect is particularly pronounced in smaller cities with thinner labor markets.

OA-6.4.2 Migration costs

The migration-cost experiment lowers the fixed component of the reduced-form cost of relocation by up to 50%. As emphasized in Section 8 of the paper, this parameter captures monetary moving costs together with information frictions, social ties, risk,

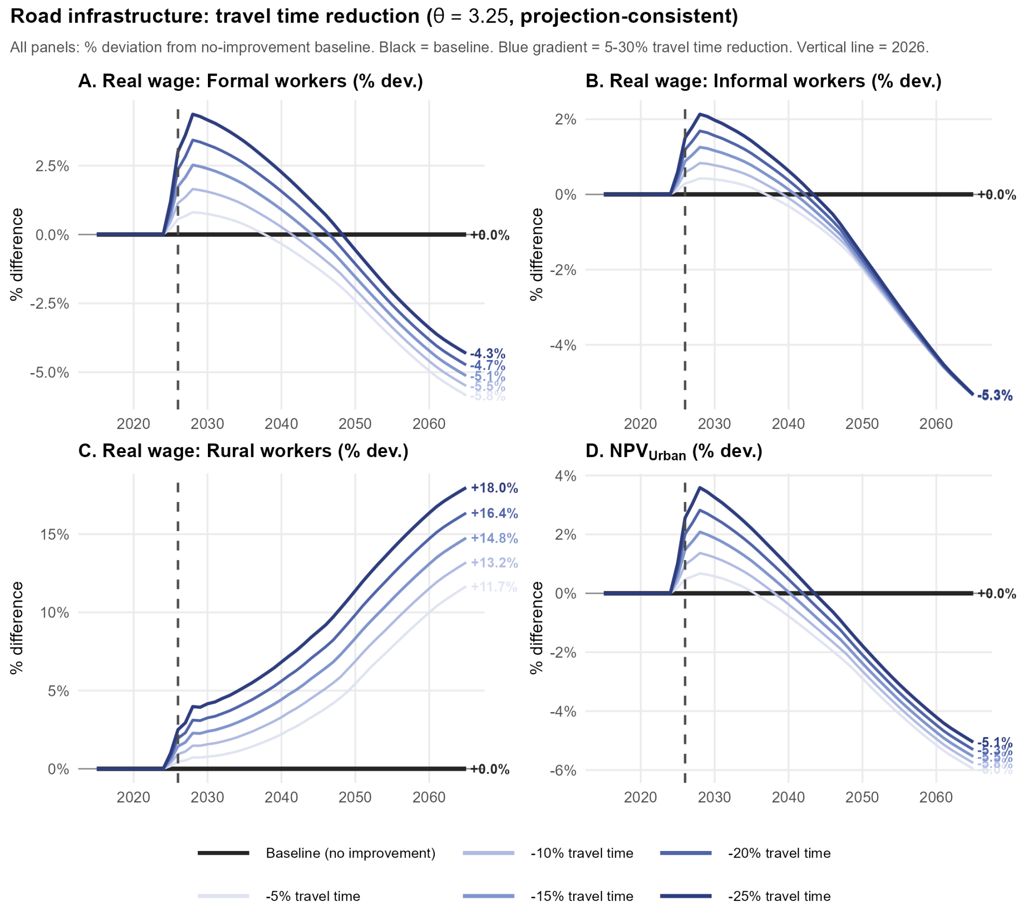

Figure OA9: Road connectivity, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding capacity-regime baseline as bilateral travel times fall by 5–25%. At the largest reduction, GDP rises by approximately 21.4%, while the urban entrant value falls by approximately 5.1% under $\theta = 3.25$ and 4.8% under $\theta = 4.75$. The negative urban-worker response reflects congestion generated by the induced spatial reallocation rather than a decline in national welfare. Source: author's computation.

and other location-specific barriers. The experiment should therefore be interpreted as a diagnostic of substantially greater mobility rather than as a literal policy that halves a single observable cost.

Greater mobility generates the largest spatial reallocation in the policy set. Under the 50% reduction, rural earnings rise sharply as workers leave agriculture, while the resulting urban inflow places substantial pressure on informal labor markets. Informal-worker value falls by about one-fifth across city-size groups despite considerably larger rural gains.

Table OA42 reports the full output and welfare decomposition for the migration-cost reduction at the 2035 and 2065 horizons under both capacity regimes; Table OA43 reports the corresponding regional-incidence cuts across the fixed location groups.

The mechanism is the reallocation result emphasized in the paper. Lower migration

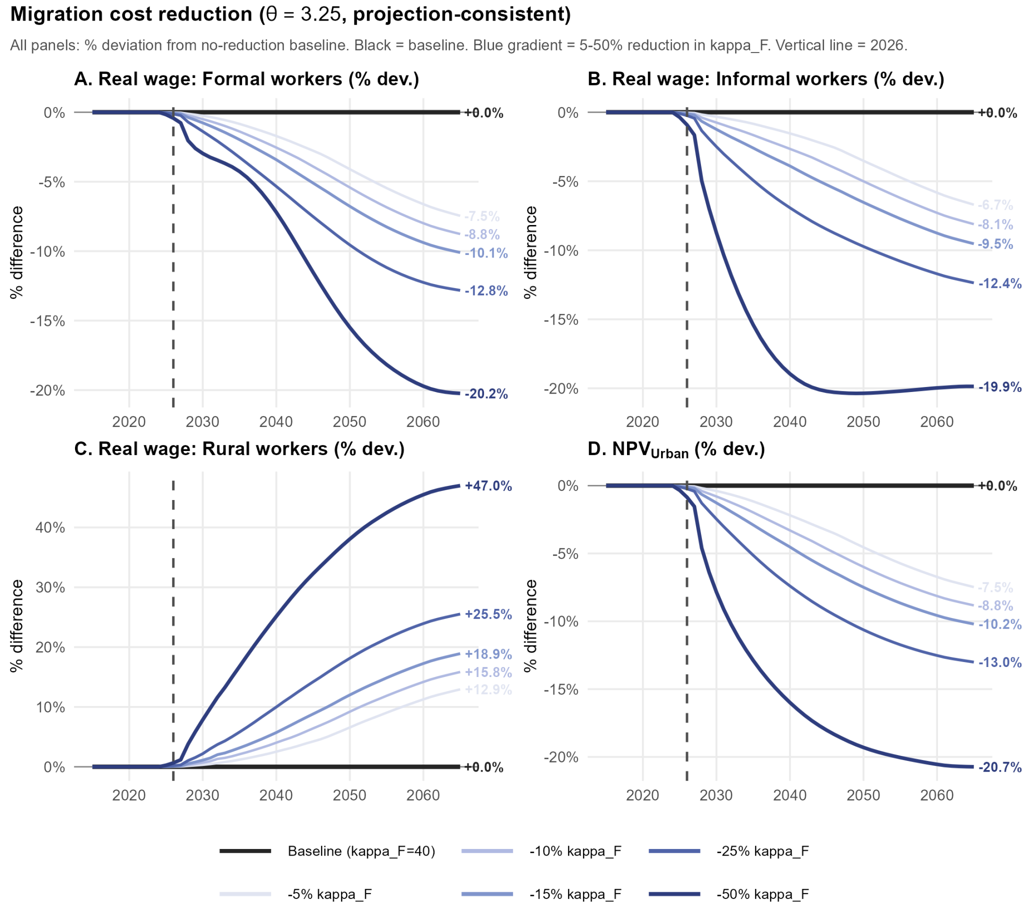

Figure OA10: Migration costs, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding capacity-regime baseline as the fixed migration-cost component falls by 5–50%. At the largest reduction, rural value rises by approximately 47.0%, GDP rises by 54.2% under $\theta = 3.25$ and 35.0% under $\theta = 4.75$, while the urban entrant value falls by 20.7% and 22.3%, respectively. The experiment therefore generates large aggregate and rural gains alongside losses for urban workers. Source: author's computation.

frictions move workers toward more productive locations and raise rural land and resources per remaining worker. At the same time, the inflow enlarges the urban informal pool. When formal absorption does not expand sufficiently quickly, incumbent urban workers bear part of the adjustment through congestion and lower lifetime value.

The entrant-surplus measure falls especially sharply because the policy reduces the difference between the value available at destination and the rural option forgone by migrants. This statistic is therefore not equivalent to either national welfare or the welfare of all migrants after the policy.

OA-6.4.3 International trade costs

The trade experiment reduces international iceberg trade costs by up to 50%. Unlike roads and lower migration costs, its principal mechanism is greater purchasing power

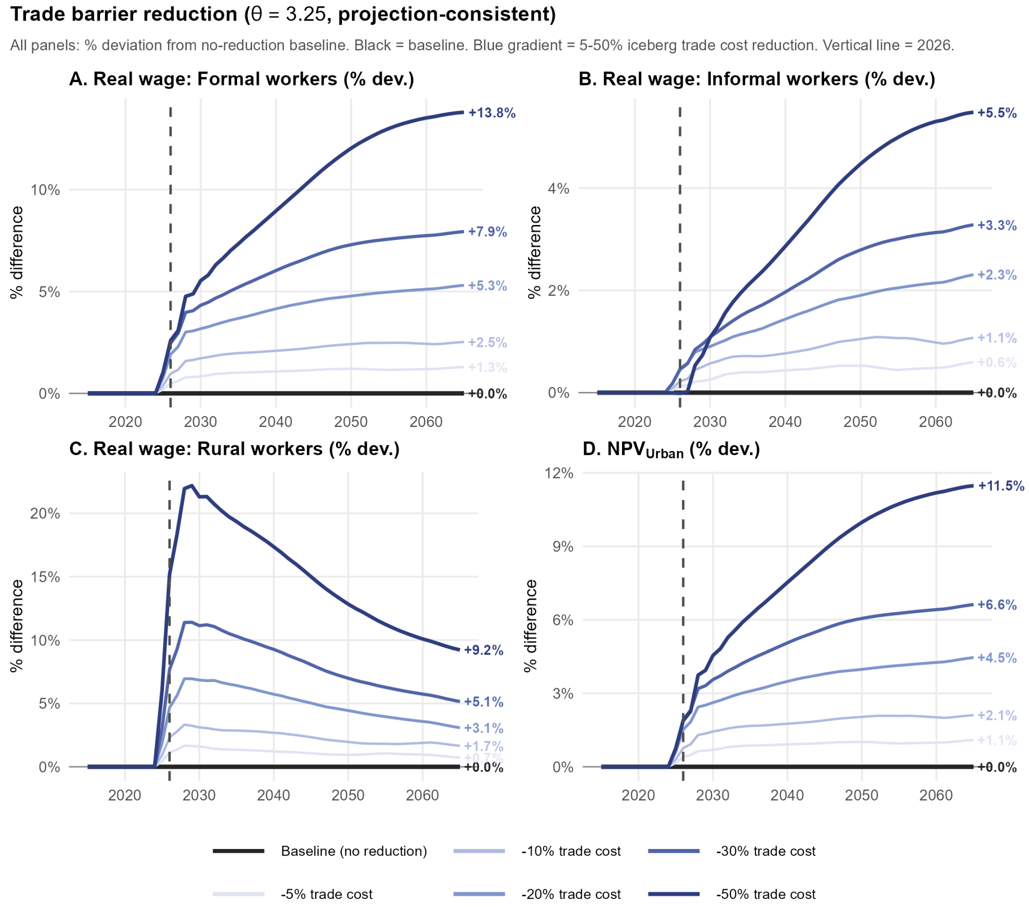

Figure OA11: International trade costs, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding capacity-regime baseline as international iceberg trade costs fall by 5–50%. At the largest reduction, rural, informal, and formal real-income measures rise by approximately 9.2%, 5.5%, and 13.8%, respectively. The urban entrant value rises by approximately 11.5% under $\theta = 3.25$ and 9.5% under $\theta = 4.75$, while the national urban share falls by approximately 1.98 percentage points. Source: author's computation.

through cheaper traded goods rather than large-scale domestic relocation.

At the largest dose, all three sectoral real-income measures rise and the national urban share falls by approximately 1.98 percentage points. Trade integration can therefore improve rural and urban purchasing power without adding comparable pressure to the informal queue.

Table OA44 reports the full output and welfare decomposition for the trade-cost reduction at the 2035 and 2065 horizons under both capacity regimes; Table OA45 reports the corresponding regional-incidence cuts across the fixed location groups.

The decline in urbanization is consistent with the model's spatial-consumption channel. Lower trade costs reduce the need to relocate toward cities merely to gain access to lower-priced or more varied traded consumption. The intervention is consequently less dependent on formalization capacity than policies that induce substantial urban

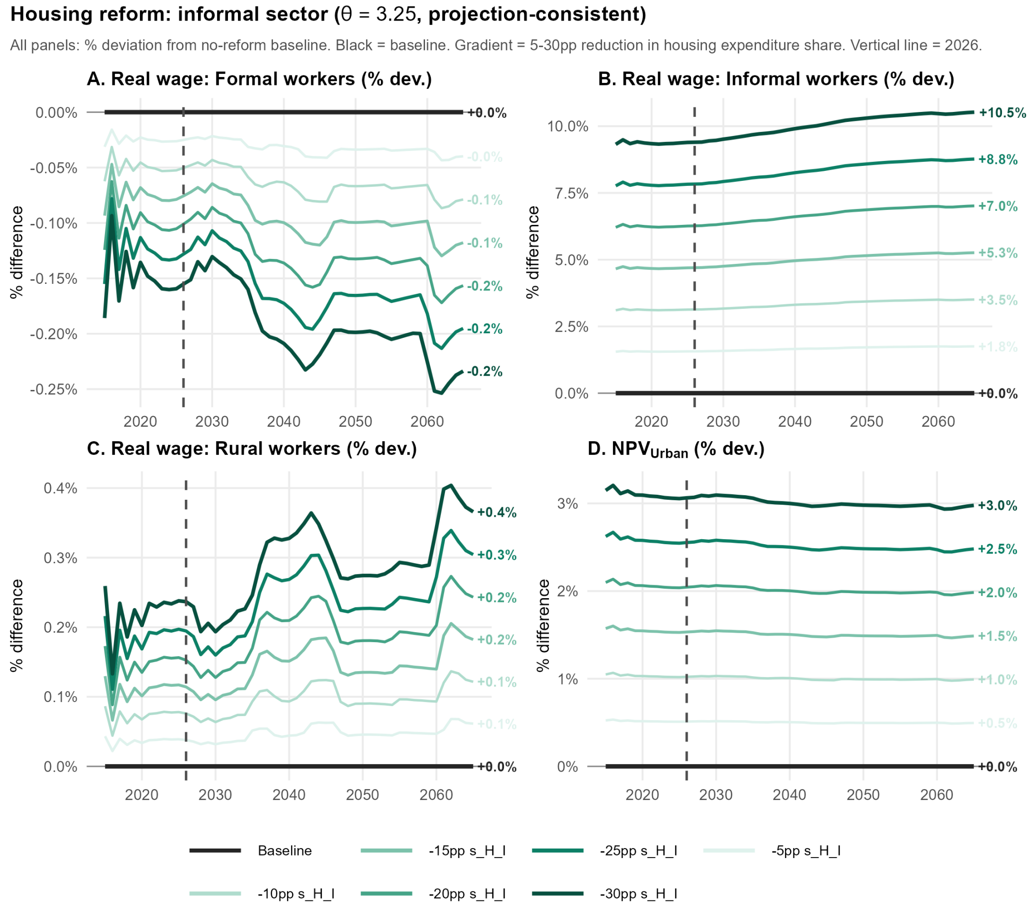

Figure OA12: Informal-household housing support, $\theta = 3.25$

Notes: Terminal 2065 deviations as the housing-expenditure burden of informal households falls by 5–30 percentage points. At the largest reduction, the treated group's net-of-housing real-income measure rises by approximately 10.5%, with comparatively small effects on formal and rural workers. The urban entrant value rises by approximately 3.0% under $\theta = 3.25$ and 4.5% under $\theta = 4.75$. The corresponding formal-targeted experiment is reported in the decomposition tables below. Source: author's computation.

inflows.

OA-6.4.4 Housing support

The housing experiments reduce the housing-expenditure burden of either informal or formal urban households by up to 30 percentage points. These are targeted affordability scenarios rather than changes in the aggregate housing-supply elasticity considered in the robustness analysis.

The incidence is highly concentrated in the treated group. Under the informal-targeted experiment, the treated group's net-of-housing real income rises by approximately 10.5%, while the corresponding changes for formal and rural workers are close to zero. The formal-targeted intervention produces the mirror pattern for formal workers.

Tables OA46–OA49 report the decompositions and regional-incidence cuts for the two housing experiments, which reduce the housing-expenditure burden of informal and formal households respectively.

Housing support therefore differs from the large reallocation instruments. It changes disposable purchasing power primarily for the targeted urban group while inducing comparatively little movement in other labor-market outcomes. This makes it a useful incidence benchmark for evaluating policies that raise urban purchasing power without materially expanding the informal queue.

Table OA22: Higher formal-sector productivity: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+13.9%	+11.6%	+20.8%	+14.0%
GDP, rural	+11.2%	+9.2%	+20.2%	+12.6%
GDP, urban formal	+26.4%	+25.4%	+28.4%	+27.0%
GDP, urban informal	+6.7%	+4.5%	−2.4%	+2.1%
Government wage bill	+0.3%	−0.3%	+1.4%	−0.1%
Panel B. Welfare and lifetime values				
National welfare	+10.6%	+9.0%	+13.6%	+9.6%
Rural value, Π^R	+6.5%	+5.3%	+11.8%	+7.1%
Informal value, V^I	+10.2%	+6.1%	+8.7%	+4.1%
Formal value, V^F	+18.4%	+19.2%	+16.1%	+16.8%
Entrant surplus	+13.0%	+8.0%	+6.8%	+4.0%
Urban entrant NPV	+10.7%	+7.0%	+8.7%	+5.2%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 25 percent increase in formal-sector productivity. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA23: Regional incidence of higher formal-sector productivity, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+10.4%	+6.0%
Anchor agricultural productivity, T2 (mid)	+11.9%	+7.3%
Anchor agricultural productivity, T3 (high)	+12.2%	+7.3%
Population density, T1 (low)	+11.0%	+5.6%
Population density, T2 (mid)	+11.5%	+6.7%
Population density, T3 (high)	+12.1%	+7.5%
Market-access cost, T1 (low)	+11.8%	+7.5%
Market-access cost, T2 (mid)	+12.0%	+7.2%
Market-access cost, T3 (high)	+11.4%	+6.1%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+8.6%	+16.6%	+2.7%	+16.7%
City size, T2 (mid)	+8.9%	+16.3%	+3.8%	+15.8%
City size, T3 (high)	+8.8%	+16.0%	+5.0%	+17.1%
Population density, T1 (low)	+8.9%	+15.9%	+4.4%	+14.0%
Population density, T2 (mid)	+8.9%	+16.4%	+3.3%	+17.5%
Population density, T3 (high)	+8.6%	+16.2%	+4.6%	+18.4%
Gateway cost, T1 (low)	+9.2%	+16.0%	+5.5%	+18.3%
Gateway cost, T2 (mid)	+9.3%	+15.8%	+4.8%	+14.5%
Gateway cost, T3 (high)	+7.4%	+16.6%	+2.5%	+16.3%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 25 percent increase in formal-sector productivity. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA24: Higher informal-sector productivity: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+5.6%	+7.1%	+6.0%	+10.4%
GDP, rural	+4.4%	+5.7%	+6.2%	+10.5%
GDP, urban formal	−0.7%	−1.4%	+0.2%	−2.0%
GDP, urban informal	+27.9%	+28.7%	+24.7%	+25.0%
Government wage bill	+0.1%	−0.7%	+1.2%	−1.1%
Panel B. Welfare and lifetime values				
National welfare	+2.5%	+4.1%	+2.0%	+6.6%
Rural value, Π^R	+3.1%	+4.2%	+4.3%	+8.1%
Informal value, V^I	+6.1%	+9.8%	+4.8%	+10.1%
Formal value, V^F	−1.6%	−0.7%	−2.5%	−0.0%
Entrant surplus	+7.1%	+11.5%	+5.1%	+8.9%
Urban entrant NPV	+5.6%	+8.7%	+4.7%	+8.6%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 25 percent increase in informal-sector productivity. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA25: Regional incidence of higher informal-sector productivity, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+3.9%	+8.0%
Anchor agricultural productivity, T2 (mid)	+4.3%	+8.5%
Anchor agricultural productivity, T3 (high)	+4.5%	+8.3%
Population density, T1 (low)	+4.3%	+10.5%
Population density, T2 (mid)	+4.2%	+8.6%
Population density, T3 (high)	+4.4%	+7.7%
Market-access cost, T1 (low)	+4.2%	+7.4%
Market-access cost, T2 (mid)	+4.3%	+7.6%
Market-access cost, T3 (high)	+4.5%	+10.5%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+5.1%	−3.2%	+11.7%	−0.9%
City size, T2 (mid)	+4.6%	−2.8%	+10.3%	+2.6%
City size, T3 (high)	+4.7%	−2.3%	+9.0%	−0.7%
Population density, T1 (low)	+4.5%	−2.4%	+9.3%	+4.9%
Population density, T2 (mid)	+4.7%	−3.0%	+10.8%	+0.3%
Population density, T3 (high)	+5.0%	−2.4%	+10.0%	−3.0%
Gateway cost, T1 (low)	+4.4%	−2.2%	+9.3%	−2.7%
Gateway cost, T2 (mid)	+4.1%	−2.4%	+8.6%	+4.2%
Gateway cost, T3 (high)	+6.1%	−3.2%	+11.1%	+1.6%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 25 percent increase in informal-sector productivity. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA26: Agricultural development: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	−0.1%	+1.0%	−0.4%	−0.0%
GDP, rural	−0.7%	+0.7%	−2.9%	−1.7%
GDP, urban formal	+1.1%	+1.2%	+2.2%	+0.4%
GDP, urban informal	+2.1%	+2.3%	+5.0%	+4.2%
Government wage bill	−0.0%	+0.0%	+1.1%	−0.2%
Panel B. Welfare and lifetime values				
National welfare	+11.4%	+11.7%	+10.7%	+9.4%
Rural value, Π^R	+11.0%	+11.7%	+8.4%	+8.3%
Informal value, V^I	+12.3%	+11.9%	+11.9%	+11.1%
Formal value, V^F	+12.2%	+11.4%	+11.6%	+9.9%
Entrant surplus	+13.1%	+12.0%	+14.0%	+12.8%
Urban entrant NPV	+12.3%	+11.9%	+11.8%	+11.0%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 30 percent increase in agricultural productivity. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA27: Regional incidence of agricultural development, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+8.5%	+8.0%
Anchor agricultural productivity, T2 (mid)	+8.5%	+8.9%
Anchor agricultural productivity, T3 (high)	+8.9%	+8.5%
Population density, T1 (low)	+8.2%	+8.2%
Population density, T2 (mid)	+7.7%	+7.5%
Population density, T3 (high)	+8.9%	+8.8%
Market access, T1 (low)	+8.3%	+8.4%
Market access, T2 (mid)	+8.8%	+8.3%
Market access, T3 (high)	+8.1%	+7.8%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+11.7%	+11.8%	+11.0%	+10.3%
City size, T2 (mid)	+11.8%	+11.8%	+11.0%	+9.5%
City size, T3 (high)	+11.9%	+11.5%	+11.1%	+10.0%
Population density, T1 (low)	+11.8%	+11.7%	+11.0%	+9.3%
Population density, T2 (mid)	+11.8%	+11.8%	+10.9%	+10.0%
Population density, T3 (high)	+11.8%	+11.4%	+11.2%	+10.2%
Gateway connectedness, T1 (low)	+11.8%	+11.4%	+11.0%	+10.1%
Gateway connectedness, T2 (mid)	+11.8%	+11.7%	+10.9%	+9.6%
Gateway connectedness, T3 (high)	+11.9%	+11.8%	+11.3%	+9.8%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 30 percent increase in agricultural productivity. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted informal and formal values, V^I and V^F.

Table OA28: Combined formal and agricultural productivity: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+10.4%	+9.4%	+16.0%	+10.5%
GDP, rural	+7.3%	+6.9%	+11.9%	+7.5%
GDP, urban formal	+22.1%	+21.2%	+26.2%	+21.6%
GDP, urban informal	+8.5%	+6.2%	+3.5%	+5.8%
Government wage bill	+0.3%	−0.3%	+3.0%	−0.5%
Panel B. Welfare and lifetime values				
National welfare	+17.2%	+15.8%	+19.9%	+15.1%
Rural value, Π^R	+12.8%	+12.3%	+15.5%	+11.5%
Informal value, V^I	+17.8%	+13.7%	+16.4%	+11.4%
Formal value, V^F	+25.0%	+25.1%	+22.7%	+22.1%
Entrant surplus	+21.3%	+15.9%	+17.1%	+12.8%
Urban entrant NPV	+18.2%	+14.6%	+16.5%	+12.3%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following simultaneous 20 percent increases in formal and agricultural productivity. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA29: Regional incidence of combined formal and agricultural productivity, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+15.0%	+10.5%
Anchor agricultural productivity, T2 (mid)	+16.1%	+11.7%
Anchor agricultural productivity, T3 (high)	+15.8%	+12.0%
Population density, T1 (low)	+14.5%	+9.5%
Population density, T2 (mid)	+15.2%	+10.6%
Population density, T3 (high)	+15.9%	+12.3%
Market-access cost, T1 (low)	+15.1%	+11.8%
Market-access cost, T2 (mid)	+16.1%	+11.8%
Market-access cost, T3 (high)	+15.3%	+10.2%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+16.2%	+23.1%	+10.3%	+22.2%
City size, T2 (mid)	+16.5%	+22.8%	+11.1%	+21.0%
City size, T3 (high)	+16.6%	+22.6%	+12.2%	+22.5%
Population density, T1 (low)	+16.6%	+22.5%	+11.6%	+19.6%
Population density, T2 (mid)	+16.5%	+23.0%	+10.7%	+22.9%
Population density, T3 (high)	+16.5%	+22.8%	+11.8%	+23.6%
Gateway cost, T1 (low)	+16.9%	+22.6%	+12.5%	+23.5%
Gateway cost, T2 (mid)	+16.9%	+22.4%	+11.8%	+20.1%
Gateway cost, T3 (high)	+15.3%	+23.3%	+10.2%	+21.7%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following simultaneous 20 percent increases in formal and agricultural productivity. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA30: Fertility dividend: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	−6.0%	−5.3%	−20.5%	−14.9%
GDP, rural	−6.2%	−5.5%	−21.4%	−15.9%
GDP, urban formal	−1.9%	+0.2%	−17.7%	+0.6%
GDP, urban informal	−13.3%	−12.0%	−24.9%	−30.7%
Government wage bill	−0.6%	+1.2%	−12.6%	+6.2%
Panel B. Welfare and lifetime values				
National welfare	+3.3%	+3.9%	+4.0%	+7.2%
Rural value, Π^R	+3.3%	+3.9%	+2.6%	+7.3%
Informal value, V^I	+1.1%	+2.2%	+3.7%	+5.6%
Formal value, V^F	+0.7%	+0.1%	+3.9%	−1.3%
Entrant surplus	−0.1%	+1.1%	+4.5%	+5.8%
Urban entrant NPV	+1.1%	+2.2%	+3.7%	+6.4%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under the largest fertility-dividend scenario, applied to both rural and urban population growth. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA31: Regional incidence of the fertility dividend, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+5.1%	+8.9%
Anchor agricultural productivity, T2 (mid)	+2.1%	+6.6%
Anchor agricultural productivity, T3 (high)	+1.8%	+6.6%
Population density, T1 (low)	+6.9%	+9.6%
Population density, T2 (mid)	+2.8%	+7.1%
Population density, T3 (high)	+1.4%	+6.5%
Market-access cost, T1 (low)	+3.1%	+8.5%
Market-access cost, T2 (mid)	+2.2%	+6.9%
Market-access cost, T3 (high)	+2.5%	+5.9%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+4.2%	+4.3%	+3.5%	−0.2%
City size, T2 (mid)	+3.7%	+4.0%	+7.2%	−2.6%
City size, T3 (high)	+3.5%	+3.7%	+5.3%	−1.5%
Population density, T1 (low)	+3.7%	+3.9%	+6.9%	−7.1%
Population density, T2 (mid)	+3.8%	+4.1%	+6.5%	−0.3%
Population density, T3 (high)	+3.6%	+3.8%	+4.0%	+0.9%
Gateway cost, T1 (low)	+3.3%	+3.8%	+4.7%	+1.3%
Gateway cost, T2 (mid)	+3.6%	+3.9%	+8.9%	−6.7%
Gateway cost, T3 (high)	+4.3%	+4.2%	+3.6%	−2.0%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under the largest fertility-dividend scenario, applied to both rural and urban population growth. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA32: Government employment expansion: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+43.1%	+42.3%	+13.1%	+10.9%
GDP, rural	+57.4%	+56.2%	+21.9%	+18.2%
GDP, urban formal	+16.0%	+17.9%	+1.5%	+8.7%
GDP, urban informal	−6.0%	−5.5%	+3.4%	−7.1%
Government wage bill	+376.3%	+409.3%	+247.7%	+307.1%
Panel B. Welfare and lifetime values				
National welfare	+36.0%	+37.3%	+19.1%	+19.6%
Rural value, Π^R	+29.4%	+29.4%	+7.3%	+7.0%
Informal value, V^I	−6.8%	−6.9%	+1.3%	+0.2%
Formal value, V^F	−1.1%	−0.4%	+5.2%	+6.4%
Entrant surplus	−22.5%	−24.2%	+0.1%	−0.9%
Urban entrant NPV	−3.8%	−4.1%	+2.9%	+2.2%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline when government employment is doubled. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA33: Regional incidence of government employment expansion, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+6.6%	+6.3%
Anchor agricultural productivity, T2 (mid)	+7.1%	+7.0%
Anchor agricultural productivity, T3 (high)	+7.3%	+6.8%
Population density, T1 (low)	+7.5%	+5.3%
Population density, T2 (mid)	+6.9%	+6.6%
Population density, T3 (high)	+7.4%	+7.3%
Market-access cost, T1 (low)	+7.0%	+7.2%
Market-access cost, T2 (mid)	+7.4%	+7.2%
Market-access cost, T3 (high)	+7.4%	+6.0%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+2.1%	+8.5%	−0.9%	+15.0%
City size, T2 (mid)	+0.9%	+4.9%	+0.2%	+6.2%
City size, T3 (high)	−1.0%	+0.9%	−0.3%	+0.7%
Population density, T1 (low)	+0.4%	+4.3%	+1.3%	−0.4%
Population density, T2 (mid)	+0.6%	+4.6%	−0.1%	+9.8%
Population density, T3 (high)	+1.0%	+4.3%	−0.7%	+5.7%
Gateway cost, T1 (low)	+1.7%	+5.9%	+0.4%	+8.4%
Gateway cost, T2 (mid)	+0.5%	+4.0%	+1.8%	−0.3%
Gateway cost, T3 (high)	−0.5%	+5.4%	−2.1%	+7.4%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline when government employment is doubled. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA34: Government-employment elimination: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	−9.0%	−8.9%	−6.6%	−4.3%
GDP, rural	−11.0%	−10.5%	−10.2%	−6.3%
GDP, urban formal	−5.9%	−7.1%	−2.6%	−4.8%
GDP, urban informal	−0.7%	−2.3%	−1.0%	+1.8%
Government wage bill	−100.0%	−100.0%	−100.0%	−100.0%
Panel B. Welfare and lifetime values				
National welfare	−9.8%	−9.3%	−10.6%	−7.3%
Rural value, Π^R	−6.8%	−6.9%	−4.8%	−3.7%
Informal value, V^I	+0.3%	−1.2%	−1.9%	−1.5%
Formal value, V^F	+2.9%	+7.5%	−4.1%	−0.0%
Entrant surplus	+3.5%	+2.5%	−1.5%	−0.0%
Urban entrant NPV	−0.2%	−1.0%	−2.8%	−1.4%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under the government-employment elimination. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA35: Regional incidence of the government-employment elimination, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	−5.3%	−3.9%
Anchor agricultural productivity, T2 (mid)	−4.9%	−3.7%
Anchor agricultural productivity, T3 (high)	−4.7%	−3.5%
Population density, T1 (low)	−5.0%	−2.2%
Population density, T2 (mid)	−5.2%	−4.0%
Population density, T3 (high)	−4.5%	−3.5%
Market-access cost, T1 (low)	−5.2%	−4.1%
Market-access cost, T2 (mid)	−4.3%	−3.7%
Market-access cost, T3 (high)	−4.9%	−2.8%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	−3.0%	−6.9%	−0.9%	−3.6%
City size, T2 (mid)	−2.3%	−5.0%	−1.5%	+2.7%
City size, T3 (high)	−0.7%	−2.1%	−1.5%	+0.7%
Population density, T1 (low)	−2.3%	−4.6%	−2.2%	+7.9%
Population density, T2 (mid)	−2.1%	−4.9%	−1.2%	−0.2%
Population density, T3 (high)	−1.0%	−2.5%	−1.2%	−2.1%
Gateway cost, T1 (low)	−1.6%	−3.4%	−1.4%	−2.6%
Gateway cost, T2 (mid)	−2.5%	−4.8%	−2.5%	+8.0%
Gateway cost, T3 (high)	−1.2%	−4.7%	−0.8%	+0.8%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under the government-employment elimination. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA36: Food subsidy: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+3.5%	+4.4%	+5.0%	+8.3%
GDP, rural	+1.4%	+1.8%	+3.3%	+4.4%
GDP, urban formal	+0.6%	−0.3%	+2.9%	−0.8%
GDP, urban informal	+25.8%	+28.3%	+21.7%	+30.4%
Government wage bill	+0.1%	−0.8%	+2.4%	−1.6%
Panel B. Welfare and lifetime values				
National welfare	+1.4%	+2.2%	+1.9%	+4.3%
Rural value, Π^R	+1.1%	+1.3%	+2.6%	+4.0%
Informal value, V^I	+5.1%	+8.1%	+3.8%	+8.4%
Formal value, V^F	−0.9%	−0.8%	−1.7%	−1.8%
Entrant surplus	+6.8%	+10.7%	+4.4%	+8.9%
Urban entrant NPV	+4.7%	+7.2%	+3.7%	+7.0%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under a subsidy covering 30 percent of food costs for informal workers. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA37: Regional incidence of the food subsidy, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+2.4%	+3.9%
Anchor agricultural productivity, T2 (mid)	+2.7%	+4.2%
Anchor agricultural productivity, T3 (high)	+2.7%	+4.1%
Population density, T1 (low)	+2.5%	+4.6%
Population density, T2 (mid)	+2.6%	+4.3%
Population density, T3 (high)	+2.7%	+3.9%
Market-access cost, T1 (low)	+2.6%	+3.6%
Market-access cost, T2 (mid)	+2.6%	+3.8%
Market-access cost, T3 (high)	+2.7%	+5.2%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+4.1%	−1.9%	+10.0%	−2.6%
City size, T2 (mid)	+3.7%	−1.7%	+8.4%	−1.0%
City size, T3 (high)	+3.6%	−1.7%	+7.5%	−2.0%
Population density, T1 (low)	+3.5%	−1.7%	+7.5%	−0.3%
Population density, T2 (mid)	+3.7%	−1.9%	+8.9%	−1.9%
Population density, T3 (high)	+4.0%	−1.7%	+8.6%	−2.7%
Gateway cost, T1 (low)	+3.5%	−1.5%	+7.7%	−2.5%
Gateway cost, T2 (mid)	+3.2%	−1.6%	+6.6%	−0.5%
Gateway cost, T3 (high)	+4.9%	−2.0%	+9.7%	−1.4%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under a subsidy covering 30 percent of food costs for informal workers. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA38: Formal-employment boost: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+21.7%	+24.7%	+19.4%	+39.7%
GDP, rural	+18.7%	+21.2%	+18.5%	+37.9%
GDP, urban formal	+53.6%	+72.1%	+35.3%	+126.6%
GDP, urban informal	−24.7%	−28.1%	−31.0%	−60.6%
Government wage bill	+19.7%	+31.8%	+8.3%	+79.0%
Panel B. Welfare and lifetime values				
National welfare	+14.6%	+17.1%	+12.0%	+22.1%
Rural value, Π^R	+11.0%	+12.9%	+9.5%	+21.3%
Informal value, V^I	+8.3%	+12.2%	+4.0%	+6.3%
Formal value, V^F	+16.1%	+14.9%	+17.1%	+8.9%
Entrant surplus	+7.9%	+13.6%	+1.0%	+3.2%
Urban entrant NPV	+9.0%	+13.4%	+4.2%	+10.2%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under the medium formal-employment boost applied to all cities. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA39: Regional incidence of the formal-employment boost, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+8.2%	+18.3%
Anchor agricultural productivity, T2 (mid)	+9.5%	+21.5%
Anchor agricultural productivity, T3 (high)	+9.7%	+21.7%
Population density, T1 (low)	+8.7%	+17.1%
Population density, T2 (mid)	+9.2%	+21.0%
Population density, T3 (high)	+9.7%	+22.1%
Market-access cost, T1 (low)	+9.4%	+21.6%
Market-access cost, T2 (mid)	+9.7%	+22.5%
Market-access cost, T3 (high)	+9.2%	+18.8%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+5.3%	+17.8%	+11.9%	+8.8%
City size, T2 (mid)	+4.2%	+17.0%	+13.1%	+4.6%
City size, T3 (high)	+3.5%	+16.6%	+2.3%	+7.6%
Population density, T1 (low)	+3.5%	+16.4%	+12.8%	−2.3%
Population density, T2 (mid)	+4.3%	+17.3%	+12.4%	+10.0%
Population density, T3 (high)	+4.3%	+17.3%	−0.9%	+12.0%
Gateway cost, T1 (low)	+3.8%	+17.4%	+5.4%	+14.2%
Gateway cost, T2 (mid)	+3.2%	+16.4%	+14.8%	−1.4%
Gateway cost, T3 (high)	+5.4%	+17.4%	+2.4%	+7.7%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under the medium formal-employment boost applied to all cities. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA40: Lower travel times: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	$+5.4\%$	$+4.5\%$	$+21.4\%$	$+13.4\%$
GDP, rural	$+4.4\%$	$+3.7\%$	$+21.5\%$	$+13.1\%$
GDP, urban formal	$+5.3\%$	$+4.2\%$	$+19.6\%$	$+4.1\%$
GDP, urban informal	$+13.3\%$	$+10.5\%$	$+26.6\%$	$+25.4\%$
Government wage bill	-0.0%	-0.8%	$+10.5\%$	-2.9%
Panel B. Welfare and lifetime values				
National welfare	$+5.3\%$	$+4.7\%$	$+11.1\%$	$+8.8\%$
Rural value, Π^R	$+5.2\%$	$+4.7\%$	$+18.0\%$	$+12.9\%$
Informal value, V^I	$+2.6\%$	$+1.6\%$	-4.2%	-4.5%
Formal value, V^F	$+3.4\%$	$+3.8\%$	-4.4%	$+1.3\%$
Entrant surplus	$+0.6\%$	-0.5%	-19.4%	-15.8%
Urban entrant NPV	$+2.2\%$	$+1.4\%$	-5.1%	-4.8%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 25 percent reduction in travel times. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA41: Regional incidence of lower travel times, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+13.7%	+9.7%
Anchor agricultural productivity, T2 (mid)	+20.5%	+15.4%
Anchor agricultural productivity, T3 (high)	+20.5%	+15.0%
Population density, T1 (low)	+15.8%	+13.1%
Population density, T2 (mid)	+17.1%	+12.7%
Population density, T3 (high)	+19.6%	+13.7%
Market-access cost, T1 (low)	+15.9%	+10.5%
Market-access cost, T2 (mid)	+19.6%	+13.7%
Market-access cost, T3 (high)	+19.6%	+16.3%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	−7.2%	−4.9%	−4.7%	+0.7%
City size, T2 (mid)	−5.8%	−4.5%	−4.5%	+3.6%
City size, T3 (high)	−4.3%	−4.6%	−4.7%	+0.7%
Population density, T1 (low)	−6.2%	−4.9%	−5.4%	+5.1%
Population density, T2 (mid)	−6.0%	−4.7%	−4.8%	+2.0%
Population density, T3 (high)	−3.1%	−4.3%	−3.8%	−0.9%
Gateway cost, T1 (low)	−3.1%	−4.4%	−4.1%	−1.3%
Gateway cost, T2 (mid)	−6.0%	−4.7%	−5.9%	+5.1%
Gateway cost, T3 (high)	−6.3%	−4.0%	−5.5%	+4.3%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 25 percent reduction in travel times. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA42: Lower migration costs: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+25.2%	+19.3%	+54.2%	+35.0%
GDP, rural	+22.2%	+16.5%	+54.9%	+38.1%
GDP, urban formal	+7.6%	−0.8%	+50.9%	+1.6%
GDP, urban informal	+86.8%	+68.5%	+61.2%	+66.8%
Government wage bill	−1.0%	−7.5%	+31.5%	−5.1%
Panel B. Welfare and lifetime values				
National welfare	+13.8%	+11.8%	+21.9%	+20.8%
Rural value, Π^R	+16.8%	+13.3%	+47.0%	+38.7%
Informal value, V^I	−13.0%	−15.2%	−20.1%	−22.5%
Formal value, V^F	−4.5%	+3.4%	−20.3%	−1.3%
Entrant surplus	−29.6%	−32.6%	−62.9%	−60.3%
Urban entrant NPV	−12.9%	−15.5%	−20.7%	−22.3%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 50 percent reduction in the fixed component of migration costs. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA43: Regional incidence of lower migration costs, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+36.4%	+30.5%
Anchor agricultural productivity, T2 (mid)	+50.6%	+42.8%
Anchor agricultural productivity, T3 (high)	+52.3%	+43.7%
Population density, T1 (low)	+39.2%	+40.6%
Population density, T2 (mid)	+44.2%	+37.1%
Population density, T3 (high)	+51.9%	+41.8%
Market-access cost, T1 (low)	+46.7%	+37.0%
Market-access cost, T2 (mid)	+49.1%	+39.2%
Market-access cost, T3 (high)	+45.8%	+42.8%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	−20.7%	−20.6%	−19.5%	−13.3%
City size, T2 (mid)	−20.3%	−20.0%	−19.6%	−7.5%
City size, T3 (high)	−20.3%	−19.8%	−24.9%	+2.4%
Population density, T1 (low)	−20.8%	−20.2%	−20.7%	−2.9%
Population density, T2 (mid)	−20.4%	−20.4%	−20.3%	−10.6%
Population density, T3 (high)	−19.9%	−19.8%	−24.9%	+2.1%
Gateway cost, T1 (low)	−19.9%	−20.2%	−24.0%	+2.4%
Gateway cost, T2 (mid)	−20.9%	−20.2%	−21.4%	−2.6%
Gateway cost, T3 (high)	−20.5%	−20.5%	−21.6%	−10.0%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 50 percent reduction in the fixed component of migration costs. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA44: Lower trade costs: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+17.9%	+19.4%	+6.5%	+9.7%
GDP, rural	+23.4%	+25.4%	+9.6%	+14.2%
GDP, urban formal	+11.7%	+14.2%	+3.5%	+14.6%
GDP, urban informal	−9.9%	−9.2%	−0.2%	−9.0%
Government wage bill	−0.6%	+1.4%	−7.2%	+3.3%
Panel B. Welfare and lifetime values				
National welfare	+13.9%	+14.5%	+8.1%	+7.7%
Rural value, Π^R	+19.4%	+20.4%	+9.2%	+11.2%
Informal value, V^I	+6.6%	+6.3%	+11.8%	+9.0%
Formal value, V^F	+7.7%	+5.9%	+14.1%	+8.8%
Entrant surplus	−1.2%	−2.7%	+12.9%	+8.5%
Urban entrant NPV	+6.2%	+6.0%	+11.5%	+9.5%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 50 percent reduction in iceberg trade costs. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA45: Regional incidence of lower trade costs, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+12.7%	+13.7%
Anchor agricultural productivity, T2 (mid)	+9.9%	+12.5%
Anchor agricultural productivity, T3 (high)	+9.5%	+11.1%
Population density, T1 (low)	+16.5%	+16.6%
Population density, T2 (mid)	+10.9%	+12.5%
Population density, T3 (high)	+8.1%	+10.5%
Market-access cost, T1 (low)	+6.5%	+9.4%
Market-access cost, T2 (mid)	+10.3%	+12.2%
Market-access cost, T3 (high)	+13.3%	+13.5%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+12.0%	+16.4%	+7.9%	+13.1%
City size, T2 (mid)	+12.5%	+16.1%	+10.1%	+10.4%
City size, T3 (high)	+10.7%	+12.2%	+8.6%	+7.1%
Population density, T1 (low)	+11.3%	+14.5%	+9.6%	+4.7%
Population density, T2 (mid)	+12.7%	+16.4%	+9.7%	+13.2%
Population density, T3 (high)	+11.0%	+12.2%	+8.1%	+8.6%
Gateway cost, T1 (low)	+10.3%	+11.2%	+7.8%	+8.0%
Gateway cost, T2 (mid)	+12.0%	+15.0%	+11.0%	+5.8%
Gateway cost, T3 (high)	+13.1%	+19.0%	+8.6%	+13.9%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline following a 50 percent reduction in iceberg trade costs. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA46: Informal-worker housing reform: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+0.4%	+0.5%	+0.4%	+1.4%
GDP, rural	+0.5%	+0.6%	+0.7%	+1.8%
GDP, urban formal	+0.1%	+0.1%	−0.0%	−0.2%
GDP, urban informal	+0.4%	+0.9%	+0.0%	+2.1%
Government wage bill	+0.0%	−0.0%	−0.0%	−0.3%
Panel B. Welfare and lifetime values				
National welfare	+0.4%	+0.6%	+0.3%	+1.1%
Rural value, Π^R	+0.2%	+0.3%	+0.4%	+1.0%
Informal value, V^I	+3.0%	+4.6%	+3.0%	+4.8%
Formal value, V^F	−0.2%	−0.3%	−0.2%	−1.2%
Entrant surplus	+4.6%	+6.9%	+4.6%	+6.8%
Urban entrant NPV	+3.1%	+4.5%	+3.0%	+4.5%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline when the housing-expenditure share of informal workers is reduced by 30 percentage points. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA47: Regional incidence of the informal-worker housing reform, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+0.3%	+1.0%
Anchor agricultural productivity, T2 (mid)	+0.4%	+1.0%
Anchor agricultural productivity, T3 (high)	+0.4%	+1.0%
Population density, T1 (low)	+0.3%	+0.8%
Population density, T2 (mid)	+0.3%	+0.9%
Population density, T3 (high)	+0.4%	+1.1%
Market-access cost, T1 (low)	+0.4%	+1.0%
Market-access cost, T2 (mid)	+0.4%	+1.0%
Market-access cost, T3 (high)	+0.3%	+0.9%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+2.1%	−0.1%	+3.9%	−0.9%
City size, T2 (mid)	+2.4%	−0.1%	+4.2%	−1.1%
City size, T3 (high)	+3.5%	−0.3%	+5.3%	−1.3%
Population density, T1 (low)	+2.7%	−0.2%	+4.6%	−1.4%
Population density, T2 (mid)	+2.5%	−0.1%	+4.4%	−0.9%
Population density, T3 (high)	+3.5%	−0.3%	+5.1%	−1.2%
Gateway cost, T1 (low)	+3.2%	−0.3%	+4.8%	−1.2%
Gateway cost, T2 (mid)	+2.5%	−0.2%	+4.1%	−1.3%
Gateway cost, T3 (high)	+3.2%	−0.2%	+5.3%	−1.1%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline when the housing-expenditure share of informal workers is reduced by 30 percentage points. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA48: Formal-worker housing reform: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+1.0%	+0.9%	+1.8%	+1.0%
GDP, rural	+1.3%	+1.1%	+3.0%	+1.7%
GDP, urban formal	+0.2%	+0.2%	+0.2%	+0.1%
GDP, urban informal	+1.2%	+0.9%	+0.4%	+0.1%
Government wage bill	−0.0%	+0.0%	+0.0%	+0.2%
Panel B. Welfare and lifetime values				
National welfare	+3.9%	+3.4%	+5.4%	+3.9%
Rural value, Π^R	+0.7%	+0.6%	+1.7%	+0.7%
Informal value, V^I	+6.9%	+5.2%	+7.2%	+4.4%
Formal value, V^F	+10.7%	+10.8%	+10.2%	+10.2%
Entrant surplus	+11.0%	+9.1%	+10.4%	+8.3%
Urban entrant NPV	+7.3%	+5.9%	+7.0%	+5.4%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline when the housing-expenditure share of formal workers is reduced by 30 percentage points. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA49: Regional incidence of the formal-worker housing reform, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+1.5%	+0.6%
Anchor agricultural productivity, T2 (mid)	+1.7%	+0.7%
Anchor agricultural productivity, T3 (high)	+1.7%	+0.8%
Population density, T1 (low)	+1.6%	+0.2%
Population density, T2 (mid)	+1.6%	+0.7%
Population density, T3 (high)	+1.7%	+0.8%
Market-access cost, T1 (low)	+1.7%	+0.8%
Market-access cost, T2 (mid)	+1.6%	+0.7%
Market-access cost, T3 (high)	+1.6%	+0.6%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+3.7%	+6.1%	+1.2%	+5.3%
City size, T2 (mid)	+5.1%	+7.8%	+2.3%	+6.0%
City size, T3 (high)	+9.0%	+12.4%	+6.3%	+12.2%
Population density, T1 (low)	+6.0%	+8.8%	+3.1%	+6.5%
Population density, T2 (mid)	+5.0%	+7.7%	+2.0%	+6.4%
Population density, T3 (high)	+9.2%	+12.5%	+6.7%	+13.5%
Gateway cost, T1 (low)	+9.2%	+12.3%	+6.8%	+13.2%
Gateway cost, T2 (mid)	+6.1%	+8.7%	+3.5%	+6.5%
Gateway cost, T3 (high)	+4.3%	+7.6%	+1.6%	+6.4%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline when the housing-expenditure share of formal workers is reduced by 30 percentage points. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

OA-7 Complete Climate and Conflict Scenario Results

This Online Appendix reports the additional climate and conflict scenario results underlying Sections 9 and 10 of the paper. Appendix H of the paper presents the principal resilience decomposition and the severe Oromia conflict episode. Here I report the uniform temperature-damage exercise, the SSP and additional climate scenarios, and the corresponding severe Tigray conflict episode.

Unless otherwise stated, scenario effects are measured relative to the zero-intervention baseline at the same formalization-capacity regime and horizon. Results are reported under the projection-consistent regime, $\theta = 3.25$, and the current-capacity benchmark, $\theta = 4.75$. Climate decompositions based on a single stochastic realization are identified explicitly and are not interpreted as Monte-Carlo means. Spatial incidence uses the fixed location groups defined in Appendix G of the paper.

OA-7.1 Uniform temperature damage

The temperature-damage exercise imposes a progressively larger national agricultural-productivity loss associated with mean warming. It is a stylized damage scenario rather than an estimated climate forecast. I report the most severe scenario, N05, in the decomposition tables and show the complete severity ladder in Figure OA13.

At N05, the model generates a large increase in food scarcity and correspondingly large losses in urban purchasing power. Under $\theta = 3.25$, national welfare is 55.9% below the corresponding no-damage baseline in 2065; under $\theta = 4.75$, the decline is 53.7%. The population-weighted urban entrant value falls by 60.9% and 60.3%, respectively.

Rural households are less adversely affected than urban households but are not insulated from the shock. Rural lifetime value falls by 50.1% under $\theta = 3.25$ and 47.3% under $\theta = 4.75$. At the same time, measured rural market-price output changes by +1.0% and +7.0%. The divergence between rural market-price output and rural welfare reflects the large equilibrium change in agricultural prices: higher nominal agricultural revenue does not imply that rural households escape the real-income consequences of the productivity loss.

Urban production contracts more sharply. Formal output falls by 31.6% under $\theta = 3.25$ and 23.6% under $\theta = 4.75$, while informal output falls by 35.2% and 42.3%. The national welfare loss is consequently somewhat smaller than the urban-only loss because the rural component declines less, but the shock remains severe for every major worker group.

Table OA50 reports the full output and welfare decomposition for the most severe

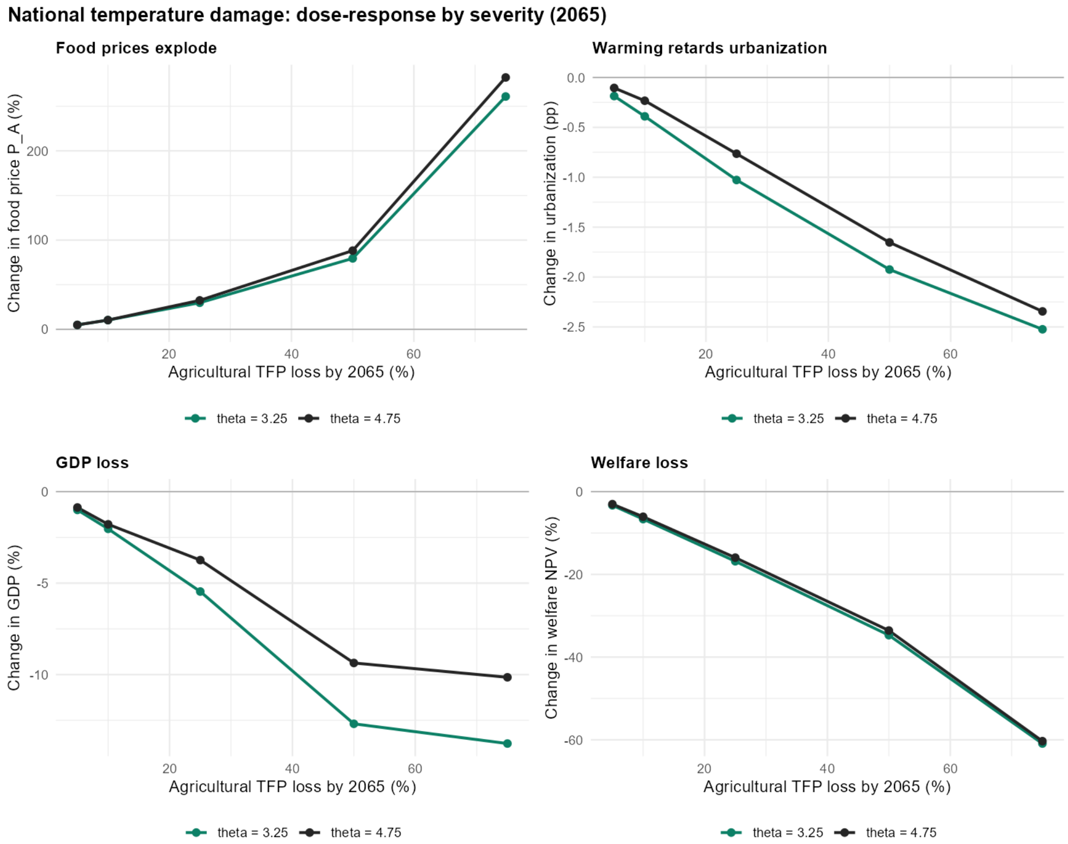

Figure OA13: Uniform temperature-damage scenarios, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding no-damage capacity-regime baseline across the N01–N05 temperature-damage scenarios, with N01 the mildest and N05 the most severe. The scenarios operate through an exogenous agricultural-productivity loss associated with mean warming. The figure reports GDP, the population-weighted urban entrant value, urbanization, and the three sectoral real-income measures. Under N05, GDP is approximately 13.8% below baseline and the urban entrant value approximately 60.9% below baseline. These are model-implied scenario outcomes rather than climate forecasts or empirical estimates. Source: author's computation.

uniform-warming rung (N05) at the 2035 and 2065 horizons under both capacity regimes; Table OA51 reports the corresponding regional-incidence cuts across the fixed location groups.

The losses accumulate over time. National welfare is approximately 9.3% below baseline in 2035 under $\theta = 3.25$ and 9.2% below baseline under $\theta = 4.75$, compared with terminal losses exceeding 50%. This convex time profile reflects the persistence of the agricultural-productivity deterioration and the resulting general-equilibrium food-price effects.

Formalization capacity improves the level of welfare before and after the climate shock, but it provides little proportional insurance against this uniform warming scenario. The urban entrant loss is 60.9% under $\theta = 3.25$ and 60.3% under $\theta = 4.75$. Stronger formal absorption therefore raises the economy's level of productive capacity without materially reducing the proportional loss generated by a sufficiently broad and persistent agricultural shock.

OA-7.2 SSP and stochastic climate scenarios

The SSP exercise combines alternative warming trajectories with stochastic extreme-weather realizations. The main text reports averages across ten simulation seeds. The decomposition table below instead reports one realization, sim01, in order to display worker-group and spatial incidence at a common underlying draw.

The distinction is quantitatively important. For the high-warming S2 scenario, the ten-seed mean urban entrant effect is -13.60% under $\theta = 3.25$ and -12.77% under $\theta = 4.75$. The sim01 realization used in the detailed decomposition produces larger losses of -19.2% and -18.7%, respectively. The decomposition should therefore be read as an incidence illustration rather than as the expected effect of S2.

Within the ten-seed scenario ladder, the difference between successful mitigation and high warming is much larger than the incremental effect of adding the modeled extreme-event component on top of high warming. Moving from S1 to S2 lowers urban entrant value by approximately 4.49 percentage points under $\theta = 3.25$ and 4.12 percentage points under $\theta = 4.75$. Moving from S2 to S3 changes it by approximately 0.21 and 0.27 percentage points, respectively. This comparison pertains to the specific scenario construction and should not be interpreted as a general quantitative ranking of mitigation and adaptation policies.

For the sim01 S2 realization, national welfare falls by 6.7% under $\theta = 3.25$ and 7.0% under $\theta = 4.75$ in 2065. These losses are substantially smaller than the corresponding urban entrant losses because rural value changes by only $+0.5\%$ and -1.8%. Rural market-price output rises by 16.6% and 12.6%, respectively, as labor reallocation and agricultural prices adjust.

The time profile is again non-monotonic. National welfare in the sim01 decomposition falls by approximately 15.1% and 14.7% in 2035 before partly recovering by 2065. Terminal outcomes should therefore not be interpreted as measuring the maximum welfare cost experienced during the transition.

OA-7.3 Localized agricultural damage

The localized-damage exercise concentrates the agricultural productivity shock in the cereal-producing zone rather than imposing it nationally. It therefore isolates the role of spatial scope in the model's migration response.

The contrast with uniform warming illustrates a spatial general-equilibrium mecha-

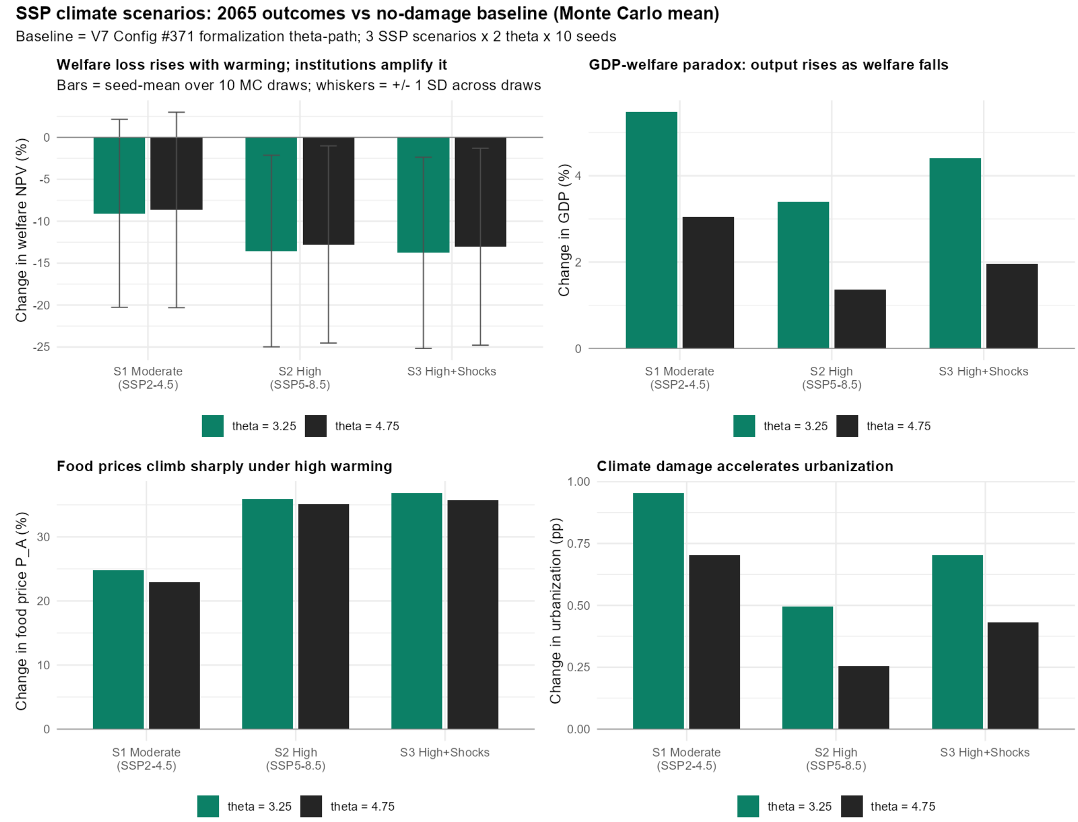

Figure OA14: SSP climate scenarios, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding capacity-regime baseline for the S1–S3 climate scenarios, averaged across ten stochastic simulation seeds. S1 represents the lower-warming scenario, S2 the high-warming scenario, and S3 adds the modeled extreme-event component to high warming. The figure reports GDP, population-weighted urban entrant value, urbanization, and the sectoral real-income measures. Source: author's computation.

nism. When agricultural damage is geographically concentrated, workers can leave the affected area while the national food-production system remains partly intact. Migration therefore plays a larger adjustment role. Under nationally pervasive agricultural damage, the same reallocation margin is much less effective because the shock simultaneously affects food supply across locations.

The positive terminal zone-level GDP responses should not be interpreted as direct productive benefits of agricultural damage. They are post-adjustment general-equilibrium outcomes that combine population movement, sectoral reallocation, and price changes.

OA-7.4 Transitory extreme-weather episodes

The extreme-weather exercises impose temporary drought episodes of different durations and geographic breadth. Because migration is costly and formalization changes workers' subsequent employment opportunities, a temporary agricultural shock can leave persistent effects on the spatial allocation of population even after the direct

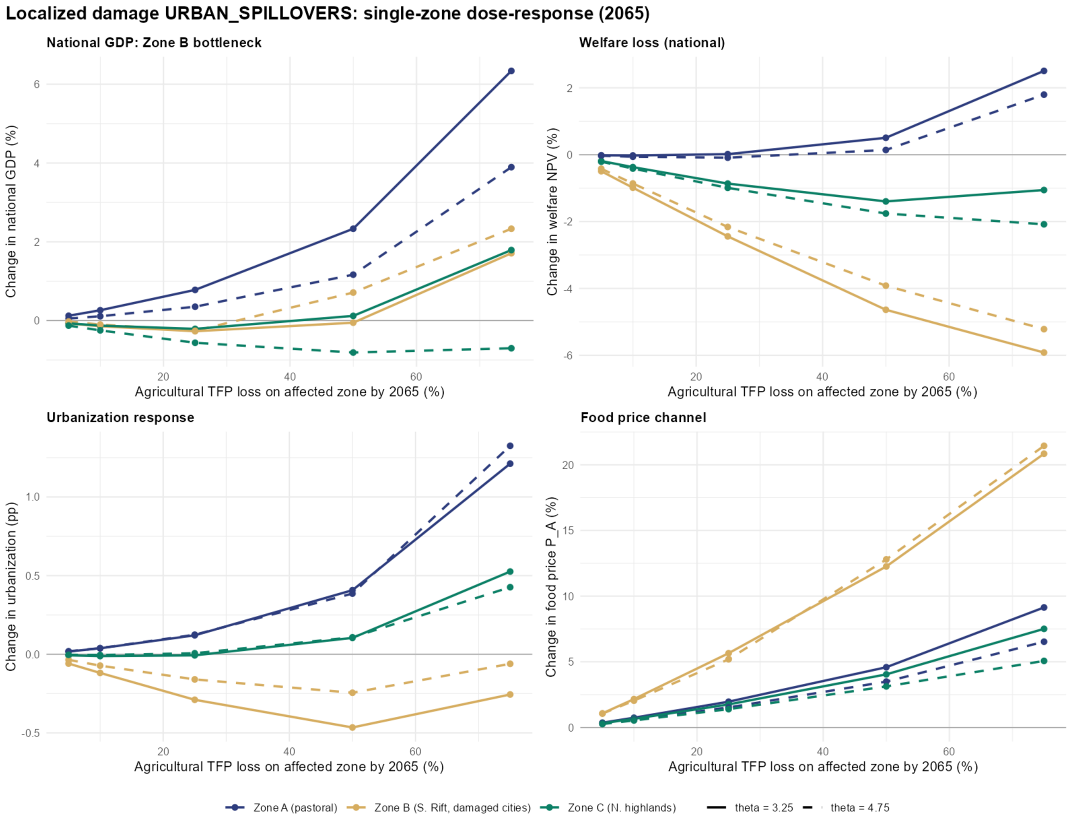

Figure OA15: Localized agricultural damage, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding capacity-regime baseline across the L1–L5 severity ladder for a productivity shock concentrated in the modeled cereal-producing zone. The figure reports GDP, population-weighted urban entrant value, urbanization, and sectoral real-income measures. Unlike the uniform national temperature-damage exercise, these localized shocks generate greater urbanization because unaffected locations remain available to absorb displaced workers. The reported zone-level GDP measure rises from approximately 0.12% above baseline under L1 to 6.34% under L5 after the resulting reallocation. Source: author's computation.

productivity shock disappears.

Under $\theta = 3.25$, national population-weighted welfare is approximately 4.0% above baseline following the five-year single-zone episode and 2.4% above baseline following the three-zone episode, even though urban entrant value remains below baseline. These positive terminal national deviations arise from the model's post-shock reallocation and should not be interpreted as implying that the drought itself raises welfare during the period in which it occurs.

The exercise instead illustrates a distributional consequence of persistent migration. Temporary shocks can alter where workers live and which labor market they subsequently occupy. National terminal aggregates may therefore recover or even exceed the no-shock path while particular receiving groups remain worse off.

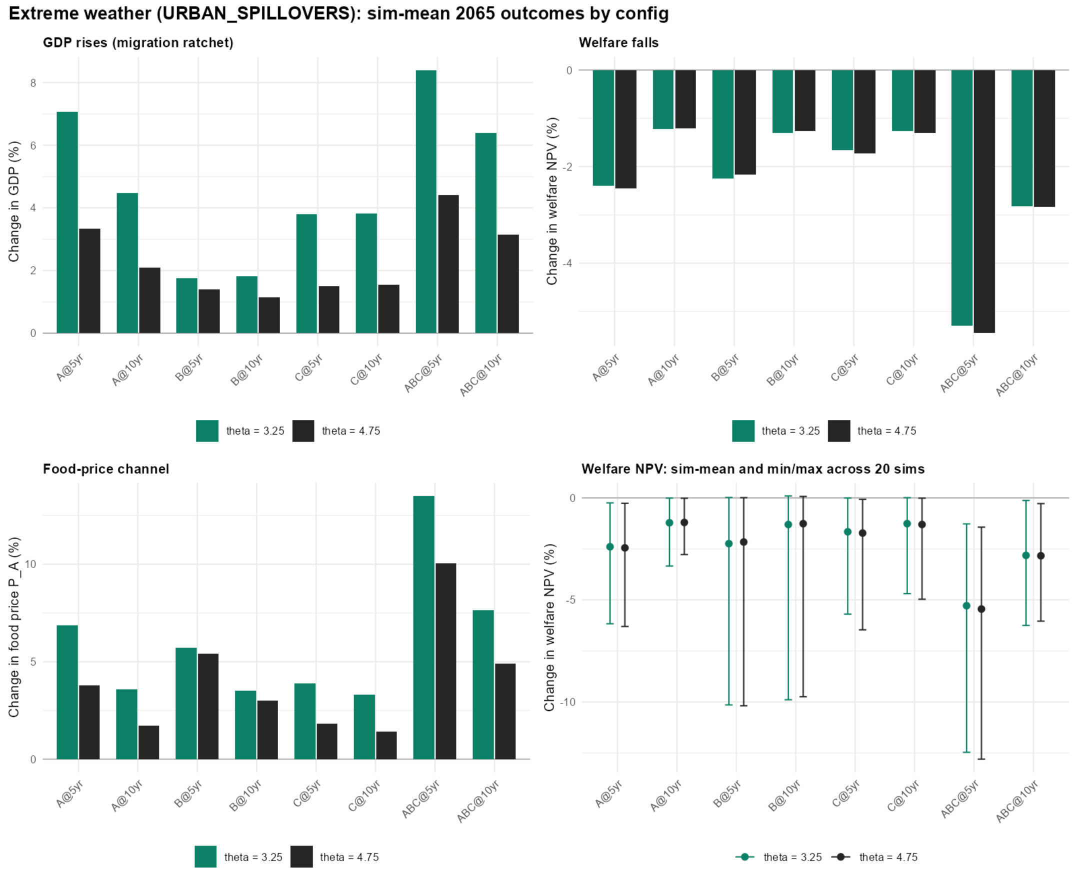

Figure OA16: Transitory drought episodes, $\theta = 3.25$

Notes: Terminal 2065 deviations from the corresponding capacity-regime baseline for temporary drought episodes differing in duration and geographic scope. A five-year single-zone drought is associated with a terminal zone-level GDP deviation of approximately +7.07%; the corresponding three-zone episode produces approximately +8.40%. Urban entrant value is approximately 2.40% and 5.29% below baseline, respectively. These are post-shock terminal outcomes and reflect persistent spatial reallocation rather than contemporaneous gains from drought. Source: author's computation.

OA-7.5 Agricultural world-price volatility

The agricultural-volatility exercise introduces stochastic persistence in world agricultural prices. Its purpose is to examine dispersion around the deterministic transition rather than to construct a separate climate-damage regime.

The exercise is therefore best interpreted as a measure of transition uncertainty rather than as another deterministic damage scenario. I do not use it to identify a separate structural mechanism or to rank policy responses.

OA-7.6 Conflict in Tigray

The severe Tigray episode provides a smaller-region counterpart to the severe Oromia experiment reported in Appendix H of the paper. Both episodes use the same severity and recovery assumptions, allowing their different national effects to reflect primarily

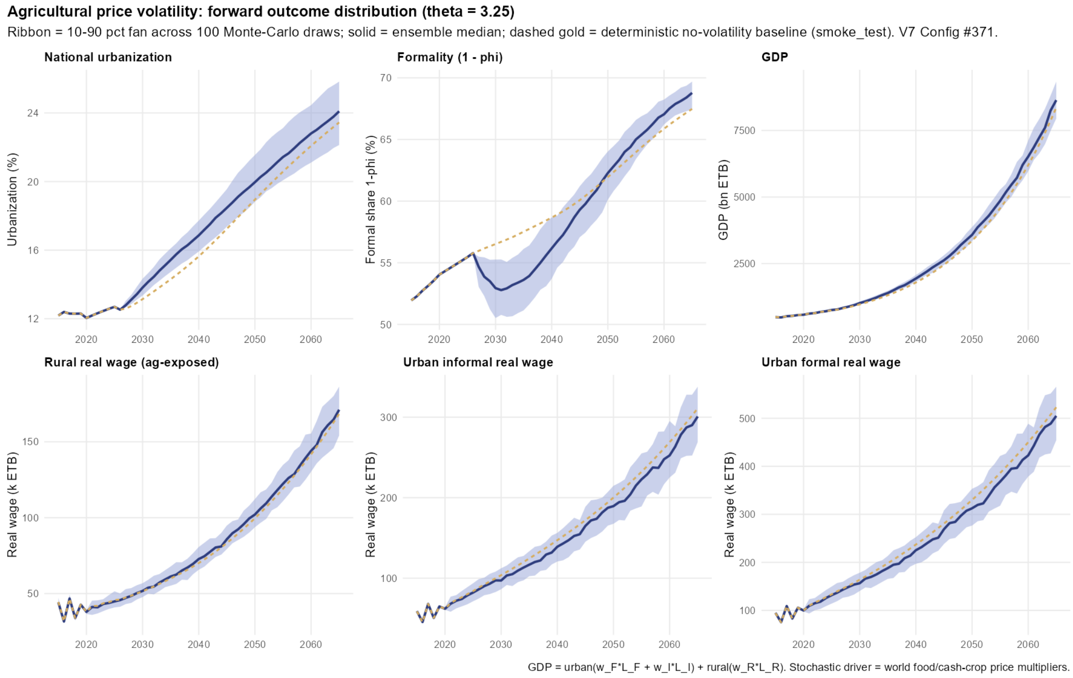

Figure OA17: Agricultural world-price volatility, $\theta = 3.25$

Notes: Distribution of terminal model outcomes under stochastic agricultural world-price variation around the baseline transition. The exercise varies agricultural world prices stochastically around the baseline path, holding all structural parameters fixed, and illustrates how price volatility widens the distribution of possible terminal outcomes without reversing the direction of the transition. Source: author's computation.

the spatial extent of the directly affected population.

As in Appendix H, the decomposition below is measured relative to the zero-conflict baseline for the same value of θ. The headline conflict results in the main text additionally use a low-conflict within-grid reference scenario. Numerical deviations from the two presentations therefore need not coincide exactly.

The national welfare trough is substantially smaller for Tigray than for Oromia. In 2035, national welfare is 1.6% below baseline under $\theta = 3.25$ and 1.5% below baseline under $\theta = 4.75$. The corresponding severe Oromia episode produces losses of approximately 7.6% and 7.4%.

By 2065, the national deviations in the Tigray exercise are close to zero, at approximately $+0.1\%$ and $+0.0\%$. The urban entrant value remains slightly below baseline, at approximately -0.1% and -0.2%.

Table OA54 reports the full output and welfare decomposition for the severe Tigray episode at the 2035 and 2065 horizons under both capacity regimes; Table OA55 reports the corresponding regional-incidence cuts across the fixed location groups.

The comparison with Oromia highlights the importance of geographic scale in the

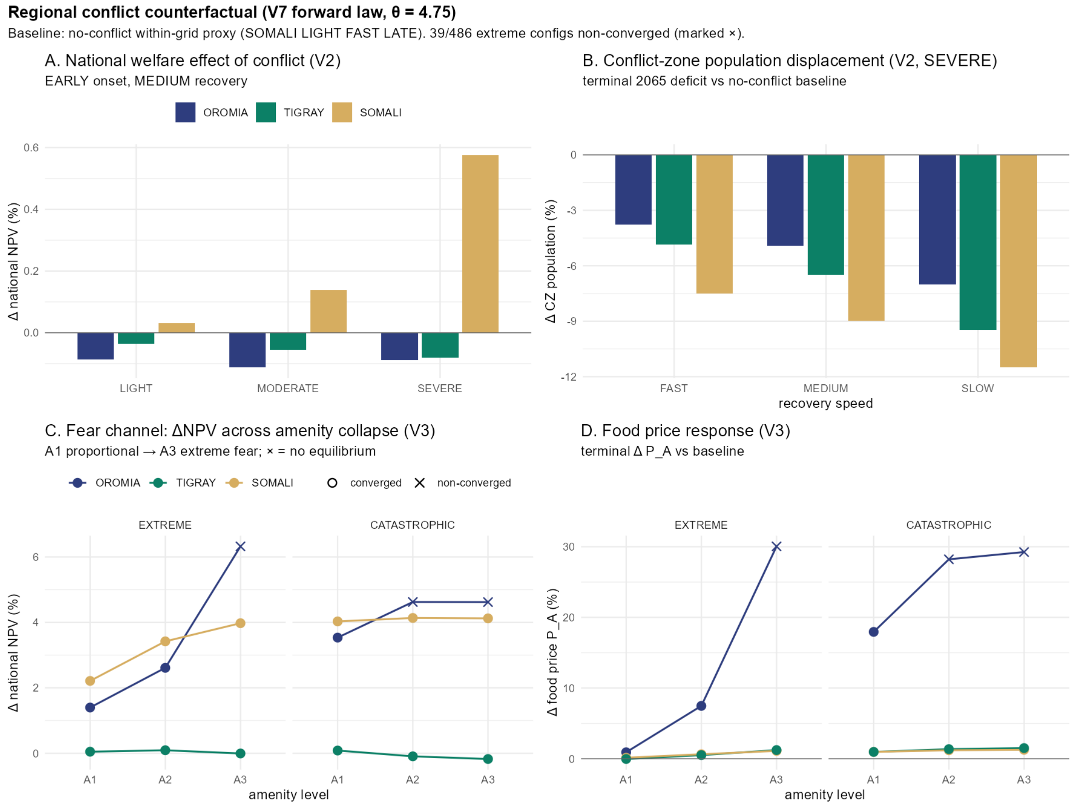

Figure OA18: Conflict scenarios, $\theta = 4.75$

Notes: Terminal 2065 deviations from the corresponding zero-conflict baseline across the modeled conflict regions and severity levels under the current-capacity benchmark $\theta = 4.75$. The figure reports GDP, population-weighted urban entrant value, urbanization, and sectoral real-income measures. The severe Tigray episode analyzed below is one member of the broader scenario set. Configurations for which the model does not converge under catastrophic local collapse are omitted. The corresponding $\theta = 3.25$ figure is reported in Appendix H of the paper. Source: author's computation.

conflict experiments. Both shocks are temporary and localized, but the Oromia episode affects a substantially larger population and therefore creates a much deeper national transition loss. The availability of unaffected domestic destinations also allows part of the displacement to be absorbed elsewhere in the economy.

The small terminal national and broad spatial-group deviations should not be interpreted as complete recovery in every directly affected location. Aggregation across terciles and across the national population can conceal persistent local losses. The result is narrower: within the model, a severe but geographically concentrated temporary conflict can leave limited long-run national effects even when its short-run regional consequences are substantial.

Table OA50: Severe temperature damage: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	−0.9%	−1.1%	−13.8%	−10.1%
GDP, rural	+1.3%	+0.9%	+1.0%	+7.0%
GDP, urban formal	−5.5%	−5.3%	−31.6%	−23.6%
GDP, urban informal	−7.1%	−6.8%	−35.2%	−42.3%
Government wage bill	+0.0%	+0.2%	−6.7%	+3.1%
Panel B. Welfare and lifetime values				
National welfare	−9.3%	−9.2%	−55.9%	−53.7%
Rural value, Π^R	−7.5%	−7.7%	−50.1%	−47.3%
Informal value, V^I	−12.5%	−11.9%	−60.9%	−60.4%
Formal value, V^F	−13.0%	−12.8%	−61.2%	−60.8%
Urban entrant NPV	−12.6%	−12.0%	−60.9%	−60.3%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under the most severe temperature-damage scenario, N05. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA51: Regional incidence of severe temperature damage, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	−56.3%	−52.8%
Anchor agricultural productivity, T2 (mid)	−51.7%	−48.7%
Anchor agricultural productivity, T3 (high)	−48.7%	−46.0%
Population density, T1 (low)	−50.7%	−47.2%
Population density, T2 (mid)	−50.2%	−47.2%
Population density, T3 (high)	−50.1%	−47.4%
Market-access cost, T1 (low)	−50.2%	−47.4%
Market-access cost, T2 (mid)	−49.8%	−47.2%
Market-access cost, T3 (high)	−50.6%	−47.3%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	−61.2%	−62.5%	−60.9%	−62.1%
City size, T2 (mid)	−61.2%	−62.1%	−60.2%	−61.0%
City size, T3 (high)	−60.7%	−60.7%	−60.5%	−60.8%
Population density, T1 (low)	−61.6%	−62.4%	−60.9%	−62.1%
Population density, T2 (mid)	−61.3%	−62.2%	−60.3%	−61.2%
Population density, T3 (high)	−60.1%	−60.1%	−60.2%	−60.3%
Gateway cost, T1 (low)	−60.0%	−60.0%	−59.6%	−59.9%
Gateway cost, T2 (mid)	−61.9%	−62.5%	−60.5%	−62.5%
Gateway cost, T3 (high)	−61.6%	−62.8%	−61.6%	−62.1%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline under the most severe temperature-damage scenario, N05. Terciles are fixed across scenarios. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA52: SSP S2 climate scenario: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	+12.6%	+11.0%	+12.0%	+7.2%
GDP, rural	+14.5%	+13.4%	+16.6%	+12.6%
GDP, urban formal	+1.5%	−2.0%	+8.5%	−2.9%
GDP, urban informal	+22.1%	+16.5%	−2.2%	+4.1%
Government wage bill	+0.7%	−2.8%	+8.7%	−2.5%
Panel B. Welfare and lifetime values				
National welfare	−15.1%	−14.7%	−6.7%	−7.0%
Rural value, Π^R	−12.4%	−12.5%	+0.5%	−1.8%
Informal value, V^I	−26.1%	−28.1%	−19.1%	−18.3%
Formal value, V^F	−24.1%	−20.0%	−18.7%	−13.1%
Entrant surplus	−34.0%	−37.6%	−31.4%	−29.2%
Urban entrant NPV	−26.2%	−28.2%	−19.2%	−18.7%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline for SSP scenario S2. Results use one representative Monte Carlo realization (sim01); the main text reports averages across ten simulation draws. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option.

Table OA53: Regional incidence of the SSP S2 climate scenario, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	−17.4%	−18.7%
Anchor agricultural productivity, T2 (mid)	+7.2%	+5.3%
Anchor agricultural productivity, T3 (high)	+0.6%	−1.4%
Population density, T1 (low)	−30.7%	−31.4%
Population density, T2 (mid)	+3.5%	+1.9%
Population density, T3 (high)	+3.0%	+0.8%
Market-access cost, T1 (low)	−8.8%	−10.9%
Market-access cost, T2 (mid)	+10.6%	+7.7%
Market-access cost, T3 (high)	+0.4%	−0.4%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	−18.2%	−18.5%	−16.6%	−15.8%
City size, T2 (mid)	−18.9%	−18.5%	−18.3%	−10.7%
City size, T3 (high)	−19.5%	−18.7%	−18.7%	−13.4%
Population density, T1 (low)	−19.0%	−18.7%	−18.6%	−5.5%
Population density, T2 (mid)	−19.0%	−18.7%	−18.2%	−14.1%
Population density, T3 (high)	−19.4%	−18.6%	−18.1%	−16.7%
Gateway cost, T1 (low)	−19.3%	−18.7%	−18.3%	−16.0%
Gateway cost, T2 (mid)	−19.0%	−18.6%	−19.0%	−5.7%
Gateway cost, T3 (high)	−18.7%	−18.9%	−17.4%	−14.6%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline for SSP scenario S2. Results use one representative Monte Carlo realization (sim01); the main text reports averages across ten simulation draws. Terciles are fixed across scenarios. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

Table OA54: Severe Tigray conflict: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	−1.3%	−1.2%	+0.2%	−0.1%
GDP, rural	−1.2%	−1.0%	+0.2%	−0.1%
GDP, urban formal	−1.4%	−1.2%	+0.2%	−0.5%
GDP, urban informal	−2.0%	−2.5%	+0.0%	+0.4%
Government wage bill	−5.3%	−5.0%	−0.1%	−0.9%
Panel B. Welfare and lifetime values				
National welfare	−1.6%	−1.5%	+0.1%	+0.0%
Rural value, Π^R	−1.4%	−1.3%	+0.2%	−0.0%
Informal value, V^I	−1.8%	−2.1%	−0.0%	−0.1%
Formal value, V^F	−0.6%	−0.6%	+0.0%	+0.3%
Entrant surplus	−1.5%	−2.2%	−0.2%	−0.2%
Urban entrant NPV	−1.5%	−1.9%	−0.1%	−0.2%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline for the severe Tigray conflict scenario with medium recovery and early onset. The government wage bill is reported separately and excluded from GDP. National welfare is population weighted. Entrant surplus measures the value of entering the urban informal sector relative to the rural option; urban entrant NPV is the population-weighted urban lifetime-value measure.

Table OA55: Regional incidence of the severe Tigray conflict episode, 2065

Panel A. Rural locations

Characteristic	$\theta = 3.25$ $\Delta\Pi^R$	$\theta = 4.75$ $\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+0.0%	−0.1%
Anchor agricultural productivity, T2 (mid)	+0.1%	−0.0%
Anchor agricultural productivity, T3 (high)	+0.3%	+0.1%
Population density, T1 (low)	+0.0%	−0.0%
Population density, T2 (mid)	+0.1%	−0.0%
Population density, T3 (high)	+0.2%	−0.0%
Market-access cost, T1 (low)	+0.1%	−0.1%
Market-access cost, T2 (mid)	+0.0%	−0.1%
Market-access cost, T3 (high)	+0.3%	+0.2%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	+0.1%	+0.4%	+0.1%	+0.7%
City size, T2 (mid)	−0.0%	−0.0%	−0.1%	+0.3%
City size, T3 (high)	−0.1%	+0.0%	−0.0%	+0.2%
Population density, T1 (low)	−0.0%	−0.0%	−0.1%	+0.4%
Population density, T2 (mid)	−0.0%	+0.1%	−0.1%	+0.4%
Population density, T3 (high)	−0.1%	+0.0%	−0.0%	+0.1%
Gateway cost, T1 (low)	−0.0%	−0.0%	+0.0%	+0.1%
Gateway cost, T2 (mid)	−0.0%	−0.0%	−0.1%	+0.4%
Gateway cost, T3 (high)	−0.0%	+0.1%	+0.1%	+0.8%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline for the severe Tigray conflict scenario with medium recovery and early onset. Terciles are fixed across scenarios. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

References

Becker-Reshef, I., C. Justice, M. Sullivan, E. Vermote, C. Tucker, A. Anyamba, J. Small, E. Pak, E. Masuoka, J. Schmaltz, M. Hansen, K. Pittman, C. Birkett, D. Williams, C. Reynolds, and B. Doorn (2010). Monitoring global croplands with coarse resolution earth observations. *Remote Sensing of Environment 114*(6), 1286–1297.

Bryan, G. and M. Morten (2019). The aggregate productivity effects of internal migration: Evidence from Indonesia. *Journal of Political Economy 127*(5), 2229–2268.

Dercon, S. and L. Christiaensen (2011). Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. *Journal of Development Economics 96*(2), 159–173.

Fuglie, K. O. (2012). Productivity growth and technology capital in the global agricultural economy. In K. O. Fuglie, S. L. Wang, and V. E. Ball (Eds.), *Productivity Growth in Agriculture: An International Perspective*, pp. 335–368. Wallingford, UK: CAB International.

Funk, C., P. Peterson, M. Landsfeld, D. Pedreros, J. Verdin, S. Shukla, G. Husak, J. Rowland, L. Harrison, A. Hoell, and J. Michaelsen (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data 2*, 150066.

Gollin, D., D. Lagakos, and M. E. Waugh (2014). The agricultural productivity gap. *Quarterly Journal of Economics 129*(2), 939–993.

Tobler, W. (1993). Three presentations on geographical analysis and modeling. NCGIA Technical Report 93-1.

UN DESA (2024). World population prospects 2024. United Nations Department of Economic and Social Affairs, Population Division.