Segmented Labor Markets and Structural Transformation

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Abstract

Most urban growth this century will occur in developing economies. Whether this urbanization translates into sustained economic development depends on how quickly workers gain access to productive formal employment. I develop a dynamic spatial general equilibrium model with three types of labor markets: rural, urban informal, and urban formal. Migrants enter an informal queue, and formalization depends on informal labor congestion and the economy's ability to move informal workers into formal employment. I quantify the model for Ethiopia using novel geospatial and microdata. The speed of transition from informal to formal labor markets emerges as a key determinant of long-run structural transformation, economic growth and welfare: improvements to formalization raise the long-run urban formal labor share by 26 pp and real GDP by 13.1 percent relative to the baseline, while leaving the urban population share largely unchanged. The formalization rate also shapes both the effectiveness of economic policies and national resilience to climate shocks and conflict. Cities become engines of structural transformation not when workers arrive, but when labor markets absorb them into productive employment.

Keywords: structural transformation; urbanization; informality; spatial equilibrium; migration; dual labor markets.
JEL codes: O14, O17, O18, R12, R23, J46.

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1 Introduction

The next major wave of urbanization is unfolding in some of the world's fastest growing and most vulnerable economies (UN DESA, 2025, 2024). This demographic transformation makes it increasingly important to understand the conditions under which rapid urban population growth translates into sustained economic development. For urbanization to raise living standards, workers must not only leave low-productivity agriculture but also gain access to more productive urban employment. Yet in many developing economies, workers who move to cities enter primarily through informal employment and reach formal work only gradually, if at all (Banerjee, 1983; Gollin et al., 2016; Imbert and Ulyssea, 2026).

This disconnect between urban growth and formalization creates a central development problem. City populations can grow rapidly while large shares of workers remain in low-productivity informal employment. This paper asks what determines whether growing cities can move these workers into productive formal jobs, and how that transition shapes structural transformation.

To formalize this disconnect, I develop a recursive dynamic spatial general equilibrium model with three labor market types: rural, urban informal, and urban formal. The model builds on quantitative spatial models that study where workers and economic activity locate across space (Redding and Rossi-Hansberg, 2017; Bryan and Morten, 2019; Morten and Oliveira, 2024), but adds segmented labor markets within cities. Rural migrants first enter informal employment and reach formal employment through an endogenous transition. When formalization rates are low, migration expands the informal workforce and traps workers in less productive informal work. This can cause cities to grow without undergoing structural transformation. Quantified for Ethiopia, the model predicts that raising formalization capacity to the pace seen in successfully transforming economies increases the urban formal employment share from 41.1 to 67.5 percent and real GDP by 13.1 percent by 2065, with little change in the urban population share. Economic development can therefore depend as much on movement between labor markets within cities as on movement across places.

The model's key mechanism is a queue. Rural migrants enter urban informal employment and wait to move into formal work. Their probability of formalizing depends on the size of this informal queue relative to the city's ability to absorb workers into formal jobs. I call this ability formalization capacity. It summarizes the institutions that govern registration and enforcement, the labor markets efficiency of matching and hiring, and firms' ability to recruit, train, and employ workers formally. Formalization therefore depends jointly on this capacity and on how many workers are waiting for access.

Conceptually, this builds on the Harris–Todaro tradition (Harris and Todaro, 1970; Fields, 1975), in which migration responds to expected urban earnings under segmented labor markets. The key departure from Harris–Todaro is that the probability of formal employment is not a static lottery but an endogenous state that migration itself changes. I link formalization rates to local informal labor shares, so access to formal employment varies across cities and over time. Embedding this transition in spatial general equilibrium creates a two-way feedback between migration and formalization. Formalization prospects shape migration, while migration changes the informal queue and therefore future access to formal employment. New arrivals can consequently affect not only their own prospects but also those of workers already in the city, allowing the same economic change to affect informal and formal workers within the same location differently.

The distinction between informal and formal urban labor markets is well supported empirically. Informal and formal employment differ in wages, contracts, firms, regulation, and access to institutions, while movement across the boundary is gradual and incomplete (La Porta and Shleifer, 2014; Meghir et al., 2015; Ulyssea, 2018; McCaig and Pavcnik, 2018; Dix-Carneiro and Kovak, 2019). The average urban wage therefore does not represent the opportunities available to a new migrant, who typically enters through informal employment and reaches formal earnings only later, if at all.

I take the model to Ethiopia, a setting that combines rapid population growth, persistent agricultural dependence, low urbanization, and extensive urban informality. Four patterns in the Ethiopian microdata motivate and discipline the model. First, informal and formal employment constitute distinct urban labor markets: their wage distributions are clearly separated, with substantially higher earnings in formal work. Second, rural–urban migration remains low relative to the average rural–urban income gap. Third, larger cities do not have a systematically larger formal labor share. Fourth, migrants formalize slowly and incompletely: the probability of holding a formal job rises with time in the city but eventually plateaus. These patterns are not unique to Ethiopia. Migrant entry through informal work is documented in India, China, Indonesia, and Brazil (Banerjee, 1983; Meng, 2001; Manning and Pratomo, 2013; Imbert and Ulyssea, 2026); limited migration relative to income gaps is documented across many developing economies (Bryan and Morten, 2019; Lagakos et al., 2023).

To quantify the model, I combine twenty one years of satellite and geospatial data with extensive Ethiopian microdata. The geospatial data measure population, agricultural output, settlement boundaries, climate, and market access, while the microdata cover workers, households, demographics, agricultural production, and prices. With these data, I construct a spatial dataset covering 681 locations, which I aggregate to 121 spatial markets for computational reasons. Across these markets, I measure migrant formalization by urban tenure, wages, incomes, market access, and productivity. The model accurately reproduces the spatial distribution of wages, rural incomes, and market access. It also closely reproduces the cross city ranking of informality, with a Spearman correlation of 0.982.

The quantified model reveals a large gap between how quickly Ethiopian cities currently move informal workers into formal employment and how quickly they would need to do so for urbanization to occur alongside declining informality. The Ethiopian microdata support a current formalization rate of roughly 2 to 4 percent per year, implying an expected wait per worker of roughly 26 years. At this capacity, migration and demographic growth replenish informal employment faster than workers leave it, lengthening the queue and allowing cities to grow while remaining predominantly informal. For population growth and urbanization to occur alongside the projected decline in informality, a central condition for productive structural transformation, the formalization rate would need to rise to roughly 6 to 7 percent per year, shortening the expected wait to about 17 years.

Closing this gap has major economic consequences. In my model, moving from the current 26 year wait to the roughly 17 year wait raises real GDP by 13.1 percent by 2065 and national welfare by 9.7 percent over the transition. The urban formal employment share rises from 41.1 to 67.5 percent, while the urban population share changes by less than one percentage point. The main challenge of structural transformation is therefore not to move substantially more workers into cities, but to change what happens to them once they arrive. More workers reach the higher–productivity formal sector, but the gains are distributed unevenly. Rural households benefit as outmigration raises average rural earnings, informal workers gain because their prospects of reaching formal employment improve, while formal incumbents lose part of the earnings premium generated by restricted access. The implied pace is demanding and require substantial reform, but lies within the range of worker transition rates observed in other developing economies (Appendix E.10).

I then examine how formalization capacity changes what policy achieves. When capacity is weak, policies that raise rural or informal productivity or household purchasing power reach workers where they already are. By contrast, the gains from mobility, infrastructure, and formal industrial policy depend more strongly on whether workers can reach formal employment. At current capacity, for example, lowering migration costs raises GDP and national welfare but lowers the value of entering urban employment because inflows outpace formal absorption and lengthen the informal queue. With stronger capacity, more of the same inflow reaches formal employment. The counterfactuals therefore imply a natural sequencing of development policy. While formal absorption remains weak, policies that raise productivity and incomes where workers already are can generate gains without relying on rapid formalization. As the queue clears, mobility, infrastructure, industrial policy, and access to external markets become more effective.

The final set of results concerns resilience to climate change and conflict (Section 9). Climate shocks reduce agricultural productivity and propagate through food prices, urban living costs, and migration, so their burden can fall heavily on urban households, especially informal workers, even when the initial damage is rural. Greater formalization capacity leaves the economy better off in levels but does not substantially reduce the proportional welfare loss from a nationwide agricultural shock. Its resilience role is much stronger when shocks displace workers across locations. Under local climate shocks and conflict, stronger capacity moves more displaced workers into productive employment and limits persistent informal congestion in receiving cities. Formalization capacity therefore helps determine whether displacement produces productive reallocation or shifts economic distress into urban informal labor markets.

These results establish four central contributions.

First, the paper identifies formalization capacity as a central constraint on structural transformation and long run development. The structural transformation literature studies the movement of workers out of low productivity agriculture (Gollin et al., 2014, 2016), while the informality literature documents large and persistent productivity gaps within cities (La Porta and Shleifer, 2014; Ulyssea, 2018). Existing frameworks, however, do not quantify the transition from urban informal to formal work as a dynamic development bottleneck. By endogenizing this transition in a dynamic spatial general equilibrium model, I show that limited formalization capacity can slow structural transformation and substantially reduce output and welfare, whereas closing the capacity gap generates large economic gains.

Second, the paper shows that formalization capacity changes both the effectiveness and distributional consequences of development policy. Quantitative spatial models evaluate migration, infrastructure, and trade policy through the spatial reallocation of workers and economic activity (Bryan and Morten, 2019; Tombe and Zhu, 2019; Morten and Oliveira, 2024), while structural models of informality study how taxes, regulation, and productivity shape formal and informal employment (Ulyssea, 2018). Neither approach captures how policies that draw workers into cities can congest access to formal employment once they arrive. By making formalization endogenous, the model shows that a city's ability to move workers into formal jobs determines both which policies are most effective and who benefits from them. Aggregate gains can therefore conceal substantial losses within the same location.

Third, the paper establishes formal labor market absorption as a determinant of resilience to climate change and conflict. When shocks displace workers across locations, formalization capacity determines whether they move into productive employment or accumulate in congested informal labor markets. This connects spatial models of climate induced migration (Cruz and Rossi-Hansberg, 2024; Conte, 2024) with evidence on the labor market effects of displacement (Calderón-Mejía and Ibáñez, 2016; Tumen, 2016), while showing that the consequences of displacement depend on which labor market workers can access once they arrive.

Fourth, the paper contributes a portable spatial general equilibrium framework that separates location choice from labor market access within locations. Workers in the same place can face different wages, institutions, entry conditions, and transition probabilities, and these differences can change endogenously over time. Beyond informality, the same framework can be adapted to labor markets segmented by skill, legal status, contract type, or restricted sectoral access.

The paper proceeds as follows. Section 3 develops the model and its central mechanism. Section 4 describes the setting and data, and Section 5 documents the four empirical patterns. Section 6 quantifies and validates the model and defines the two formalization capacities. Section 7 establishes the formalization-capacity gap, and Section 8 evaluates the policy implications. Section 9 studies resilience to climate change and conflict, Section 10 reports the robustness exercises, and Section 11 concludes.

2 Theoretical Background and Related Literature

Three literatures bear directly on this paper and have largely developed independently: quantitative spatial general-equilibrium models of migration and structural change, the empirical study of urban informality, and the Harris–Todaro theory of migration into segmented labor markets. The first provides a general-equilibrium structure the second does not have, while the second provides a labor-market segmentation the first typically lacks. This paper places a dual urban labor market, disciplined by the empirical structure of informality, inside a dynamic spatial economy and extends the Harris–Todaro mechanism from a static expected-wage condition into an endogenous transition between informal and formal employment.

Spatial equilibrium and the two-market city. The quantitative spatial literature synthesized in Redding and Rossi-Hansberg (2017) provides the natural framework for studying where workers live, how locations trade, and how policy reallocates economic activity. A smaller dynamic strand, including Desmet and Rossi-Hansberg (2014), Caliendo et al. (2019), and Kleinman et al. (2023), traces spatial economies along transition paths rather than comparing only static equilibria or steady states. In migration-focused models in this tradition, location choices are typically forward-looking and depend on expected future prices and wages. I retain this transition-path perspective but use a recursive, limited-foresight formulation suited to the development setting. Workers value destinations through current earnings and the prospect of formalization, so they are forward-looking over the labor-market transition that can be disciplined by the data rather than over the full future path of equilibrium prices and wages. The key evolving state is the composition of urban labor markets, which links migration today to formalization prospects tomorrow. Section 3.8 states the timing precisely.

This toolkit has increasingly been applied to migration and development. Bryan and Morten (2019) quantify the productivity losses generated by internal migration frictions in Indonesia, Morten and Oliveira (2024) show how transport infrastructure reshapes Brazil's spatial economy, and Tombe and Zhu (2019) measure the contribution of declining migration and trade barriers to Chinese growth. These papers establish how spatial frictions govern the movement of workers and economic activity across locations. A complementary development-macro literature documents the large agriculture–nonagriculture productivity gaps that give rural-to-urban reallocation its economic significance (Gollin et al., 2014; Lagakos and Waugh, 2013; Lagakos et al., 2023).

Despite their differences, these frameworks generally share a consequential simplification. The city is represented as a single labor market. A migrant who arrives obtains an urban wage, potentially differentiated by sector or skill, but does not face a distinct boundary between formal employment governed by contracts, registration, and enforcement and informal employment outside those arrangements. This abstraction is innocuous where informal employment is negligible, but becomes first-order in the low-income economies to which these models are increasingly applied, where informality accounts for much of urban employment and declines only slowly with development (International Labour Organization, 2018; La Porta and Shleifer, 2014).

The empirical literature shows that formal and informal employment are not merely two labels attached to a single integrated market. Formal and informal firms coexist under distinct wage-setting and employment arrangements (Meghir et al., 2015). Movement across the boundary is gradual, incomplete, and responsive to institutions and economic shocks (Ulyssea, 2018; McCaig and Pavcnik, 2018; Dix-Carneiro and Kovak, 2019). Informal work can constitute productive employment rather than simply disguised unemployment (De Mel et al., 2008; Franklin, 2018).

For rural-to-urban reallocation, informality is also a central entry margin through which developing cities absorb migrants. Evidence from Delhi, urban China, four Indonesian cities, and Ethiopia shows that rural migrants are disproportionately, and often predominantly, absorbed into informal or casual work (Banerjee, 1983; Meng, 2001; Gagnon et al., 2009; Manning and Pratomo, 2013; Bundervoet, 2018). Exploiting drought-induced rural immigration in Brazil as plausibly exogenous variation in migrant inflows, Imbert and Ulyssea (2026) show that cities initially absorb migrants through informal employment, while formal firms and jobs expand only subsequently. The same sequencing appears in the Ethiopian data used in this paper. Section 5 documents the corresponding worker-level tenure gradient.

Taken together, this evidence motivates two distinct paid urban labor markets and an explicit, gradual, and incomplete transition between them. It also supports the baseline approximation that net rural-origin inflows enter informal employment. A particularly close spatial antecedent is Zárate (2022), who shows in a static metropolitan setting that transport infrastructure moves workers across the formal–informal boundary. I extend this margin to dynamic rural-to-urban migration across a national system of cities and make formalization itself an endogenous, congestible, and capacity-constrained transition.

This distinction changes the questions the model can answer. A one-market city cannot distinguish urbanization that reallocates workers into high-productivity employment from urbanization that primarily expands lower-productivity employment. This distinction is central to understanding the weak link between urbanization and structural transformation documented by Gollin et al. (2016), de Vries et al. (2015), and McMillan and Rodrik (2014).

From expected urban earnings to endogenous formalization. The evidence above establishes the importance of the informal-to-formal transition but does not explain what determines its speed in general equilibrium. The natural theoretical starting point is the dual-economy tradition. Lewis (1954) placed movement from traditional to modern employment at the center of development, while Harris and Todaro (1970) showed that migration responds to expected rather than current urban earnings. Fields (1975) adapted this logic to developing cities by allowing workers who have not secured formal employment to earn positive informal wages while continuing to search.

In the classical framework, access to formal employment is represented by a contemporaneous employment probability rather than an explicit transition technology. It summarizes the current allocation of formal jobs but does not explain how informal workers become formal over time, how firms and institutions govern that process, or how migration changes future formalization prospects. I retain the expected-earnings logic but make formalization dynamic and endogenous. A migrant values a city through informal earnings while waiting and formal earnings after probabilistic absorption, while the annual probability of crossing between the two markets depends on formal hiring capacity relative to the informal pool.

This dependence follows naturally from search and matching theory. A standard constant-returns matching technology implies that an informal worker's probability of finding a formal job rises with hiring capacity per worker seeking entry (Petrongolo and Pissarides, 2001). If effective hiring capacity scales with the formal sector, the transition rate can be written as

$$\frac{M_j}{L_j^I} = \mu_j \kappa_j^\alpha \left(\frac{L_j^F}{L_j^I} \right)^\alpha , \tag{1}$$

where M_j/L_j^I is the rate at which informal workers enter formal employment, μ_j captures matching efficiency, and κ_j maps formal employment into effective hiring capacity. Recruiting intensity and matching efficiency vary with firm behavior and labor-market conditions (Gavazza et al., 2018). Search frictions shape access to regular employment (Meghir et al., 2015; Franklin, 2018), while registration, compliance, and hiring decisions determine whether employment becomes formal (Ulyssea, 2018).

To incorporate this mechanism into a modern spatial general-equilibrium model, let $\lambda(\varphi_j)$ denote the annual probability that an informal worker in city j enters formal employment, where urban labor-market composition is summarized by

$$\varphi_j = \frac{L_j^I}{L_j^I + L_j^F}, \qquad 1 - \varphi_j = \frac{L_j^F}{L_j^I + L_j^F} = \frac{L_j^F / L_j^I}{1 + L_j^F / L_j^I}.$$

The formal share $1 - \varphi_j$ is therefore a bounded measure of the formal sector's scale relative to the informal pool it must absorb. At its core, the formalization hazard is

$$\lambda(\varphi_j) = \underline{\lambda} + (1 - \underline{\lambda})(1 - \varphi_j)^\theta, \tag{2}$$

where the floor $\underline{\lambda}$ keeps the hazard positive even in a city that is almost entirely informal.

The specification retains the matching logic. Because $1 - \varphi_j = (L_j^F / L_j^I)/(1 + L_j^F / L_j^I)$, the term $(1 - \varphi_j)^\theta$ corresponds to the matching hazard in equation (1) with $\alpha = \theta$, rescaled by $(1 + L_j^F / L_j^I)^{-\theta}$ so that the annual transition probability remains bounded by one at any capacity ratio. The key addition is the feedback missing from the classical expected-earnings framework. Migration expands the informal pool and lowers each worker's probability of formalization, while formalization shrinks that pool and raises the transition probability of those who remain. This feedback lets the model reproduce two patterns that a static employment lottery cannot. Migrants' formal-employment share rises with tenure and then plateaus (Section 5). Cross-city differences in informality persist rather than converge when capacity is weak (Section 6 and Appendix E.12).

The curvature parameter θ governs how strongly formal absorption deteriorates as the informal queue grows. It is a reduced-form formalization friction, or equivalently an inverse measure of formalization capacity, capturing three margins emphasized in the literature. The first is search and matching efficiency, including information, spatial search costs, and the ability of workers and employers to find one another (Petrongolo and Pissarides, 2001; Meghir et al., 2015; Franklin, 2018). The second is firm-side hiring capacity, including vacancy creation, recruiting, training, and the scale of firms capable of creating regular employment (Gavazza et al., 2018; La Porta and Shleifer, 2014). The third is administrative and regulatory capacity, including registration, compliance, enforcement, and the cost of converting informal relationships or enterprises into formal ones (Ulyssea, 2018). A high θ means these constraints bind tightly and a long queue drains slowly. A low θ means the formal sector absorbs a given informal pool more effectively. The model does not separate these three margins. θ summarizes their joint effect, so the quantification measures the value of relaxing the formalization bottleneck without identifying which margin binds or what relaxing it would cost. Appendix E.11 translates every value of θ used in the paper into annual formalization rates and expected waiting times and compares them with measured transition rates.

The full specification, given in Section 3.8, adds a saturation term and a low-informality brake to this core. These features capture the persistence of informal employment even after sustained development and the broader evidence that formalization is gradual and incomplete (La Porta and Shleifer, 2014; International Labour Organization, 2018; McCaig and Pavcnik, 2018; Ulyssea, 2018).

The data determine the quantitative strength of these forces, and the next section embeds the resulting hazard in a dynamic spatial equilibrium.

3 Model

The model is a recursive dynamic spatial general equilibrium with three labor markets, rural agriculture, urban informal employment, and urban formal employment. Its one non-standard element is that workers reach a city and its informal labor market in a single step but reach its formal labor market only through a congestible transition. Section 3.1 first isolates the central mechanism in a one-location illustration, while the remainder of the section builds the full spatial economy.

3.1 A one-location illustration

Consider the central mechanism in the simplest setting, a single rural region and one city. The example removes trade, housing, agglomeration, geography, and demographic change, and is used for illustration. A unit mass of workers is divided between rural and urban employment, $L^R + L^U = 1$, while the urban workforce is divided between informal and formal employment, with private informality share $\varphi = L^I/L^U$.

Rural workers produce with fixed land and earn $w^R(L^R) = (1-\alpha)A_R(L^R)^{-\alpha}$, so rural wages rise as workers leave the countryside. The city pays constant real wages $w^I < w^F$. New rural migrants enter informal employment and subsequently formalize at the core hazard of equation (2), $\lambda(\varphi) = \underline{\lambda} + (1-\underline{\lambda})(1-\varphi)^\theta$, without the saturation and brake terms that Section 3.8 adds. A larger informal pool relative to the formal sector lowers the probability that each informal worker is absorbed, and a higher θ strengthens this congestion effect. The value of entering the city discounts informal earnings while waiting and formal earnings after absorption,

$$\Pi^{I\to F} = \underbrace{\frac{w^I}{1-\beta\,[1-\lambda(\varphi)]}}_{\text{informal earnings while queuing}} + \underbrace{\frac{\beta\lambda(\varphi)}{(1-\beta)\,\{1-\beta\,[1-\lambda(\varphi)]\}}\,w^F}_{\text{formal earnings after absorption}}, \tag{3}$$

where β is the annual discount factor and the hazard is realized at the end of each period, so a migrant earns w^I for at least one full period. Section 3.8 generalizes this value to the full spatial setting.

Let a fraction δ of formal workers leave formal employment each period and be replaced by informal entrants, a simplistic stand-in for the migrant and demographic inflows that replenish the informal pool endogenously in the full model. Urban composition is stationary when formalization offsets this turnover:

$$\delta(1-\varphi^*) = \lambda(\varphi^*)\varphi^*, \qquad \varphi^* = \frac{\delta}{\delta + \lambda(\varphi^*)}. \tag{4}$$

This condition has a simple interpretation. Turnover replenishes the informal queue, while formalization drains it. A higher θ lowers the formalization hazard and raises stationary informality along a given equilibrium branch.

The stationary condition is nonlinear in φ^* and admits multiple steady states once the friction is strong enough. At a critical curvature θ^*, a stable high-informality steady state, the informality trap, and an intermediate unstable steady state appear together. The low-informality transformation equilibrium itself vanishes in a fold at a higher threshold. Panel (b) of Appendix Figure 9 traces φ^* against θ and shows this fold. At the illustrative calibration ($\delta = 0.12$, $\underline{\lambda} = 0.015$) the economy is bistable for $\theta \in (2.6, 3.7)$, a window that contains the calibrated baseline value of 3.25 (Section 6.3). Because both flows in equation (4) scale with urban population, both thresholds depend only on the turnover rate δ and the hazard floor $\underline{\lambda}$. Migration determines the size and cost of the trap, not its existence. In the calibrated spatial model the corresponding reversal in the formalization feedback occurs near $\theta \approx 4$ (Section 7.2), because saturation, the brake, endogenous inflows, and cross-city heterogeneity all move the boundary. The illustration establishes that a trap exists and what generates it, not where it lies. Appendix C.11 derives the tangency conditions and stability properties.

The stationary informality share is therefore determined separately from city size. The composition condition determines φ^*, while spatial mobility equates the rural wage with the annuitized value of entering the city and thereby determines L^U. This separation is the source of the model's urbanization–formalization asymmetry. A city can continue attracting workers even when weak formalization capacity leaves most of its employment informal.

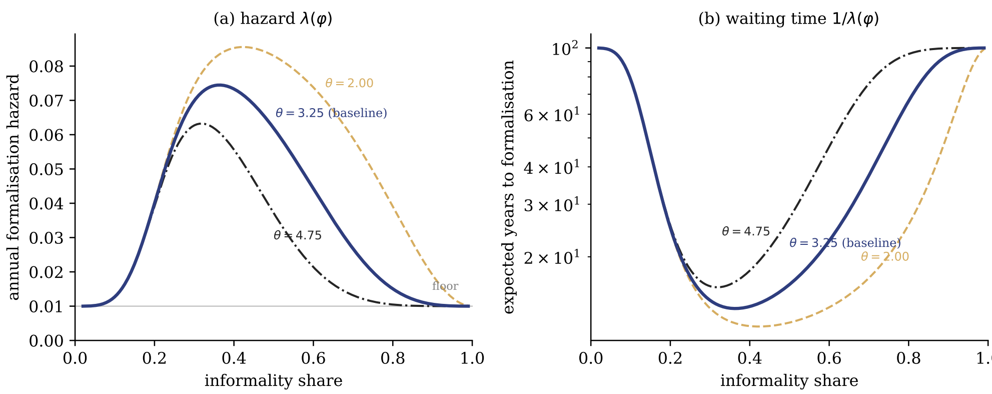


Figure 1: Weaker formalization capacity, a higher θ, lowers the annual formalization hazard and lengthens the expected wait for a formal job.

Notes: Panel (a) plots the annual formalization hazard and panel (b) the implied expected waiting time, $1/\lambda(\varphi)$. Higher θ lowers formalization and lengthens informal spells in high-informality cities. The panels plot the full hazard of equations (28)–(29) in Section 3.8, whose saturation and brake terms generate the non-monotonicity at low informality shares. The core hazard of equation (2) is monotone. Other hazard parameters are held at their calibrated values. The waiting times in panel (b) can be read directly against the measured transition evidence in Appendix E.11.

The example isolates the feedback operating in the quantitative model and the point at which it departs from Harris–Todaro, where a single expected-wage condition with fixed odds of formal work sets both composition and city size. Formal employment creates an option value that attracts migrants, but informal entry enlarges the queue, lowers the formalization hazard, and weakens that same option value. The turnover rate δ has no counterpart in the full model, which contains no flow from formal back to informal employment and instead replenishes the informal pool through endogenous migration and demographic inflows. The trap logic therefore does not depend on exogenous turnover. It requires only that inflows replenish the pool faster than the hazard drains it. Appendix C.11 derives the mobility condition, comparative statics, Harris–Todaro limiting case, and nonlinear equilibrium properties.

3.2 Environment

The economy consists of $N = N_R + N_U$ locations and evolves in annual periods indexed by t. Rural locations, indexed by i, produce an agricultural good A. Urban locations, indexed by j, contain private informal workers (I), private formal workers (F), and government workers (G). I use ℓ for a generic location and $k \in \{A, I, F, G\}$ for sectors.

Agricultural and formal goods are differentiated by origin and traded domestically and internationally subject to iceberg costs. Informal goods are nontradable across cities and clear within local urban market areas, including demand from their rural hinterlands.

At the beginning of period t, the predetermined state is

$$\mathcal{S}_t = \left\{ L^A_{i,t},\ L^I_{j,t},\ L^F_{j,t},\ L^G_{j,t},\ H^U_{j,t} \right\}.$$

Conditional on $\mathcal{S}_t$, the within-period equilibrium determines prices, wages, rents, and trade flows. Demographics, migration, formalization, government employment, housing adjustment, and changes in fundamentals then map $\mathcal{S}_t$ into $\mathcal{S}_{t+1}$.

3.3 Technology

Production combines labor with a spatial factor, rural land or urban built surface, using Cobb–Douglas technology. Rural land H^R_i is fixed. Urban built surface H^U_j is predetermined within each period.

Rural production. Rural location i produces

$$Y^A_i = A^A_i \zeta^A_i (L^A_i)^{1-\alpha_A} (H^R_i)^{\alpha_A}, \tag{5}$$

where A^A_i is persistent local productivity, ζ^A_i is a time-varying agricultural shock, and α_A is the land share. Location productivity A^A_i is recovered by model inversion rather than treated as a free parameter, as Section 6 and Appendix C.8 describe.

Urban informal production. Informal firms combine labor with built surface:

$$Y^I_j = A^I_j (L^I_j)^{\eta_I} (L^I_j)^{1-\alpha_I} (H^I_j)^{\alpha_I}, \tag{6}$$

where $(L_j^I)^{\eta_I}$ captures agglomeration through thicker input markets, customer proximity, and denser local supply networks. The share α_I is interpreted as a composite return to built surface and movable capital used by small urban enterprises (De Mel et al., 2008).

Urban formal production. Formal firms produce

$$Y_j^F = A_j^F \mathrm{MA}_j^{\eta_{MA}} (L_j^F + L_j^G)^{\kappa_F} (L_j^F)^{1-\alpha_F} (H_j^F)^{\alpha_F}, \tag{7}$$

where $(L_j^F + L_j^G)^{\kappa_F}$ captures agglomeration through the combined private formal and government employment base, including shared regulatory infrastructure, knowledge spillovers, and procurement networks. Market access is $\mathrm{MA}_j = (1/\tau_j^g)/\overline{\mathrm{MA}}$, normalized inverse access to the international gateway, and η_{MA} governs its effect on formal productivity.

Wages. Under perfect competition, sectoral wages satisfy

$$w_\ell^k = q_\ell^k (1-\alpha_k) \frac{Y_\ell^k}{L_\ell^k}, \qquad k \in \{A, I, F\}, \tag{8}$$

where $q_i^A = p_i^A$, $q_j^I = P_j^I$, and $q_j^F = p_j^F$ are origin prices. Wages therefore equal physical marginal products valued where output is produced rather than at delivered consumer prices. Rural land rents and the allocation of urban built surface are derived in Appendix C.2.

Fixed rural land makes outmigration raise rural wages. In cities, informal agglomeration raises productivity, but greater informal supply lowers local prices and tightens space constraints, so real informal earnings may still fall.

3.4 Preferences

Households have nested preferences. The upper tier is a nonhomothetic CES aggregator over food and an urban composite, following Comin et al. (2021); Conte (2024). The lower tier is a homothetic CES aggregator over informal and formal urban goods. Nonhomotheticity generates demand-side structural transformation, since expenditure shifts from food toward urban goods as real income rises even at unchanged relative prices.

This structure is not a modeling convenience. Ethiopian households devote roughly three-quarters of total expenditure to food, and the decline of that share as incomes rise is the demand-side engine of structural transformation (Comin et al., 2021). The Stone–Geary subsistence term bounds food consumption from below, capturing the priority of food needs at low incomes, so productivity gains translate into demand for urban goods only once subsistence is met. Both nonhomotheticity parameters are estimated from Ethiopian Engel curves rather than imposed (Section 6), and Section 10 shows the structure is genuinely load-bearing. With homothetic demand the model cannot reproduce the observed urban premium.

Upper tier. Let P_A and P_U denote the local agricultural and urban composite price indices, and define subsistence expenditure as $\tilde{v} = \max\{v^{\text{goods}} - \bar{c}_A, 1\}$. Suppressing location subscripts, the aggregate price index P is defined implicitly by

$$\mu_A \left(\frac{P_A}{P}\right)^{1-\rho+e_A} \left(\frac{\tilde{v}}{P}\right)^{e_A} + \mu_U \left(\frac{P_U}{P}\right)^{1-\rho+e_U} \left(\frac{\tilde{v}}{P}\right)^{e_U} = 1, \tag{9}$$

where ρ is the substitution elasticity, e_A and e_U govern nonhomotheticity, and $\bar{c}_A$ is a Stone–Geary food subsistence requirement. Setting $e_A = e_U = 0$ yields the homothetic case. The implied demand system is derived in Appendix C.3.

Lower tier. Informal goods are non-tradable, so the local consumption basket must track the composition of local supply. The informal weight therefore scales the reference expenditure weight $\bar{\omega}_I$, measured in the household survey, by the city's demand-relevant informality share relative to a reference value φ_{ref}. The urban composite price index is

$$P_j^U = \left[\omega_j^I (P_j^I)^{1-\nu} + \omega_j^F (P_j^F)^{1-\nu}\right]^{1/(1-\nu)}, \qquad \omega_j^I = \bar{\omega}_I \frac{\varphi_j^D}{\varphi_{\text{ref}}}, \qquad \omega_j^F = 1 - \omega_j^I. \tag{10}$$

Here ν is the within-urban substitution elasticity and $\varphi_j^D = L_j^I/(L_j^I + L_j^F + L_j^G)$ is the demand-relevant informality share. The reference value φ_{ref} is the population-weighted mean of φ_j^D across cities in the anchor year, so a city at the reference composition places weight $\bar{\omega}_I$ on informal goods. Unlike the private informality share φ_j governing formalization, φ_j^D includes government employment.[1]

Expenditure shares. Expenditure shares are

$$s_A = \mu_A \left(\frac{P_A}{P}\right)^{1-\rho+e_A} \left(\frac{\tilde{v}}{P}\right)^{e_A}, \qquad s_U = 1 - s_A, \qquad s_I = s_U \omega_j^I \left(\frac{P_j^I}{P_j^U}\right)^{1-\nu}. \tag{11}$$

[1]Government workers consume but do not produce a separate good. Their contribution to economic activity enters through local productivity, formal sector agglomeration, and the reduced form institutions governing formalization.

The formal share is the residual, $s_F = s_U - s_I$. Food consumption is $C_A = \bar{c}_A/P_A + s_A\tilde{v}/P_A$, so the subsistence requirement bounds food demand below. Rural households access informal goods through their associated urban center, with residual urban expenditure allocated to formal goods.

3.5 Prices and trade

Local prices are jointly determined by production, demand across the domestic spatial economy, and access to world markets.

Domestic trade. For each tradable sector $k \in \{A, F\}$, delivering one unit from origin ℓ to destination m requires shipping

$$\tau_{\ell m} = \left(1 + \frac{d_{\ell m}}{d_{\text{ref}}}\right)^{\eta_{tr}}, \tag{12}$$

where $d_{\ell m}$ is the travel time and η_{tr} is the time elasticity of trade costs. Urban destinations additionally face a retail margin on agricultural goods that captures food market intermediation (Minten et al., 2014).

Additionally, Armington weights increase with the scale of production:

$$\omega_\ell^A \propto (L_\ell^A)^{\gamma_v}, \qquad \omega_\ell^F \propto (L_\ell^F + L_\ell^G)^{\gamma_v}, \tag{13}$$

where γ_v is the variety elasticity. These weights govern how much of national demand each origin can serve. With equal weights, every location would supply an equally valued variety regardless of size, forcing demand toward small producers and understating the observed concentration of production. Scaling weights with employment follows the variety logic of Krugman (1980) and allows formal production to concentrate in a small number of large cities, as it does in the data. Urban population is heavily concentrated in Addis Ababa and a few large cities, while the private informality share is nearly flat across city-size terciles (Appendix B). Private formal employment is therefore concentrated in the largest cities.

The domestic component of the price index is

$$\mathcal{D}_m^k = \sum_\ell \omega_\ell^k \left(\tau_{\ell m} p_\ell^k\right)^{1-\sigma_k}, \qquad k \in \{A, F\}, \tag{14}$$

where p_ℓ^k is the origin mill price and σ_k is the elasticity of substitution across origins. I discipline σ_A and σ_F using the agricultural and manufacturing trade evidence in Donaldson (2018) and Broda and Weinstein (2006).

Informal market clearing. Informal goods do not trade across cities and clear within local urban market areas:

$$Y_j^I = C_j^I, \tag{15}$$

where C_j^I includes demand from city residents and the associated rural hinterland. This condition determines the local informal price P_j^I, transmitting changes in informal supply and local demand into informal earnings.

International gateway. All international trade is routed through a single gateway g, following Coşar and Fajgelbaum (2016). The iceberg cost of reaching the gateway from location ℓ is

$$\tau_\ell^g = \left(1 + \frac{d_{\ell g}}{d_{\text{ref}}}\right)^{\eta_{tr}}, \tag{16}$$

so proximity to the gateway lowers both import and export costs. Adding the rest of the world variety to domestic demand gives

$$P_m^k = \left[\mathcal{D}_m^k + \omega_{\text{world}}^k \left(\tau_m^g p_k^{\text{world}}\right)^{1-\sigma_k}\right]^{1/(1-\sigma_k)}, \qquad k \in \{A, F\}. \tag{17}$$

The same gateway distance also enters formal productivity through MA_j in equation (7).

International trade bands and cash crops. Because the gateway cost must be paid in either direction, each location faces a corridor of prices within which it neither imports nor exports. It exports when its mill price falls below the world price net of the cost of reaching the gateway, and it imports when its mill price rises above the delivered import price. Inside the corridor, which is the Samuelson band, international flows are zero and domestic clearing sets the mill price (Samuelson, 1954; Coşar and Fajgelbaum, 2016). Outside it, trade quantities respond linearly to the price gap rather than closing it at once, and formal goods respond more strongly than agricultural goods. An agricultural export cap captures thinner markets and limited export infrastructure. A small set of exogenously designated locations may additionally export a capped share of agricultural output at crop-specific world prices, so that concentrated high-value cash-crop exports coexist with widespread net imports of basic food without separate crop markets. Appendix C.4 states the band equations and the cash-crop premium.

Market clearing and price determination. For each tradable sector, origin supply and imports equal domestic demand and exports:

$$S_\ell^k + M_\ell^{k,\text{imp}} = \sum_m D_{\ell m}^k + X_\ell^{k,\text{exp}}, \qquad k \in \{A, F\}, \tag{18}$$

where agricultural exports include both basic and cash-crop quantities.

International trade need not balance period by period. The aggregate net export position implied by the band flows, NX_t, is returned to households as an equal per-capita income component in the within-period equilibrium (Section 3.7), so external surpluses or deficits are absorbed through household income rather than through an economy-wide balancing restriction on prices. Domestic markets, by contrast, clear exactly. Equation (18) holds for every origin, and informal goods clear locally through equation (15).

3.6 Housing

Housing expenditure. Urban households devote a city-size-dependent share of income to housing:

$$s_j^H = \min\left\{\omega_H \left(\frac{L_j}{L^{\text{ref}}}\right)^{\psi_H}, s_{\text{cap}}^H\right\}, \qquad v_j^{\text{goods}} = v_j^U(1 - s_j^H), \tag{19}$$

where ω_H is the housing share at the reference city size, ψ_H is its city-size elasticity, s_{cap}^H is an upper bound, and $L^{\text{ref}} = \sum_\ell L_\ell^2 / \sum_\ell L_\ell$ is the employment-weighted mean location size. The expenditure rule is a reduced form for housing demand facing rents that rise with city size under gradually adjusting supply (Combes et al., 2019). Its parameters are taken from the literature and calibrated rather than derived (Section 6). Deducting housing expenditure before goods consumption creates a cost-of-living wedge that rises with city size. Because the same measure of urban scale also drives agglomeration, the specification disciplines the benefits and costs of city growth jointly.

The stock of urban built surface is predetermined within the period but adjusts endogenously between periods. Its law of motion is specified in Section 3.8.

3.7 Within-period equilibrium and solution

Conditional on the inherited state $\mathcal{S}_t$ and current fundamentals, the conditions above determine the period-t spatial equilibrium. Worker populations and the stock of urban built surface are fixed within the period, while outputs, wages, rents, prices, expenditure allocations, and trade flows adjust until firms and households satisfy their optimality conditions, informal goods clear within local market areas, agricultural and formal goods clear across domestic and international markets, and urban built surface is allocated across productive uses.

Per-capita income combines labor earnings, spatial-factor rents, and an equal per-capita allocation of the aggregate trade balance:

$$v_{i,t}^{R} = \frac{w_{i,t}^{A} L_{i,t}^{A} + r_{i,t}^{R} H_{i}^{R}}{L_{i,t}^{A}} + \frac{\mathrm{NX}_t}{L_t^{\mathrm{tot}}}, \tag{20}$$

$$v_{j,t}^{U} = \frac{w_{j,t}^{I} L_{j,t}^{I} + w_{j,t}^{F} L_{j,t}^{F} + w_G L_{j,t}^{G} + r_{j,t}^{U} H_{j,t}^{U}}{L_{j,t}} + \frac{\mathrm{NX}_t}{L_t^{\mathrm{tot}}}, \tag{21}$$

where $L_t^{\mathrm{tot}} = \sum_\ell L_{\ell,t}$. Urban built surface is allocated such that $H_{j,t}^{I} + H_{j,t}^{F} = H_{j,t}^{U}$. Because the equilibrium is homogeneous of degree one in nominal prices, one formal mill price is fixed as the computational numeraire. Reported prices are subsequently rescaled so that the population-weighted formal price aggregate equals one.

The model solves jointly for origin prices, informal prices, and urban spatial allocations. Appendix C.9 describes the equilibrium system and numerical algorithm. Appendix D details the solver implementation and the between-period operator. The resulting real incomes and local labor-market conditions govern the between-period transition from $\mathcal{S}_t$ to $\mathcal{S}_{t+1}$.

3.8 Between-period dynamics

The model moves recursively from one spatial equilibrium to the next. Given the wages, prices, and real incomes determined in period t, demographic change first updates the population of each location. Workers then choose whether and where to migrate using destination values, amenities, and bilateral moving costs. These values incorporate the formalization hazard implied by the inherited private employment composition. Incumbent informal workers formalize at this hazard, while migrant inflows are assigned across sectors according to the origin-specific entry rules. Productivity and government employment subsequently evolve, and urban built surface adjusts with a lag to the new city population. These updates determine $\mathcal{S}_{t+1}$, conditional on which the next within-period equilibrium is solved.

Demographics. Natural population growth converges smoothly from its observed base-year rate toward a long-run floor:

$$n_\ell(t) = n_\ell^{\mathrm{floor}} + \left(n_\ell^{\mathrm{base}} - n_\ell^{\mathrm{floor}}\right)\left[1 - \Lambda\left(k_{\mathrm{demog}}\left(t - t_\ell^{\mathrm{mid}}\right)\right)\right], \tag{22}$$

where $\Lambda(x) = (1 + e^{-x})^{-1}$ is the logistic function, t_ℓ^{mid} is the transition midpoint, and k_{demog} governs its speed. Rural and urban locations follow different transition paths, disciplined by international demographic projections as described in Section 6.

Migration values. After demographic change, workers in every location evaluate alternative destinations using the wages and prices determined in the period-t equilibrium. Entry into an urban labor market depends on the worker's origin. In the baseline, rural migrants enter informal employment and can move into formal employment only subsequently through the formalization hazard. Urban arrivals instead enter informal or formal employment with probabilities equal to the destination's current private employment shares, $\varphi_{j,t}$ and $1-\varphi_{j,t}$[2].

Let real disposable urban earnings be

$$\widetilde{w}^k_{j,t} = (1-s^H_{j,t})\frac{w^k_{j,t}}{P_{j,t}}, \qquad k \in \{I, F\}. \tag{23}$$

Valuing current equilibrium earnings as a perpetuity, the value of a rural destination is

$$\Pi^R_{i,t} = \frac{\widetilde{w}^A_{i,t}}{1-\beta}, \qquad \widetilde{w}^A_{i,t} = \frac{w^A_{i,t}}{P_{i,t}}, \tag{24}$$

whereas the value of entering the informal sector of city j generalizes the one-location value in equation (3):

$$\Pi^{I\to F}_{j,t} = \underbrace{\frac{\widetilde{w}^I_{j,t}}{1-\beta(1-\lambda_{j,t})}}_{\text{informal earnings while queuing}} + \underbrace{\frac{\beta\lambda_{j,t}}{(1-\beta)\left[1-\beta(1-\lambda_{j,t})\right]}\widetilde{w}^F_{j,t}}_{\text{formal earnings after absorption}}. \tag{25}$$

The first term is the expected value of informal earnings while queuing, while the second is the discounted claim on formal earnings after absorption.[3] When formalization is slow, migration responds primarily to informal earnings. When it is fast, the formal wage becomes an important component of urban value. For an urban arrival, the destination value is the corresponding expectation over informal entry, valued by $\Pi^{I\to F}_{j,t}$, and direct formal entry, valued by $\widetilde{w}^F_{j,t}/(1-\beta)$, with probabilities $\varphi_{j,t}$ and $1-\varphi_{j,t}$. Government wages do not enter migration values because workers cannot choose government employment.

Location choice. Workers choose among domestic destinations according to a multinomial logit over origin-specific destination values, amenities, and bilateral moving

[2] A robustness exercise allows a share of rural migrants to enter formal employment directly.

[3] Equation (25) embeds the timing convention that the formalization hazard is realized at the end of each period. An entrant earns the informal wage for at least one full period, and formal earnings begin in the period after formalization. Appendix C.6 derives the expression under this convention, which is also the convention implemented in the computational model.

costs:[4]

$$\pi_{\ell\to m,t} = \frac{\exp\left\{\vartheta\left[\log \Pi_{\ell m,t} + \gamma a_{m,t} - \log C_{\ell m,t}\right]\right\}}{\sum_n \exp\left\{\vartheta\left[\log \Pi_{\ell n,t} + \gamma a_{n,t} - \log C_{\ell n,t}\right]\right\}}, \tag{26}$$

where $\Pi_{\ell m,t}$ incorporates the entry rule associated with origin ℓ and destination m, ϑ governs responsiveness to differences in destination attractiveness, and $a_{m,t}$ is the destination amenity with loading γ. Amenities capture residual local attractiveness not explained by wages, prices, housing expenditure, formalization prospects, or migration costs. The baseline component $\hat{a}m$ is recovered through a mean centered Sinkhorn fixed point that matches predicted destination populations to their observed values at the calibration transition. Amenity values then evolve as $am, t = \hat{a}_m + \mathbf{1}m \in Ug_a(t - t_0)$, where g_a captures gradual improvements in urban infrastructure, public services, and technology. The loading γ is normalized to one. I discipline the drift so that changing amenities account for roughly 15 percent of projected urbanization. This places amenities as a meaningful but secondary driver of migration, consistent with evidence that amenity differences affect internal migration and account for a nontrivial share of observed mobility (Morrison and Clark, 2011; Bryan and Morten, 2019). Appendix C.8 provides the inversion algorithm and Section 6 describes the calibration.

Bilateral moving costs are

$$C_{\ell m,t} = \left(\kappa_{\text{fixed}} + \kappa_{\text{dist}} d_{\ell m}^{\eta_d}\right)\left(\frac{L_{m,t}}{L_t^{\text{ref}}}\right)^{-\kappa_s}, \qquad C_{\ell\ell,t} = 1, \tag{27}$$

where κ_{fixed} captures relocation, information, network, and liquidity costs, while $\kappa_{\text{dist}} d_{\ell m}^{\eta_d}$ captures the additional cost of distance (Morten and Oliveira, 2024). The destination-size term captures lower migration costs to larger locations through denser migrant networks, better information, and more frequent and therefore cheaper public transport connections.[5]

Formalization. Define the private informality share, excluding government employment, as

$$\varphi_{j,t} = \frac{L_{j,t}^I}{L_{j,t}^I + L_{j,t}^F}.$$

[4]The baseline abstracts from international migration, so all location choice is domestic.

[5]The model permits sequential moves. Workers re-optimize every period and face no restriction on onward migration, and urban arrivals enter destination labor markets according to current employment shares, so a worker may move from a remote origin to a nearby secondary city and onward to a larger destination later. Whether such a stepwise path is chosen depends on the trade-off between the fixed cost of each move and the convexity of the distance cost. The census migration matrix used in calibration records origin and current residence and therefore aggregates over intermediate steps.

The annual probability that an informal worker becomes formal is

$$\lambda(\varphi_{j,t}) = \underline{\lambda} + \frac{(1-\underline{\lambda})(1-\varphi_{j,t})^{\theta}}{1+\psi_{\text{eff}}(\varphi_{j,t})(1-\varphi_{j,t})^{\theta}}, \tag{28}$$

$$\psi_{\text{eff}}(\varphi_{j,t}) = \psi_0 \left[1 + \left(\frac{\varphi_c}{\varphi_{j,t}}\right)^{\zeta_{\text{brake}}}\right]. \tag{29}$$

When the formal sector is small relative to the informal pool it must absorb, each informal worker faces a low probability of crossing into formal employment. The parameter θ governs how sharply absorption deteriorates as the queue lengthens and is the paper's central reduced-form formalization friction, summarizing the search, hiring, training, registration, and enforcement margins set out in Section 2.[6]

Setting $\psi_0 = 0$ recovers the core hazard of equation (2). The denominator imposes diminishing returns to formal capacity and caps annual formalization throughput, with ψ_0 governing the strength of this constraint. The adaptive brake raises ψ_{eff} once informality falls below φ_c, preventing the informal sector from disappearing mechanically, while the floor $\underline{\lambda}$ prevents highly informal cities from becoming absorbing states. Appendix C.7 derives the limits and comparative statics, and Section 3.1 illustrates the implied hazard and waiting times.

The hazard depends on the private share $\varphi_{j,t}$ rather than the demand-relevant share $\varphi^{D}_{j,t}$ in equation (10). Government workers contribute to demand and formal-sector agglomeration but belong neither to the informal queue nor to the private formal sector that absorbs it. These migration and formalization flows determine the private employment stocks carried into the next period.

Private employment stocks. Let $\Delta M^{I}_{j,t}$ and $\Delta M^{F}_{j,t}$ denote net migration into the two private urban sectors after applying the origin-specific entry rules. The stock equations below are applied after the demographic update. I suppress a separate post-demographic superscript for readability. Formal and informal employment then evolve as

$$L^{F,\text{preG}}_{j,t+1} = L^{F}_{j,t} + \lambda(\varphi_{j,t})L^{I}_{j,t} + \Delta M^{F}_{j,t}, \tag{30}$$

$$L^{I,\text{preG}}_{j,t+1} = \left[1-\lambda(\varphi_{j,t})\right] L^{I}_{j,t} + \Delta M^{I}_{j,t}. \tag{31}$$

Entry follows the origin-specific rules stated in the migration block above.[7]

[6]The model abstracts from explicit formal-firm entry, vacancy posting, and capital accumulation. Their contribution to formal absorption is summarized by the formalization hazard.

[7]The superscript preG denotes stocks before the subsequent government-employment adjustment. The associated movements between private and government employment are described in Appendix C.10.

These stock equations make the model's central asymmetry transparent. Rural migration expands urban population immediately but initially adds to informal employment. Formal employment rises only through subsequent absorption, so urbanization can outpace formalization while a growing informal pool weakens future formalization prospects.

Productivity drift. After migration and formalization determine private employment, sectoral productivity evolves for the next period. For $s \in \{A, I, F\}$, the sectoral growth rate converges from its initial value toward a long-run rate:

$$g_s(t) = g_s^{\text{long}} + \left(g_s^{\text{init}} - g_s^{\text{long}}\right) \exp\left[-\lambda_d(t - t_0)/10\right], \tag{32}$$

where λ_d governs convergence and t_0 is the base year (Barro and Sala-i Martin, 1992). Agricultural productivity initially grows faster as it catches up from a low base but converges to a lower long-run rate than urban productivity, preserving a permanent nonagricultural growth premium. Section 6 reports the corresponding growth rates.

Government employment. Government employment is updated after private labor-market transitions. Its target share of the local formal employment pool is

$$g_{j,t+1} = \beta_0 + \beta_{\text{pop}} \log L_{j,t+1} + \beta_{\text{cap}} \mathbf{1}\{j \text{ is the capital city}\}, \tag{33}$$

where $g_{j,t+1} = L^G_{j,t+1}/(L^F_{j,t+1} + L^G_{j,t+1})$, $\beta_{\text{pop}} < 0$ allows the government share to decline with city size, and β_{cap} captures the concentration of public employment in the administrative center. The implied adjustment reallocates workers between private and government employment, with the accounting detailed in Appendix C.10. Government workers earn a spatially uniform wage w_G, consume but do not produce a separate good, and enlarge the formal agglomeration base in equation (7).[8]

Housing adjustment. After population and employment have been updated, urban built surface adjusts with a lag to the new city size:

$$\log H_j^U(t+1) = b_0 + a_j + b_1 \log L_j(t+1) + \varrho \log H_j^U(t), \tag{34}$$

where b_0 is a common intercept, a_j is a location fixed effect, b_1 is the impact elasticity with respect to city size, and ϱ governs persistence. The implied long-run supply

[8]The model contains no explicit fiscal sector. Government wages enter local income in equation (21) without a modeled tax counterpart. This reduced-form treatment is innocuous in the baseline, where the government share follows its estimated relationship with city size, but it matters for interpreting the public-employment counterfactual, which Section 8 accordingly flags as an uncosted employment experiment rather than a financed fiscal policy.

elasticity is $b_1/(1-\varrho)$, calibrated below unity in line with evidence on constrained urban housing supply (Saiz, 2010). Because built surface responds only gradually, rapid urban growth temporarily raises employment relative to available space and tightens the urban spatial constraint. Appendix C.5 provides the derivation and implementation.

Recursive equilibrium. Suppressing exogenous drivers for notation, the model alternates between the within-period equilibrium operator $\mathcal{E}$ and the transition operator $\mathcal{T}$:

$$\mathcal{E}_t = \mathcal{E}(\mathcal{S}_t), \qquad \mathcal{S}_{t+1} = \mathcal{T}(\mathcal{S}_t, \mathcal{E}_t). \tag{35}$$

Given the initial state, parameters, and paths of exogenous fundamentals, a recursive competitive equilibrium is the sequence $\{\mathcal{S}_t, \mathcal{E}_t\}_{t=0}^{T}$ satisfying these two conditions in every period. Markets clear conditional on the inherited state, while migration values current equilibrium earnings and formalization prospects rather than a perfect-foresight path of future prices. Migration nevertheless has forward consequences because it changes the state on which the next spatial equilibrium is solved. Appendix C.10 provides the complete transition accounting and solution algorithm.

4 Setting and Data

The model of Section 3 is general and applies to all settings in which segmented labor markets separate location from access to earning opportunities. This section and the next introduce the economy to which it is applied in this paper. Ethiopia provides a particularly sharp setting for the model. The country remains roughly three-quarters rural, is urbanizing quickly, and absorbs much of that growth into informal work. Ethiopia is Africa's second most populous country and one of the region's fastest growing economies, yet its structural transformation remains incomplete. In 2025, only about 24 percent of the population lived in urban areas, despite rapid urban population growth (World Bank, 2026, 2025). The model's stricter satellite-based city definition implies an even lower share (Section 6). Urbanization in Ethiopia and the reallocation of labor into formal, higher-productivity employment have proceeded more slowly than the classical pattern of structural transformation would suggest (Kuznets, 1973). As documented in more detail in Section 5, urbanization has lagged the large rural–urban earnings gap, while high rural population growth continues to expand the pool of potential migrants. Ethiopia is great example where a countries limited formalization capacity slows the national transition into regular urban employment.

Equally important, Ethiopia offers unusually rich data for disciplining a spatial model at this resolution. I combine a twenty-one-year panel of satellite and gridded geospatial inputs for 2000–2020, covering population, built-up surface, vegetation, temperature, and precipitation, with restricted-access microdata from the Ethiopian Central Statistical Agency (CSA),[9] public administrative records, repeated demographic and agricultural surveys, and price as well as output data from the National Bank of Ethiopia. This section describes the spatial framework and principal data sources. Appendix A documents their construction, harmonization, and validation.

4.1 Spatial units and urban boundaries

The spatial framework partitions Ethiopia into 681 units, 126 urban and 555 rural, which together cover 99.8 percent of national territory (mapped in Appendix A). Urban boundaries are constructed using a dual-threshold classification. A pixel is classified as urban only if it has both a population density of at least 1,250 persons per km^2, adapted from the metropolitan criterion in OECD (2012), and a GHSL built-up surface share of at least 25 percent (Angel et al., 2016). Connected qualifying pixels define city footprints. Requiring both conditions limits false positives from either measure alone, particularly in the densely settled agricultural highlands of the Southern Nations region.

Three further adjustments keep the classification consistent over time, a Voronoi partition that prevents neighboring cities from absorbing one another as they expand, a monotonic boundary rule that removes year-to-year raster noise, and a census-anchored delineation for four cities in the Southern Nations region where the dual threshold overreaches. Appendix A documents the delineation procedure, the population calibration underlying the rasters, and these manual adjustments.

For the equilibrium computation, I aggregate the 681 units to 121 locations, comprising 43 urban and 78 rural locations. Urban locations with fewer than 15,000 inhabitants are merged with their nearest neighboring unit, while rural units are aggregated to administrative zones. Very small Ethiopian towns rarely have labor markets large enough to identify separate informal and formal segments, so the aggregation improves measurement of the labor-market composition central to the paper while preserving spatial variation in wages and housing costs and keeping the annual equilibrium system tractable. Appendix A provides the aggregation rule and spatial crosswalk.

4.2 Data sources

The empirical framework integrates 47 raw datasets spanning three broad groups, namely remote sensing and geospatial records, restricted survey microdata, and publicly available administrative and institutional data. Together, they provide the labor-market,

[9] I am grateful to the Ethiopian Central Statistical Agency and Dr. Tigist Bekele for their cooperation and generous access to restricted microdata on labor markets, prices, agriculture, and household conditions.

agricultural-productivity, migration, housing, demographic, trade-cost, and macroeconomic measures used to discipline the model. Table 1 summarizes the principal inputs, while Appendix Table 8 reports the complete inventory, coverage, and role of each source.

Remote sensing and geospatial data. The Global Human Settlement Layer (GHSL) provides built-up surface measures at 100-meter resolution for 2000–2020, which enter both the delineation of urban boundaries and the housing-stock panel (Pesaresi and Politis, 2023). WorldPop constrained rasters provide spatially disaggregated population counts, which I recalibrate to match national census totals. MODIS vegetation indices, CHIRPS precipitation, and ERA5 temperature data measure annual agricultural conditions (Funk et al., 2015). OpenStreetMap and Ethiopian Roads Authority networks provide bilateral road distances, from which I construct the travel times underlying domestic trade costs and market access using the travel-cost function in Tobler (1993).

Survey microdata. The restricted CSA Urban Employment and Unemployment Survey (UEUS), comprising eleven waves between 2003 and 2018, is the principal source for urban labor-market outcomes. It provides wages by employment status, the allocation of employment among private informal, private formal, and government work, and tenure–formality profiles for approximately 76 survey zones. The CSA Informal Sector Survey supplies an external benchmark for own-account earnings. The Agricultural Sample Survey (AgSS) reports crop production, prices, cultivated area, and yields, while the Ethiopian Socioeconomic Survey (ESS) provides household consumption, food expenditure shares, crop own-consumption, and independent migration-validation moments. Bilateral migration patterns are constructed from the Labour Force Survey and the 2007 Population and Housing Census.

Demographic, price, and national-accounts data. Demographic and Health Survey waves from 2000, 2005, 2011, and 2016 provide fertility, child mortality, and age and sex distributions separately for rural and urban residents (CSA and ICF, 2016). A monthly consumer price index from FAOSTAT, cross-validated against the World Bank series and rebased to the National Bank of Ethiopia's 2010/11 national-accounts base year, expresses nominal values in constant 2010/11 birr. The 2004/05 Household Income, Consumption and Expenditure Survey supplies the national food expenditure share used to discipline the nonhomothetic preference system. National Bank of Ethiopia sectoral accounts provide the agricultural and nonagricultural value-added totals used to construct spatially disaggregated output measures.

Labor market measurement. I classify UEUS employment as formal or informal using establishment registration and contract status, following the status-based approximation recommended when the complete ILO decision rule cannot be implemented with the available survey variables (International Labour Organization, 2018). The resulting urban informality shares closely track the corresponding ILOSTAT estimates, and the classification rule is held fixed across locations and years.

The formal wage measure includes private formal employment only. Government wages display little spatial variation and are treated separately, consistent with the government-employment block of the model. Informal earnings combine observed employee wages with own-account income benchmarked to the Informal Sector Survey. All earnings are cleaned, annualized, spatially deflated, and expressed in constant 2010/11 birr. Table 16 reports the resulting sectoral wage moments.

Table 1: Overview: Data inputs

Data sources	Use case
Panel A. Remote sensing and geospatial data	
WorldPop, GHSL, census records, and administrative boundaries	Urban delineation, census-calibrated population, settlement growth, and urban built surface
MODIS, CHIRPS, ERA5, SRTM, and land-cover products	Agricultural productivity, weather shocks, vegetation, temperature, rainfall, and agro-ecological conditions
OpenStreetMap, Ethiopian Roads Authority networks, night lights, and air-quality data	Bilateral travel times, market access, migration costs, amenities, and validation of local economic activity
Panel B. Survey and census microdata	
Urban Employment and Unemployment Survey and Informal Sector Survey, CSA	Formal and informal employment, private and government wages, own-account earnings, and tenure–formality profiles
Agricultural Sample Survey and Ethiopian Socioeconomic Survey, CSA and World Bank	Crop production, cultivated area, yields, prices, consumption, rural income, and spatial price indices
Labour Force Surveys, 2007 Population and Housing Census, and Demographic and Health Surveys	Migration matrices, employment benchmarks, fertility, mortality, and population structure
Panel C. Administrative and institutional data	
National Bank of Ethiopia national accounts and World Bank series	Sectoral value added, spatial output allocations, structural transformation, and macroeconomic benchmarks
FAOSTAT, HICES, UN demographic series, and USDA FoodData Central	Price deflation, food expenditure, agricultural benchmarks, demographic projections, and crop conversion factors
Additional auxiliary and validation sources	17 further datasets used for concordances, calibration targets, robustness exercises, and independent validation

Notes: Rows pool the principal sources listed individually in Appendix Table 8. The construction integrates 47 raw datasets. CSA denotes the Ethiopian Central Statistical Agency.

I measure formalization from the relationship between urban tenure and employment status in the 2014 UEUS migration module. The tenure profiles for the full migrant sample and for rural-origin workers provide the microeconomic moments used to discipline the formalization hazard. Section 5 reports the profile and Section 6.3 explains its role in identification.

Agricultural productivity and shocks. Rural income is measured using agricultural value added per worker rather than observed wage earnings, as appropriate for a predominantly self-employed agricultural workforce (Gollin et al., 2014). National agricultural value added is allocated across rural locations using production shares constructed from AgSS crop records and satellite-based yield estimates, with separate adjustments for livestock production in pastoral areas. Persistent agricultural productivity A_i^A is recovered by model inversion from rural income, employment, and prices (Allen and Arkolakis, 2014). The transitory component $\zeta_{i,t}^A$ combines MODIS vegetation measures with the relative strength of the belg and meher rainy seasons and is checked against observed AgSS yields.

Appendix A documents the complete data construction, including survey harmonization, spatial and temporal price indices, national-account allocations, bilateral travel costs, agricultural yield prediction, migration matrices, city-level sectoral output, shift-share measures and instruments, and input-level validation. Full construction mechanics for the agricultural, travel-time, demographic, and amenity pillars are in Online Appendix OA-1.

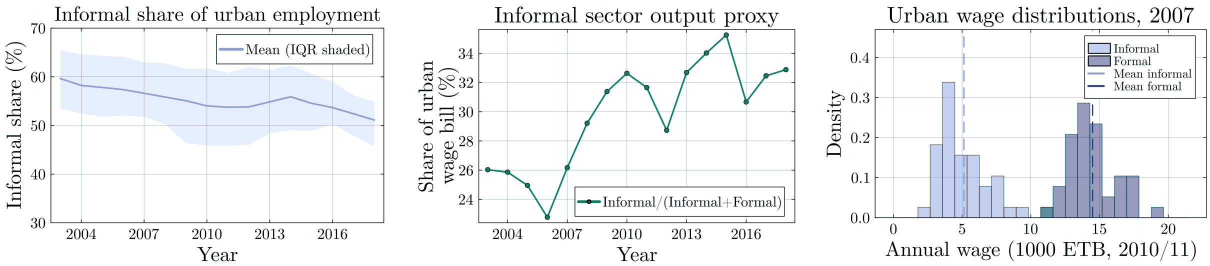
5 Four Empirical Patterns in Ethiopia

The data assembled in Section 4 reveal four patterns that mirror the empirical regularities motivating this paper: urban employment is divided between distinct formal and informal markets; urbanization remains low relative to rural–urban income differences; larger cities are not systematically more formal; and access to formal work rises only slowly with time in the city and remains incomplete. Together, they provide the empirical basis for the central mechanism of the general model in Section 3 and discipline its calibration. They are not particular to Ethiopia. Segmented urban labor markets, migration that is low relative to measured income gaps, and informal work as the entry margin for rural migrants are reviewed in Section 2 and documented across developing-country cities (Banerjee, 1983; Meng, 2001; Gollin et al., 2014; Ulyssea, 2018; Imbert and Ulyssea, 2026). Ethiopia exhibits these patterns sharply, and the microdata described above allow them to be measured jointly at the level of individual cities. Together, they indicate that formalization is a gradual transition that affects both migration incentives and the composition of expanding cities.

Fact 1: Formal and informal work are distinct urban labor markets. Informal employment accounts for more than half of private urban employment in Ethiopia and is especially prevalent outside the largest cities (Figure 2). Its share of employment substantially exceeds its share of urban value added, indicating lower average labor productivity than in the formal sector. The wage data show the same separation. At the 2007 model anchor, private formal wages were approximately 2.82 times informal wages. The ratio narrowed to about 1.85 by 2015, driven by rapid informal wage growth against a broadly flat private formal wage rather than by any change in classification, but remained economically large, and the wage distributions remained clearly distinct. This mirrors evidence that informal and formal activity remain separated by persistent productivity and earnings differences (Ulyssea, 2018).

These patterns motivate the model's division of urban employment into separate informal and formal markets. Moving into formal employment represents a meaningful change in earnings and productivity, not simply a relabeling of otherwise similar work. The two sectors also differ in the activities performed. In the UEUS microdata, 45 percent of informal workers would need to change industry, and 34 percent occupation, for the two activity distributions to coincide, a moderate but robust separation that is stable across waves and formality definitions. Informal employment concentrates in petty trade, personal services, and small-scale production, patterns familiar from the broader informality literature (La Porta and Shleifer, 2014; International Labour Organization, 2018). That activities overlap while wages remain sharply separated is itself informative. It supports treating the boundary between the two markets as an institutional labor-market distinction rather than a difference in activities alone, which is how the model represents it.

Fact 2: Urbanization is low relative to the measured income gap. Real urban incomes remain substantially above rural incomes even after accounting for local prices and housing expenditure. After that adjustment urban incomes are roughly 2.5 times rural incomes, yet Ethiopia remained only about 24 percent urban in 2025 on the national definition. Rural-to-urban migration remains modest relative to the size of the measured gap. Bilateral migration also declines strongly with distance, consistent with substantial monetary, informational, and network costs of moving. This is the familiar under-migration puzzle, in which large spatial income differences coexist with gradual population reallocation (Harris and Todaro, 1970; Gollin et al., 2014; Lagakos et al., 2023; Morten and Oliveira, 2024). Part of the answer is that the private formal wage is not the income immediately available to a rural migrant, a point that Fact 4 makes precise.



(a) *Informal employment* (b) *Employment and output* (c) *Urban wage distributions*

Figure 2: Informal work accounts for more than half of private urban employment, a smaller share of urban value added, and is associated with a distinctly lower wage distribution.

Notes: Panel (a) reports the share of private urban employment that is informal. Panel (b) compares the informal shares of private urban employment and urban value added. Panel (c) plots real wage densities for private formal and informal workers. Government employment is excluded throughout. Wages are annualized and expressed in constant 2010/11 birr. Sample: UEUS urban wage and own-account workers, 2003–2018. Source: author's construction from CSA microdata and national accounts.

Fact 3: Larger cities are not more formal. Informality declines only weakly with city size. In 2015, the private informality share was approximately 55, 56, and 53 percent across successive city-size terciles, with a correlation between city population and informality of only -0.20. Even the largest cities retain substantial informal sectors, so urban scale alone does not deliver a formal employment structure. This is consistent with evidence that urban growth need not coincide with industrialization or productive structural transformation (Gollin et al., 2016).

Fact 4: Migrants formalize slowly and incompletely. New migrants typically enter informal employment, where real earnings are much closer to the rural outside option, and reach formal work only gradually. This is consistent with evidence on informal work as an entry point into urban labor markets (Fields, 1975; Meghir et al., 2015; Franklin, 2018). The 2014 UEUS migration module also shows a clear tenure gradient. Under the broad status based definition, the formal employment share of urban migrants rises with time since arrival and then plateaus (Table 2). The relatively high formal share in this broader migrant sample reflects that it includes urban to urban migrants, who are more likely to arrive with access to formal employment. The hazard itself is disciplined by the corresponding profile for rural origin workers on the informality definition used in the calibration, whose estimation Appendix E.12 reports (Table 24). On either profile the transition is gradual and incomplete at long tenures, echoing evidence of slow movement into formal work in other developing economies (McCaig and Pavcnik, 2018).

Three features of the model follow from these patterns. Migration is valued through informal earnings upon entry, the prospect of future formalization, amenities, and

Table 2: Formal employment by migration tenure, UEUS 2014

Years since migration	N	Formal employment share
0–1 year	1,004	57.8%
1–3 years	1,345	70.5%
3–5 years	1,299	81.3%
5–10 years	2,000	86.5%
10+ years	4,138	86.5%

Notes: Survey-weighted formal-employment shares among urban migrants in the UEUS 2014 migration module. The table uses the broad status-in-employment definition. The unweighted sample contains 9,786 migrant workers.

bilateral moving costs, rather than through the formal wage. Formalization is a gradual and incomplete transition. The model makes it endogenous by letting the hazard depend on the city's capacity to absorb its informal pool, while preserving a residual informal sector after sustained urban growth. Formality is not tied to city size, so a growing city can remain largely informal. The next section disciplines these mechanisms and the remaining model parameters using the spatial and temporal moments constructed from the data. Additional descriptive statistics are reported in Appendix B.

6 Calibration and Validation

I discipline the model in the same sequence in which the economy evolves. I first calibrate the within-period equilibrium, which determines production, wages, prices, expenditure, trade, housing costs, and government employment conditional on the inherited spatial distribution of workers and built surface. I then calibrate the recursive transition governing demographics, migration, formalization, productivity, and housing adjustment between years. I validate each block immediately after calibration. Section 6.3 then defines the two formalization capacities compared throughout the paper. Appendix E.1 collects the detail that this section summarizes.

6.1 Within-period equilibrium

Calibration strategy. The within-period block contains most of the model's parameters, but relatively few are chosen freely. I use four sources of discipline. First, parameters with well-established estimates in the literature are set to values appropriate for low-income and spatial applications. Second, several objects are estimated directly from Ethiopian microdata, including nonhomothetic expenditure responses, agglomeration elasticities, government employment, and housing adjustment. Third, location-specific productivities and amenities are recovered by inversion from the observed spatial equilibrium. Finally, a small set of preference, housing, and trade parameters is selected within empirically credible ranges to reproduce the spatial distributions of wages, employment, prices, expenditure, and trade. Table 3 summarizes the resulting parameterization. Appendix E reports the estimating equations, literature intervals, admissible calibration ranges, and sensitivity to alternative values, with the full search-corridor documentation in Online Appendix OA-4.

Production and urban labor markets. Production combines labor with rural land or urban built surface. The factor shares are literature benchmarks for low-income settings, $\alpha_A = 0.40$ for agricultural land, $\alpha_I = 0.20$ for informal production, and $\alpha_F = 0.10$ for formal production (Gollin et al., 2014; De Mel et al., 2008; Tombe and Zhu, 2019). I estimate the agglomeration elasticities from repeated UEUS city cross-sections by relating sectoral employment to wages while controlling for region and year effects. The estimates are $\eta_I = 0.05$ for informal employment and $\kappa_F = 0.06$ for the combined private-formal and government employment base, consistent with the small but positive elasticities commonly found in the urban agglomeration literature (Combes et al., 2012). The model does not impose the formal–informal productivity gap directly. Location-sector productivity levels are recovered from observed earnings and employment. The urban wage gap documented in Section 5 is therefore a sector fundamental rather than an arbitrary wage wedge or a return to selection on ability (Appendix E.1).

Preferences and expenditure. Household demand is disciplined by the ESS and HICES expenditure data. The upper-tier elasticity between food and the urban composite is set to $\rho = 0.50$, following the nonhomothetic structural-transformation estimates of Comin et al. (2021). The nonhomotheticity terms $e_A = -0.103$ and $e_U = 0.109$ are estimated directly from ESS Engel curves and reject the homothetic benchmark in both cases. The expenditure weights h_A, ω_I, ω_F, and μ_A come from observed consumption patterns in the ESS and the 2004/05 HICES. The Stone–Geary subsistence term is set to $\bar{c}_A = 2{,}000$ birr per person per year in constant 2010/11 birr. It corresponds to roughly 40 percent of median annual rural or informal earnings per worker at the 2007 anchor. The elasticity between informal and formal urban goods, $\nu = 8$, is selected within the empirically admissible range reported in Appendix E, and robustness exercises vary both $\bar{c}_A$ and ν over literature-based intervals.

Trade and market access. The trade block combines literature-based substitution elasticities with Ethiopian transport data. The Armington elasticities $\sigma_A = 4$ and $\sigma_F = 6$ (Simonovska and Waugh, 2014; Broda and Weinstein, 2006), the travel-time elasticity of trade costs $\eta_{tr} = 0.40$ (Atkin and Donaldson, 2015), and the 15 percent urban food retail and intermediation margin (Minten et al., 2014) are taken from the literature. The maximum exportable agricultural share is $s_{xA} = 0.10$, within the 8 to 12 percent range implied by ERCA and National Bank of Ethiopia records. Conditional on these elasticities, the international price and gateway terms are calibrated to reproduce the observed external balance. Cash-crop exports equal approximately 3.3 percent of GDP, while net food and formal-goods imports equal about 1.4 and 7.5 percent. They are held fixed in the forward simulations (Appendix E).

Housing. The housing expenditure share at the reference city, $\omega_H = 0.35$, follows Davis and Ortalo-Magné (2011), and its city-size gradient $\psi_H = 0.30$ is benchmarked to evidence on urban costs and density (Combes et al., 2019). The cap $s_H^{\text{cap}} = 0.40$ prevents implausibly large housing burdens in the largest cities. The supply side is estimated from the GHSL panel rather than imported from another setting. Regressing built-up surface on city population with city effects and a lagged dependent variable gives a short-run population elasticity of $b_1 = 0.50$ and persistence $\varrho = 0.438$. Built surface therefore expands substantially but gradually as cities grow.

Government employment. Government employment is measured directly from the UEUS waves of 2003 to 2018 as a function of city population and capital status. Table 3 reports the fitted coefficients and the median government wage. The estimates reproduce the concentration of public employment in administrative centers while allowing its share to decline with city size.

Spatial fundamentals. Location-specific productivities $A_{i,0}^A$, $A_{j,0}^I$, and $A_{j,0}^F$ are recovered by inverting the production first-order conditions at the 2007 anchor following Allen and Arkolakis (2014). Destination amenities $\hat{a}_\ell$ are recovered from the 2007 population distribution through the migration-choice system. The agricultural fundamental is combined with the time-varying shock $\zeta_{i,t}^A$ constructed from MODIS vegetation and CHIRPS rainfall data, which has a correlation of 0.758 with observed AgSS yield measures. Appendix E.1 describes what these objects capture and how the informal demand weights and formal market access are constructed.

Parameter selection and equilibrium. Conditional on these layers, only the urban substitution elasticity, the food subsistence level, the housing-share cap, and the international scale terms remain internally calibrated. They are chosen jointly within prespecified empirical ranges to reproduce the spatial patterns in wages, employment, prices, expenditure, and trade that the measured, estimated, literature-based, and inverted objects do not pin down. The selected values are the lowest-loss point over this admissible domain rather than a global optimum. Table 3 makes the division between these layers explicit.

Table 3: Principal parameters of the within-period equilibrium

Parameter	Value	Basis	Empirical discipline or benchmark
Panel A. Production and agglomeration			
α_A	0.40	Literature	Agricultural land share (Gollin et al., 2014)
α_I	0.20	Literature	Factor use in small informal enterprises (De Mel et al., 2008)
α_F	0.10	Literature	Urban spatial factor share (Tombe and Zhu, 2019)
η_I	0.05	Estimated	UEUS informal employment–wage gradient, benchmarked to urban agglomeration estimates (Combes et al., 2012)
κ_F	0.06	Estimated	UEUS formal employment–wage gradient, benchmarked to urban agglomeration estimates (Combes et al., 2012)
Panel B. Preferences and expenditure			
ρ	0.50	Literature	Upper-tier substitution between food and urban goods (Comin et al., 2021)
e_A	-0.103	Estimated	ESS food Engel curve, standard error 0.005
e_U	0.109	Estimated	ESS urban-goods Engel curve, standard error 0.014
h_A	0.08	Measured	Agricultural own-consumption in the ESS
ω_I	0.531	Measured	Informal expenditure share in the ESS
ω_F	0.469	Measured	Formal expenditure share in the ESS
μ_A	0.965	Calibrated	National food expenditure share of 0.76 in HICES
$\bar{c}_A$	2,000	Calibrated	Ethiopian food expenditure and real-income distribution
ν	8.0	Calibrated	Informal–formal expenditure split and relative-price variation. Lower elasticities from related models are examined in Appendix E (Bachas et al., 2024; Abreha et al., 2022)
Panel C. Trade and market access			
σ_A	4.0	Literature	Agricultural Armington elasticity (Simonovska and Waugh, 2014)
σ_F	6.0	Literature	Manufacturing Armington elasticity (Broda and Weinstein, 2006)
η_{tr}	0.40	Literature	Internal trade-cost elasticity (Atkin and Donaldson, 2015)
d_{ref}	600 km	Normalization	Scale of the bilateral travel-cost function
τ_{retail}	0.15	Literature/data	Ethiopian food retail and intermediation margins (Minten et al., 2014)
s_{xA}	0.10	Measured	Agricultural export eligibility, within the ERCA and NBE benchmark range of 8–12 percent
World-price and variety scales	Appendix E	Calibrated	Cash-crop exports and net imports of food and formal goods in Ethiopian trade data
Panel D. Housing and government employment			
ω_H	0.35	Literature	Housing expenditure share (Davis and Ortalo-Magné, 2011)
ψ_H	0.30	Literature/data	Housing-cost gradient with city size (Combes et al., 2019)
s_H^{cap}	0.40	Calibrated	Upper bound on urban housing expenditure, with sensitivity reported in Appendix E
$b_1,\ \varrho$	0.50, 0.438	Estimated	Short-run response and persistence of GHSL built-up surface
β_0	1.35	Estimated	Intercept in the UEUS government-employment share relationship
β_{pop}	-0.067	Estimated	UEUS government-employment share gradient with city population
β_{cap}	0.051	Estimated	UEUS government-employment differential associated with capital-city status
w_G	21,600	Measured	Median annual government wage in the UEUS
Panel E. Spatial fundamentals			
$A^A_{\ell,0}, A^I_{j,0}, A^F_{j,0}$	Location-specific	Inverted	Anchor wages, employment, land, and built surface (Allen and Arkolakis, 2014)
$\hat{a}_\ell$	Location-specific	Inverted	Anchor population distribution through the migration-choice system
$\zeta^A_{i,t}$	Location-year	Constructed	MODIS vegetation and CHIRPS rainfall, with correlation 0.758 with AgSS yields
$\omega_I[j]$	City-specific	Constructed	Local demand-relevant informality share and ESS expenditure weight
MA_j	City-specific	Constructed	Delivered access to the international gateway

Notes: "Estimated" denotes parameters obtained econometrically from Ethiopian data, "measured" values taken directly from observed moments, "calibrated" values selected within empirical ranges, and "inverted" location-specific fundamentals recovered from the anchor equilibrium. Appendix E reports the full parameter inventory, ranges, and alternative values. The search corridors for grid-searched parameters are documented in Online Appendix OA-4. Monetary values are in constant 2010/11 birr.

Within-period validation. Table 4 evaluates the calibrated within-period equilibrium against the 2010–2014 location panel used in calibration and against an independent aggregation of the raw UEUS microdata at the survey's native zone level. Fit is strongest for employment composition and relative location attractiveness, the objects central to the model, and weakest for informal earnings, the object measured with the least spatial precision in the underlying survey. Appendix E.1 discusses each correlation, and Figure 10 in Appendix E.5 plots model against data.

Table 4: Validation of the within-period equilibrium

Outcome	Spearman ρ	Observations	Spatial support
Panel A. Calibration-panel fit, 2010–2014			
Real private-formal wage	0.894	215	43 urban locations
Real rural income per worker	0.981	390	78 rural locations
Local formal-to-rural wage premium	0.940	175	43 urban locations
Migration-relevant market access	0.976	390	78 rural locations
Panel B. Independent UEUS aggregation, 2010–2014			
Private informality share φ	0.982	100	26 UEUS zones
Private-formal wage	0.622	100	26 UEUS zones
Informal-to-formal wage ratio	0.318	97	26 UEUS zones

Notes: Panel A reports pooled rank correlations between model outcomes and the location-level calibration panel. Formal wages refer to private-formal earnings, rural income to agricultural value added per worker, the local wage premium to each city's formal wage relative to income in its rural hinterland, and market access to the origin-side migration-attractiveness index. Panel B uses zone-level medians constructed independently from the raw UEUS microdata. Thirty model cities map to 26 survey zones in 2010, 2011, 2012, and 2014. Unavailable zone-year cells account for the smaller observation counts. Monetary outcomes are expressed in constant 2010/11 birr. Source: author's computation from CSA UEUS and AgSS data.

External transformation benchmarks. As a final check, I evaluate the within-period equilibrium along externally disciplined paths for population, urbanization, and private informality, which also serve as the benchmarks for the recursive transition below. Population follows the United Nations World Population Prospects 2024 medium variant and rises from 135.5 million in 2025 to 262.4 million in 2060 (UN DESA, 2024). The urban share follows the satellite-based Degree of Urbanization series of the 2025 World Urbanization Prospects (UN DESA, 2025) and rises from approximately 15.0 percent in 2025 to 24.1 percent in 2060. The private informality share declines from approximately 45.0 percent in 2025 to 35.5 percent in 2060, a path intermediate between the cross-country relationship of La Porta and Shleifer (2014) and the slower decline among least-developed economies (International Labour Organization, 2018). Evaluated at these projected states, the equilibrium reallocates labor and demand smoothly far outside the 2007–2014 calibration window. Appendix E, Sections E.7 to E.10, documents the construction of the three paths and their position within the experience of comparable countries, and Appendix E.1 their interpretation.

6.2 Recursive dynamics

The recursive block moves the economy from one within-period equilibrium to the next. Most transition parameters are disciplined directly by external data, and a smaller set is selected jointly to reproduce the population, urbanization, and informality benchmarks introduced above.

Demographics. The demographic transition is anchored to the United Nations World Population Prospects 2024 medium variant (UN DESA, 2024) and occurs earlier in cities than in rural areas, reflecting Ethiopia's persistent rural–urban fertility differential. The urban natural-increase rate approaches a floor of 0.6 percent per year around 2030, while the rural rate approaches a floor of 2.0 percent around 2040, with transition steepness $k = 0.40$. Because migration changes the local bases on which subsequent natural increase operates, the national population path emerges from spatially heterogeneous demographics and endogenous mobility rather than being imposed as an aggregate total. Appendix E.1 explains how the floors and the steepness are disciplined.

Migration. Migration parameters are disciplined by origin–destination patterns from the 2007 Census and labor-force surveys, together with distance and the subsequent evolution of city populations. The distance elasticity is estimated at $\eta_d = 1.3$, within the range found in quantitative studies of internal migration (Morten and Oliveira, 2024). The migration-logit parameter $\vartheta = 2.50$ is close to values used in spatial development models such as Bryan and Morten (2019). The remaining migration-cost parameters, $\kappa_{\text{fixed}} = 40$, $\kappa_{\text{dist}} = 0.0025$, and $\kappa_s = 0.30$, are selected jointly to reproduce the level and spatial distribution of migration, and the discount factor entering migration values is $\beta = 0.95$ (Lagakos et al., 2023). Migration responds to the value of entering each labor market rather than to its contemporaneous wage. Because rural movers enter urban informal employment and value the prospect of formalization, the hazard affects migration before a worker obtains a formal job, and the two blocks must be disciplined jointly.

Productivity and amenities. Productivity growth decelerates as Ethiopia converges from a lower initial level. Rural productivity growth declines from 4.5 to 2.0 percent per year, with the long-run value anchored to agricultural productivity evidence for developing economies (Fuglie, 2012). Informal and formal productivity share a common path, declining from 4.0 to 2.5 percent, and all rates converge at $\lambda_d = 0.10$. The common urban trend prevents formalization from being generated mechanically by a widening formal-sector productivity advantage, so changes in urban employment composition must arise through demand, migration, agglomeration, and the formalization mechanism. Destination amenities remain at their inverted spatial values apart from a common urban adjustment of $g_a = 0.006$ log points per year. The amenities themselves are recovered by a mean-zero inversion with the loading γ normalized to one, so their level is not separately scaled. The drift is selected in the joint calibration subject to the restriction that it accounts for between 5 and 25 percent of projected urbanization over 2025 to 2065, about 15 percent at the selected value, so that urbanization is driven mainly by measured fundamentals rather than by a preference trend. Online Appendix OA-5 varies the drift from zero to four times its baseline, and Appendix E.1 explains the choice of the productivity corridor and the role of the drift.

Government employment and housing adjustment. Government employment and built surface evolve according to the relationships estimated from Ethiopian data in Table 3, and neither block receives an additional forward-calibration parameter. Delayed construction raises urban costs when migration outpaces it, so urban growth is neither unconstrained nor imposed through an exogenous city-size path.

Formalization. The formalization block determines how rapidly informal workers enter private formal employment. Its calibration keeps the transition gradual and incomplete rather than an automatic consequence of urban growth (McCaig and Pavcnik, 2018; Ulyssea, 2018), for the reasons given in Appendix E.1. The minimum annual hazard $\underline{\lambda} = 0.01$ prevents complete informality from becoming an absorbing state, and the saturation parameter is $\psi_0 = 9.0$. The low-informality brake, with midpoint $\varphi_c = 0.25$ and sharpness $\zeta_{\text{brake}} = 4.0$, prevents unrealistically rapid convergence once the informal workforce becomes small. The central curvature parameter, θ, determines how strongly a larger informal queue lowers an individual worker's probability of formalization. I calibrate θ jointly with ψ_0 below and interpret it in Section 6.3.

Joint calibration of the transition. The dynamic parameters cannot be calibrated one block at a time because each affects all three aggregate transformation paths. I therefore select them jointly by minimizing

$$\min_{\Theta_D} \sum_{t \in \mathcal{T}} \left[|u_t - u_t^*| + |\varphi_t - \varphi_t^*| + \frac{|L_t - L_t^*|}{L_t^*} \right], \qquad \mathcal{T} = \{2025, 2030, 2040, 2050, 2060\}, \tag{36}$$

where u_t is the urban population share, φ_t the national private informality share, and L_t total population. The starred values are the benchmark paths introduced above. The three deviations enter with equal weight as soft penalties. Appendix E documents the target series, admissible parameter corridors, and comparator-country envelope.

Table 5: Principal parameters of the recursive dynamics

Parameter	Value	Basis	Empirical discipline
η_d	1.30	Estimated	Census bilateral migration flows, within the literature range (Morten and Oliveira, 2024)
ϑ	2.50	Calibrated	Migration responsiveness and city population dynamics (Bryan and Morten, 2019)
$\kappa_{\text{fixed}}, \kappa_{\text{dist}}, \kappa_s$	40, 0.0025, 0.30	Calibrated	Net migration and persistence of spatial population rankings
β	0.95	Literature	Annual valuation of migration and formalization prospects (Lagakos et al., 2023)
$n^U_{\min}, n^R_{\min}, k$	0.006, 0.020, 0.40	Benchmarked	UN WPP demographic-transition path (UN DESA, 2024)
θ, ψ_0	3.25, 9.0	Calibrated	Population, urbanization, and informality paths, with the current-capacity comparator in Section 6.3
$\varphi_c, \zeta_{\text{brake}}$	0.25, 4.0	Calibrated	Shape of the low-informality adjustment
$\underline{\lambda}$	0.01	Calibrated	Positive formalization from highly informal initial states
$g_R^{\text{init}} \to g_R^{\text{long}}$	$0.045 \to 0.020$	Benchmarked	Agricultural productivity evidence (Fuglie, 2012)
$g_U^{\text{init}} \to g_U^{\text{long}}$	$0.040 \to 0.025$	Calibrated	Output growth and comparable catch-up transitions
λ_d, g_a	0.10, 0.006	Calibrated	Productivity convergence and restrained urban amenity adjustment

Notes: The table reports parameters additional to the housing and government-employment estimates in Table 3. Estimated values are obtained from Ethiopian data, benchmarked values are anchored to external evidence, and calibrated values are selected within prespecified empirical corridors.

The objective is minimized by grid search over the admissible corridor documented in Online Appendix OA-4. The best-fitting configuration sets the formalization curvature to $\theta = 3.25$ and the saturation parameter to $\psi_0 = 9.0$. I call this value the projection-consistent capacity, the formalization capacity at which the model reproduces the projected population, urbanization, and informality paths that enter equation (36). Section 6.3 contrasts it with Ethiopia's current capacity. The aggregate targets do not separately point-identify these two parameters. Because higher curvature can be offset by weaker saturation, the aggregate targets pin down a diagonal ridge in (θ, ψ_0) space rather than a point. Over approximately $\theta \in [2, 4]$, ψ_0 falls along the ridge as θ rises. Appendix E.12 reports five alternative configurations on this ridge. Their terminal urbanization, informality, and urban–rural value ratio differ only modestly from the best-fitting pair, so the central results do not depend on a knife-edge parameter pair. Along the ridge the calibration objective rises by at most 28 percent above its minimum, and by at most 6 percent for $\theta \leq 3.25$, while at the off-ridge point D6 it rises to 2.3 times the minimum (Appendix E.12).

Joint forward performance. Figure 3 presents the resulting transition path. Because population, urbanization, and informality enter the calibration objective, their close fit is not itself validation. The informative outcomes are those not targeted. Aggregate output, the urban–rural wage ratio, and rural-to-urban migration are generated endogenously and evolve smoothly within economically sensible ranges. The joint fit is nevertheless more demanding than matching three independent trends because the target paths are linked by opposing feedbacks, which Appendix E.1 describes.

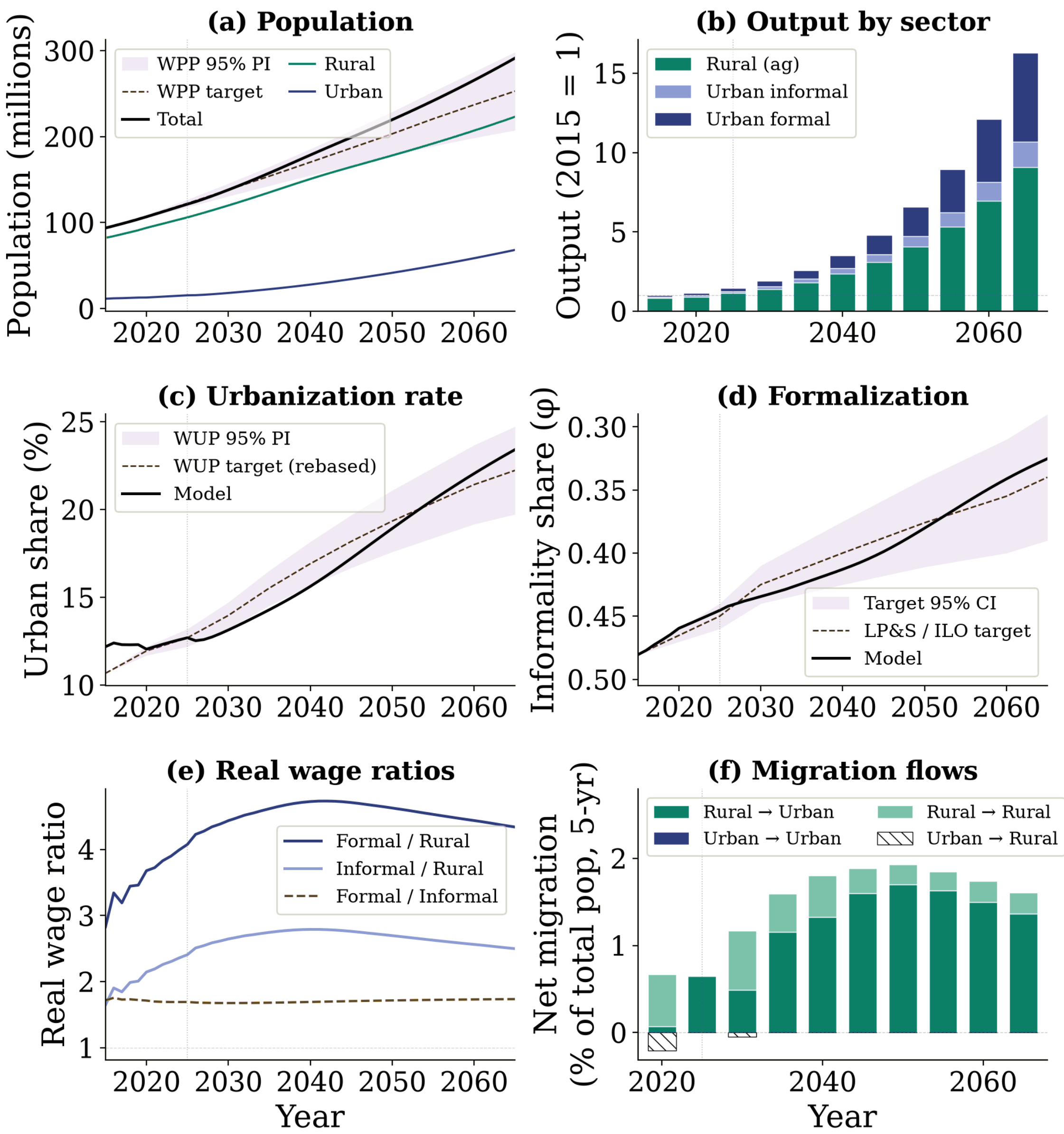


Figure 3: The calibrated model reproduces the three external benchmark paths, 2007–2065, while generating output, wages, and migration endogenously.

Notes: The panels show national population, aggregate output, the urban share, private informality φ, the urban-to-rural wage ratio, and net rural-to-urban migration. Shading marks the 2007–2014 calibration period, and dashed lines indicate external benchmarks. Population, urbanization, and informality enter as soft targets at the five dates in equation (36). All annual paths are otherwise endogenous. Sources: UN WPP 2024, UN WUP 2025, Appendix E.9, and author's computation.

6.3 Two formalization capacities

The remainder of the paper compares two economies that differ only in the curvature parameter θ. Expressed as the annual probability that an urban informal worker obtains a formal job and the implied expected wait, they differ sharply. In the current-capacity economy, $\theta = 4.75$, the annual formalization rate is about 3.8 percent in 2015 and falls to 2.6 percent by 2065, so the expected wait lengthens from 26 to 39 years. In the projection-consistent economy, $\theta = 3.25$, the rate is 5.8 percent in 2015 and rises to 7.3 percent by 2065, so the wait shortens from 17 to 14 years. These rates are population-weighted national means of city-level hazards along each economy's baseline path, and each wait is $1/\lambda$ under the year's hazard, the wait a worker faces if that year's conditions persist. Appendix E.11 reports both paths and the snapshot values at the 2015 national composition. The projection-consistent economy is the calibrated baseline. The current-capacity economy is a comparator disciplined by auxiliary moments that do not enter the aggregate objective.

Projection-consistent capacity. Lower values of θ represent greater formalization capacity because the formalization hazard deteriorates less sharply as the informal queue grows. At $\theta = 3.25$, the model sustains rapid urban growth while moving workers into formal employment at the pace required by the benchmark trajectory. The annual formalization probability is roughly 6 to 7 percent and the expected wait about 14 to 17 years. Demographic growth and migration continually refill the informal pool, so even this fast gross transition produces a net decline in informality of only around three percentage points per decade. That net pace is consistent with observed structural transformations rather than implied by the projection exercise alone (Appendix E.10).

Current capacity. The projection-consistent value is not an estimate of Ethiopia's current formalization capacity. At $\theta = 4.75$, an urban informal worker formalizes at roughly 2 to 4 percent per year, implying an expected wait of about 25 to 40 years if conditions persist. Ethiopian micro evidence supports this pace. Two estimators applied to the tenure-to-formality profiles of rural-origin migrants imply $\theta = 5.00$ and $\theta = 7.05$, corresponding to hazards in this range. The comparator $\theta = 4.75$ lies inside the minimum-distance confidence interval of 3.90 to 6.25 and below both point estimates, so it is a conservative measure of current frictions.

A separate spatial diagnostic on cross-city informality dispersion points in the same direction, and the implied slow pace accords with persistent informality across much of the developing world (International Labour Organization, 2018). Appendix E.1 reports the diagnostic, and Appendix E.11 maps capacity into formalization rates and waiting times and compares them with measured worker-level transition rates (Danquah et al., 2021; Donovan et al., 2023).

Throughout the paper, $\theta = 4.75$ therefore denotes the current-capacity economy, with a queue of roughly 26 years, and $\theta = 3.25$ the projection-consistent economy, with a queue of roughly 17 years. The relevant margin is the distance between these two capacities rather than the frictionless case, since even at $\theta = 0$ the annual formalization rate is capped near 11 percent by ψ_0 (Appendix E.11).

Productivity drift versus capacity. A natural concern is whether the forward fit is driven by the assumed productivity drift rather than by formalization capacity. The two affect different margins. Perturbing trend productivity growth by ±50 percent changes long-run welfare substantially but shifts terminal urbanization and informality by less than three percentage points. Moving θ along its calibrated ridge likewise changes the aggregate transformation paths only modestly, while moving away from that ridge shifts terminal informality by more than twenty percentage points with a much smaller effect on welfare (Section 10 and Appendix F). Productivity drift therefore governs primarily the level of income and welfare, while θ governs the formalization regime. The headline formalization results are not driven by the drift assumptions. The next section quantifies the economic cost of the gap between Ethiopia's current formalization capacity and the capacity required to sustain the projection-consistent transformation.

7 Main Results

Section 6.3 measures Ethiopia's current formalization capacity from the tenure-to-formality profiles of rural-origin migrants. An urban informal worker formalizes at roughly 2 to 4 percent per year, an expected wait of about 26 years. To match the United Nations projections for population growth and urbanization while also delivering the projected decline in informality, workers need to move into formal employment much faster. Workers must formalize at roughly 6 to 7 percent per year, a wait of about 17 years, the projection-consistent capacity. The two capacities correspond to $\theta = 4.75$ and $\theta = 3.25$. The parameter θ is the curvature of the formalization hazard, and a lower value means the formalization rate deteriorates less as the informal queue grows. Section 6.3 summarizes both economies.

To understand the general equilibrium effects of higher or lower formalization capacity, I compare the same economy under the two capacity regimes, holding all other parameters fixed from 2015 to 2065. This experiment does not attribute the improvement to any single reform. It asks how much the economy gains when cities clear the informal queue at the pace sustained structural transformation requires. Two metrics summarize the answer. The first is real GDP, the private wage bill $w^R L^R + w^I L^I + w^F L^F$ summed over all locations and measured in units of the formal composite good, whose population-weighted price aggregate equals one in every year, excluding government wages and land rents. The second is national welfare, which denotes the population-weighted lifetime value of workers across all locations and labor-market states. Both are deviations from the current-capacity economy.

7.1 The formalization-capacity gap

The formalization capacity gap is the difference between the roughly 26 years an informal worker currently waits to reach formal employment and the roughly 17 year wait needed for projected urban growth to occur alongside a sustained decline in informality. Formalization capacity summarizes how effectively firms, institutions, and labor markets can move informal workers into formal employment, given the size of the formal sector. Closing this gap has large aggregate effects. Reducing the expected wait from about 26 years under current capacity ($\theta = 4.75$) to about 17 years under higher capacity ($\theta = 3.25$) raises real GDP by 13.1 percent by 2065 and national welfare by 9.7 percent over 2015–2065. The urban formal employment share rises from 41.1 to 67.5 percent, the share of the total population employed formally from 7.6 to 11.3 percent, and the population weighted average real wage by 6.1 percent. Yet urbanization changes by less than one percentage point. Greater capacity changes access to productive employment within cities far more than the rate at which workers move to them.

These effects compare current capacity with the capacity needed for projected population growth and urbanization to occur alongside falling informality, not with an arbitrary high capacity economy. Because welfare accumulates over the entire transition path, the headline 9.7 percent gain compares the two regimes over 2015–2065.[10] The welfare gain reaches 4.8 percent by 2035 and 9.0 percent by 2050 and remains stable along the calibrated θ–ψ_0 ridge, where deviations are below one percent.

Table 6 places the two capacities within a wider sweep, where each row shares a common history through 2025 and operates at the stated capacity from 2026, as in Figure 4. The columns give the annual chance of a formal job in 2065 and the wait it implies, output and welfare relative to the current-capacity row, and the composition of employment and population in levels.

Figure 4 shows how these effects build over time across the full capacity sweep. The formal share in panel B is the state variable that matters to every worker, not only to those waiting in the informal pool. A larger informal pool slows formal entry, so it sets the hazard that each informal worker faces. It matters to formal incumbents because faster entry compresses the formal wage premium, and to rural households because it enters the value of migrating and outmigration raises rural wages. Section 7.4 follows these channels into lifetime values by group. Panel A shows that greater capacity does not raise output immediately. It shortens the informal queue, so successive cohorts

[10] Two reform-from-2026 variants appear, and neither is the headline. Both share one history through 2025 and raise 2065 GDP by about 13.1 percent. Their 2065 welfare gains differ in how urban residents are valued. Table 6 values every urban resident at the informal-entrant lifetime value, 5.3 percent. Appendix G.2 values formal and government workers at the formal lifetime value, 3.8 percent.

Table 6: Formalization timelines and structural transformation: outcomes in 2065

Formalization capacity	Formalization		Deviation from current capacity		Composition		
	Annual rate	Wait (years)	Real GDP	Welfare	Urban formal	Formal in population	Urban share
Projection-consistent ($\theta = 3.25$)	7.27%	13.7	+13.1%	+5.3%	67.5%	11.3%	23.42%
Ambitious reform ($\theta = 3.75$)	6.83%	14.6	+12.4%	+5.1%	64.4%	11.0%	23.40%
Moderate reform ($\theta = 4.25$)	4.74%	21.1	+8.0%	+3.2%	54.1%	9.5%	23.04%
Current capacity ($\theta = 4.75$)	2.41%	41.5	0.0%	0.0%	41.1%	7.6%	22.62%
Institutional deterioration ($\theta = 5.50$)	1.21%	82.8	−8.9%	−1.3%	30.4%	5.9%	22.72%

Notes: Rows share a common history through 2025 and differ only in formalization capacity from 2026, holding $\psi_0 = 9.0$ fixed. "Projection-consistent" denotes the capacity required to match the projected decline in informality alongside projected urban growth. The annual rate is the population-weighted probability that an informal worker enters formal employment; expected years to formalize is its reciprocal. GDP and welfare changes are relative to current capacity. Welfare is the population-weighted lifetime value across workers. Source: author's computation.

reach formal employment sooner and the formal share rises gradually. As more workers move into the higher-productivity sector, aggregate output and the average real wage rise with a lag. The separation across regimes therefore appears first in the formalization hazard and employment composition, and only later in wages and output.

The GDP response is strongly nonlinear. Moving from $\theta = 4.75$ to $\theta = 3.75$, the ambitious-reform row of Table 6, already produces a 12.4 percent gain, close to the 13.1 percent obtained at $\theta = 3.25$. Around this range, additional capacity does more than raise the formalization rate mechanically. It prevents the informal queue from expanding, allowing a growing share of workers to reach formal employment and raising the productive capacity of the urban economy. Once the queue is sufficiently short, however, further improvements run into the saturation term ψ_0, which caps the annual formalization hazard near 11 percent even when congestion is small. Returns therefore rise sharply around the range where the queue begins to clear and then flatten as the remaining bottleneck shifts from congestion to firm-level and institutional throughput. Most of the economic value is consequently concentrated around the gap between current and projection-consistent capacity.

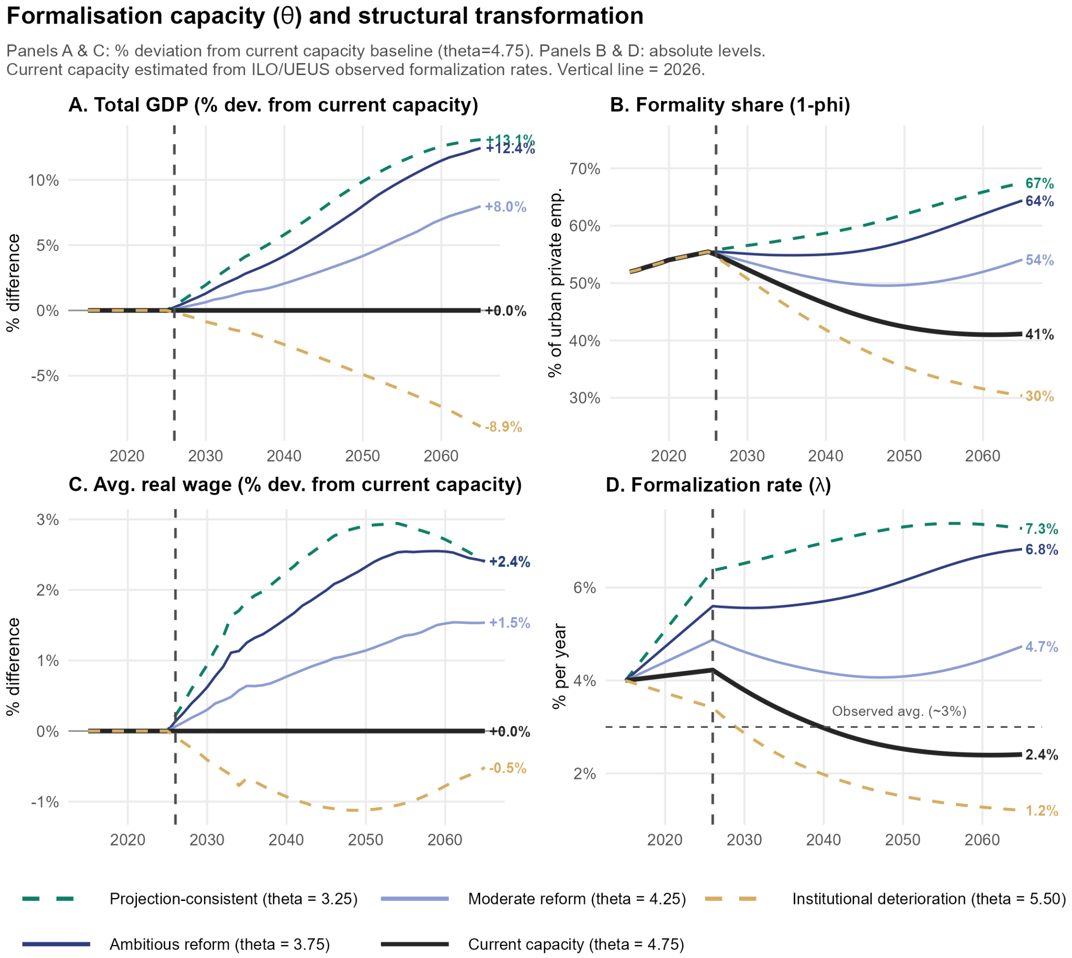


Figure 4: Greater formalization capacity raises GDP and formal employment, with a sharply nonlinear response around $\theta \approx 4$.

Notes: The panels show real GDP relative to the current-capacity path, the urban formal employment share, the population-weighted average real wage relative to current capacity, and the annual formalization rate. Lower θ denotes greater capacity. The projection-consistent and current-capacity values are $\theta = 3.25$ and $\theta = 4.75$, respectively, and the intermediate paths are labeled as in Table 6. The dashed vertical line marks 2026, when capacity begins to differ across paths. Source: author's computation.

7.2 The informality trap

The key nonlinearity is whether the path into formal employment becomes easier or harder as cities grow. Around $\theta \approx 4$, the direction of this feedback changes. With sufficiently high formalization capacity, workers leave informal employment fast enough for the informal queue to shrink. A smaller queue then makes it easier for the remaining informal workers to formalize. Under the capacity needed for projected urban growth to occur alongside declining informality ($\theta = 3.25$), the expected wait for formal employment falls from about 17 years in 2015 to about 14 years in 2065. Formalization becomes progressively easier as the economy develops.

Under current capacity, the opposite occurs. Migration adds workers to informal employment faster than firms, institutions, and labor markets can move them into formal jobs. The informal queue expands, making formalization increasingly difficult. At $\theta = 4.75$, the expected wait rises from about 26 years around 2030 to more than 41 years by 2065. With still weaker capacity ($\theta = 5.50$), the wait exceeds 80 years by 2065 and the urban economy remains predominantly informal.

This is the quantitative informality trap. Urbanization does not by itself generate structural transformation. If workers enter cities faster than they can move into formal employment, city growth expands the informal workforce and makes future formalization harder. If capacity is sufficiently high, the same process works in reverse: the informal queue gradually clears and access to formal employment improves. Current capacity and the capacity required for declining informality lie on opposite sides of this boundary. The headline GDP and welfare gains therefore capture the value of moving from a path in which the wait for formal employment becomes progressively longer to one in which it becomes progressively shorter.

7.3 How capacity raises output

Structural reallocation. The output gain comes mainly from moving workers into more productive formal employment. Relative to current capacity, formal value added is 62.0 percent higher in 2065 and informal value added is 44.2 percent lower. Rural value added also rises by 12.5 percent. Stronger capacity therefore does not raise all sectors proportionally. It changes the composition of production by shifting workers out of lower-productivity informal activity and into formal employment, while rural earnings rise as workers leave agriculture.

The two formal employment measures in Table 6 show this transition from different perspectives. The formal share of private urban employment rises by 26.4 percentage points, from 41.1 to 67.5 percent. The share of the total population employed formally rises by 3.7 percentage points, from 7.6 to 11.3 percent. The second measure is broader because rural residents and new informal migrants remain in the denominator. By this measure, stronger capacity increases the formally employed population by almost one-half relative to the current-capacity path.

Why average wages rise when urban wages fall. Closing the capacity gap raises the population-weighted average real wage by 6.1 percent even though informal and formal wages fall by 8.2 and 5.5 percent. Rural wages rise by 7.9 percent. The reason is composition. Stronger capacity moves many workers from informal into formal employment, where wages remain about 1.68 times higher in 2065 even after greater entry compresses the formal wage premium. The economy-wide average therefore rises despite lower wages within both urban sectors.

Rural wages move in the opposite direction. Outmigration reduces the agricultural workforce while land remains fixed, raising income per worker and narrowing the formal-to-rural wage ratio from 3.55 to 3.11.

The decline in urban wages reflects the baseline trade environment rather than a direct cost of formalization. As formal employment expands, formal output rises sharply. With world prices and export opportunities held fixed, much of this additional supply must be absorbed domestically, lowering formal prices and, through competitive factor pricing, formal wages. Section 8 relaxes this constraint through the export-competitiveness experiments. The two margins are complementary. Formalization capacity supplies workers to the formal sector, while access to external demand allows firms to employ them without relying as heavily on domestic price and wage compression.

7.4 Who gains, and where

Welfare and the value of leaving the queue. National welfare rises by 9.7 percent, but the gains are distributed unevenly across labor-market states. Rural welfare rises by 7.9 percent as outmigration raises agricultural earnings and strengthens the rural outside option. Informal workers gain 4.3 percent in lifetime value despite an 8.2 percent fall in their current wage because stronger capacity sharply improves their chance of reaching formal employment. Formal incumbents are the only group that loses. Their value falls by 5.5 percent as greater entry erodes the scarcity premium attached to formal jobs. Population-weighted urban welfare nevertheless rises by 8.0 percent because many more workers gain access to those jobs.

This incidence is precisely what separating informal and formal urban labor markets reveals. A single urban wage would miss both the gain to workers waiting for formal employment and the loss to workers already inside it. Greater capacity raises welfare not by making every urban worker better off at each moment, but by changing workers' prospects of moving between labor-market states.

Reallocation itself accounts for part of the national gain. Within-group value changes explain 82.9 percent of the welfare increase, while changes in population weights account for the remaining 17.1 percent, or about 1.7 percentage points.[11] The main point

[11] National welfare can therefore rise by more than the conditional value of any individual group. The aggregate is not a fixed-weight average of group-specific changes. Stronger capacity also shifts workers toward higher-value locations and labor-market states. The partition is by location, rural and urban, so the within-group term already contains the informal-to-formal reallocation occurring inside cities. A three-way partition by labor-market state would attribute a correspondingly larger share to reallocation. Like the headline welfare gain, the decomposition compares the two capacity regimes over the full 2015–2065 transition (Table 31). Appendix G.2 reports the separate reform-from-2026 experiment

is that formalization capacity changes both the value of occupying each state and who is able to occupy it.

The resulting incidence also creates a potential political-economy tension. Benefits are spread across rural households, migrants, and informal workers, while losses are concentrated among formal incumbents. The model contains no political process, but it shows why an aggregate welfare-improving increase in formalization capacity can reduce the rents of workers who already have access to formal employment.

Urbanization without formalization. The same experiment separates two margins that are often treated as one. Across the capacity sweep, the urban formal employment share varies by 37.1 percentage points, while the urban population share changes by only 0.80 percentage points. Formalization capacity therefore has little effect on how urban the economy becomes but a large effect on what workers do once they are there.

This distinction follows directly from the model's recursive structure. Urbanization depends mainly on demographics, agricultural productivity, migration costs, amenities, and housing. Formalization instead governs movement between informal and formal employment within cities. Economies can consequently reach similar urbanization rates while differing sharply in formal employment, productivity, and welfare. Urbanization alone is therefore an incomplete measure of structural transformation.

The gains are concentrated outside Addis Ababa. Addis Ababa accounts for only 5.6 percent of the 2065 increase in private formal employment when capacity moves from its current to its projection-consistent level. Large secondary cities contribute 24.2 percent, medium-sized cities 36.5 percent, and small cities 33.7 percent. Medium and small cities together account for 70.2 percent of the aggregate formalization gain.

Stronger capacity also reduces differences across cities. The population-weighted cross-city standard deviation of informality falls from 0.110 in 2014 to 0.015 by 2065 under projection-consistent capacity. Under current capacity it instead rises to 0.135. Weak absorption therefore leaves a persistent divide between cities that formalize and those in which informal employment continues to accumulate. Stronger capacity raises national formal employment primarily by allowing secondary cities to catch up rather than by concentrating further growth in Addis Ababa.

alongside it.

8 Policy Counterfactuals

Section 7 valued formalization capacity holding policy fixed. Governments, however, do not choose formalization capacity directly. They choose policies that raise productivity, improve market access, change migration incentives, or support particular sectors. The effects of these policies depend in part on whether the workers they target or reallocate can subsequently move from informal into formal employment. This section asks how the length of the informal queue changes policy effectiveness and uses the model to trace how the same policy can have different effects across labor market groups within the same location. Each intervention is evaluated under the current and projection-consistent formalization regimes, holding the underlying capacity parameter fixed while the informal queue and realized formalization rate evolve endogenously. Two questions organize the results. Does a policy's gain depend on workers being able to cross the formalization boundary? And can the same policy affect informal and formal workers differently, both in magnitude and even in direction?

All counterfactuals begin in 2026 and run through 2065. Policy doses are simple and transparent rather than cost-equivalent, so the experiments reveal mechanisms rather than rank instruments. I group them into supply-side policies, demand-side policies, and infrastructure and mobility.[12]

8.1 Supply-side policies

Supply-side policies differ in whether their gains require workers to reach formal employment. Formal-sector productivity works through the jobs at the end of the queue. Informal and agricultural productivity instead raise incomes where workers already are. As formal employment expands, external demand becomes a further constraint.

Industrial policy. Investment incentives, subsidized finance, technology adoption, and other support to formal firms can raise formal-sector productivity. Their aggregate effect, however, depends on whether workers can reach the jobs created by more productive firms. With stronger absorption, higher productivity draws more workers into formal production. With current capacity, access remains scarce and more of the gain accrues to workers already inside the formal sector.

[12] The full set is broad. Supply-side counterfactuals cover formal, informal, and agricultural productivity and a joint formal–agricultural productivity intervention. Demand-side and demographic counterfactuals cover food support, fertility, public employment, and direct formal-employment support. Infrastructure and mobility counterfactuals cover migration costs, roads, trade integration, and housing support. An export-competitiveness scenario isolates the interaction between external demand and formalization capacity. The main text focuses on the experiments that most clearly develop the argument. Appendix G summarizes the full set, with complete decompositions and additional results in Online Appendix OA-6.

The quantitative experiment shows that this difference is economically large. For a 25 percent increase in formal-sector productivity, national welfare rises by 13.6 percent under projection-consistent capacity and 9.6 percent under current capacity. Incidence within cities also differs. Formal wages rise, while informal wages can fall as activity shifts toward formal production. Informal workers can nevertheless gain in lifetime value because the prospect of eventually reaching formal employment improves. A single urban wage would miss this distinction between current earnings and access to future formal jobs.

The mechanism is consistent with evidence that industrial policy works alongside complementary institutional and financial capacity (Juhász et al., 2024; Lane, 2025; Choi and Levchenko, 2025). Ethiopian experiments provide a useful counterpart. Factory-job offers and support to industrial-park applicants produced limited persistence in employment and income gains (Blattman and Dercon, 2018; Blattman et al., 2022; Abebe et al., 2025). In the model, stronger formal labor demand likewise produces broad transformation only when workers can reach the jobs it creates.

Informal and agricultural productivity. Informal and agricultural productivity provide the opposite comparison. Working capital, equipment, training, and business services raise the productivity of informal workers without requiring them to formalize first. Their reach is therefore greatest when the queue is long. In the experiment, a 25 percent increase in informal productivity raises national welfare by 2.0 percent under projection-consistent capacity but 6.6 percent under current capacity. The difference is compositional. When the queue is long, more workers remain in the sector receiving the gain. Experimental evidence of high returns to capital in informal firms makes this a relevant policy margin (De Mel et al., 2008).

Agricultural development reaches workers even more broadly. Improved seeds, irrigation, extension, and other yield-enhancing technologies raise rural productivity directly while lowering food prices for urban households. A 30 percent increase in rural productivity raises national welfare by about 10 percent under either capacity regime, despite little change in market-price GDP. Greater agricultural supply lowers food prices, so real purchasing power can rise substantially even when the value of measured agricultural output does not. At low income levels, where food absorbs a large share of expenditure, this price channel is first-order (Gollin et al., 2007; Gollin and Rogerson, 2014; Gollin et al., 2021).[13]

These experiments highlight the contrast. Formal productivity is most powerful when

[13] In an open economy, agricultural productivity growth can slow industrialization by strengthening comparative advantage (Matsuyama, 1992). In the calibrated Ethiopian economy, costly food trade and limited international arbitrage (Section 3.5) make the domestic food-price channel important here.

workers can leave the queue. Informal and agricultural productivity raise welfare while workers remain in it. Figure 5 shows how this contrast plays out across rural, informal, and formal workers, and it previews the incidence of the food-support, mobility, road, and trade experiments that follow. Each policy creates its own configuration of winners and losers, and that configuration shifts with capacity. The joint productivity experiment in the broader counterfactual set combines the two productivity margins and confirms their complementarity.

Export competitiveness. Once formalization succeeds, the constraint shifts. A growing formal workforce produces more formal output, and Section 7.3 showed that limited external demand can force part of that expansion through lower domestic prices and wages. Better trade logistics, customs, export finance, or other improvements in access to foreign markets therefore become more valuable as the formal sector grows.

The calibrated economy begins far from export parity, so the experiment imposes a large improvement in export demand. Its main result is sharp. The improvement raises formal-worker value by roughly the same amount under both capacity regimes, but formal employment rises by about 5 percent under projection-consistent capacity and hardly at all under current capacity. External demand creates formal jobs only when workers can reach them. Otherwise much of the gain remains with existing formal workers.

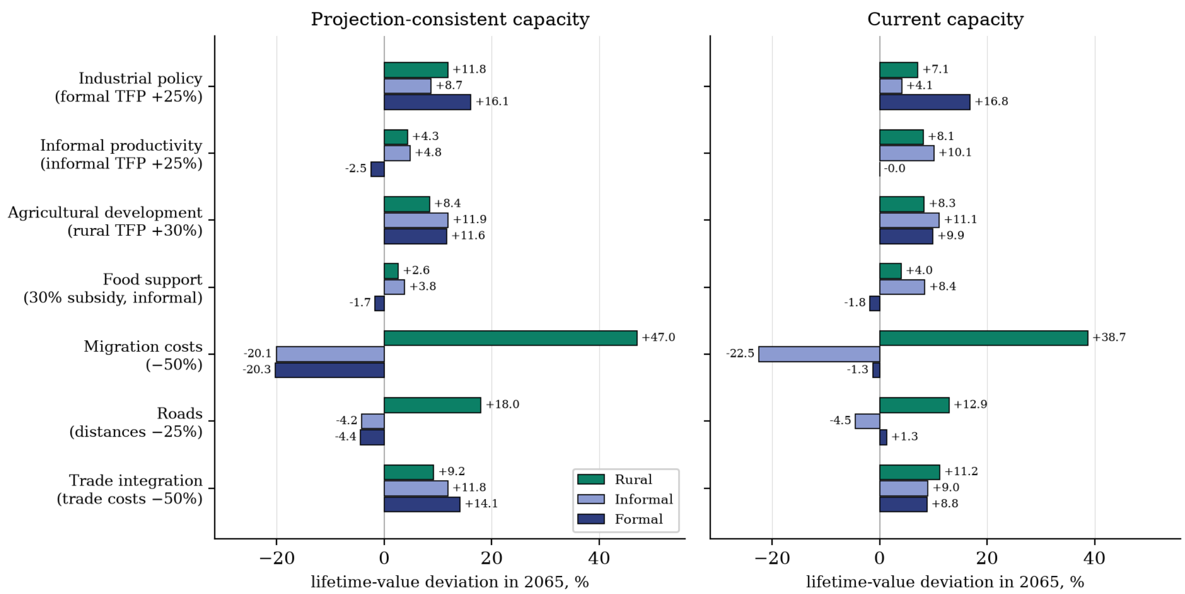


Figure 5: Policies create different winners and losers, not merely gains of different size.
Notes: Lifetime-value effects in 2065 for rural, informal, and formal workers under the main-text policy experiments, relative to the no-policy baseline within each capacity regime. Appendix G reports the full counterfactual set and real-wage incidence. Online Appendix OA-6 reports complete dose-by-dose results. Source: author's computation.

8.2 Demand-side policies

Demand-side interventions provide a complementary comparison. Some support workers while they remain informal. Others expand formal employment directly.

Food support. Food subsidies and targeted transfers can protect households without requiring them to formalize first. Their reach is therefore greater when the informal workforce is large. In the experiment, a subsidy covering 30 percent of informal households' food expenditure raises informal-worker welfare by 3.8 percent under projection-consistent capacity and 8.4 percent under current capacity. The difference is primarily compositional. Weak absorption leaves more households in the group receiving support.

Food support therefore works as a transitional instrument. It can protect workers while the queue remains long, but it does not shorten the queue itself and naturally becomes less important as formalization proceeds.

Direct formal-employment support. Industrial parks, hiring incentives, placement and training programs, or administrative reforms can instead combine stronger demand for formal workers with easier access to formal jobs. I capture this with a composite intervention that raises formal labor demand and the formalization hazard together.

The intervention is especially powerful when absorption initially binds because it attacks the bottleneck directly. Its spatial design also matters. Broad expansion can depress informal earnings, whereas targeting secondary-city corridors preserves much of the formal-employment gain with smaller spillovers. The lesson is not simply to create formal jobs, but to combine job creation with a route through which workers can reach them. Appendix G reports the alternative designs.

The additional demand-side exercises reinforce the distinction. Lower fertility eases future pressure on the informal queue, while public hiring expands urban employment without improving private formalization.

8.3 Infrastructure and mobility

Infrastructure provides the clearest distinction between moving workers and moving goods. Migration and roads can generate large reallocation gains, but they also send workers toward urban labor markets that may not be able to absorb them. Trade integration improves market access with much less movement of people.

Mobility and roads. Lower migration barriers can come from transport improvements, better information and matching, relocation assistance, or stronger links between rural areas and cities. The model's migration cost is broader, capturing networks, attachment, risk, and other barriers to relocation alongside transport. Halving it is a substantial increase in mobility rather than a change in one observable cost.

Greater mobility produces large gains because workers leave low-productivity locations and rural stayers gain from having more land per worker. But what happens in destination cities depends on formalization capacity. At current capacity, halving migration costs raises GDP by 35.0 percent and national welfare by 20.8 percent, yet lowers the value of entering urban employment by 22.3 percent. Migration is therefore nationally beneficial while making the receiving urban labor market substantially worse for entrants.

The segmented labor market explains this apparent contradiction. When absorption is weak, new migrants accumulate in informal employment and lengthen the queue. When absorption is stronger, more eventually reach formal jobs, spreading the productivity gains more widely but also increasing competition with formal incumbents. Mobility changes not only where workers live, but who competes in each urban labor market.

Road investment makes the same mechanism tangible. Intercity and feeder roads lower the cost of moving workers and goods together. Welfare rises under both capacity regimes, but the gains are larger when receiving cities can absorb the additional migrants. Under current capacity, the same improved connectivity increases urban informality. Roads and formalization capacity are therefore complements. Infrastructure works better when the cities it connects can convert migration into productive employment.

Trade integration. Lower trade costs provide the natural contrast. Better logistics, customs, wholesale networks, and domestic market integration allow goods to move without requiring workers to do so. Households gain access to cheaper goods where they already live, placing little additional pressure on the informal queue.

Halving trade costs raises national welfare by about 8 percent under either regime, a gain that is broad and relatively insensitive to formalization capacity. Rural, informal, and formal workers all benefit. Trade integration therefore illustrates a wider principle. Policies that improve purchasing power in place rely much less on the economy's capacity to process workers through the formalization transition.

Housing support. Housing construction, serviced land, upgrading, and targeted housing assistance can lower the cost of urban residence without requiring workers to move or formalize. The model captures this margin through a 30 percent reduction in the targeted group's housing expenditure. The gains are concentrated among the targeted workers and generate little additional pressure on the informal queue. Housing support can therefore improve urban purchasing power without reproducing the congestion generated by policies that induce large migrant inflows.

8.4 Policy synthesis

The counterfactuals establish two policy implications. First, formalization capacity matters most for interventions whose gains require workers to change labor-market states. Formal productivity, migration, roads, and export demand generate broader gains when workers can move through the informal queue. Informal and agricultural productivity, food support, and trade integration reach workers where they already are and remain effective when formalization is slow. Capacity therefore changes the transmission of development policy rather than uniformly raising or lowering its return.

Second, segmentation changes incidence, as Figure 5 makes visible. Industrial policy can raise formal returns while informal earnings fall. Mobility and roads generate large gains for rural households while imposing losses on workers in receiving cities. Policies directed toward informal workers naturally have the opposite distributional pattern. Combining informal and formal workers into one urban labor market would conceal these effects and, for some interventions, obscure who bears the cost of adjustment.

A capacity-contingent sequencing. The experiments imply a simple development logic. While absorption remains weak, productivity and purchasing-power gains that reach workers where they are can raise welfare without relying on rapid formalization. Policies that directly expand formal access help relax the bottleneck itself.

As the queue clears, industrial policy, migration, and connective infrastructure can translate more readily into productive formal employment. A larger formal sector then raises the value of external demand. Formalization capacity, productive firms, infrastructure, and export competitiveness are therefore complements in sustained structural transformation. The same issue arises when workers move because they must rather than because policy makes migration more attractive. Section 9 asks how formalization capacity shapes reallocation after climate shocks and conflict.

9 Resilience to Climate Change and Conflict

Section 8 showed that reallocation is productive only when receiving labor markets can absorb new entrants. Large climate or conflict shocks are the policy-free version of that same mechanism, with migration flows that are forced rather than induced. This section stress-tests the economy against two shocks that have repeatedly reshaped low-income spatial economies and that differ in precisely the dimension the model cares about. Climate change tests resilience to broad and persistent damage to the agricultural base, while conflict tests resilience to sudden, spatially concentrated displacement. In both cases the decisive question is whether the economy converts forced reallocation into productive employment or into persistent informal congestion.

9.1 Climate change

Climate change provides a demanding test of the resilience margin because it damages the agricultural sector from which workers are already expected to reallocate. I model climate exposure through persistent agricultural-productivity losses, localized shocks, recurrent drought, and agricultural-price volatility. Each experiment is evaluated under both projection-consistent and current formalization capacity, corresponding to the roughly 17-year and 26-year queues established in Section 6.3. Appendix H and Online Appendix OA-7 report the complete scenario design, spatial decompositions, and stochastic results.

The results reveal two distinct patterns. Under persistent national warming, the largest welfare losses can fall on urban informal workers rather than rural producers, as higher food prices erode urban purchasing power while agricultural earnings partly adjust. Greater formalization capacity does not substantially reduce the proportional welfare loss from this shock, although its development gains survive in levels. By contrast, formalization plays a direct resilience role under local and temporary shocks by making the resulting migration more productive and preventing agricultural volatility from generating persistent formalization risk.

9.1.1 Persistent warming, food prices, and structural transformation

A broad decline in agricultural productivity produces a striking incidence pattern. Although the damage originates in rural areas, rural workers are partly protected by the resulting rise in food prices, which supports agricultural earnings despite lower physical productivity. In this low-connectivity economy, costly food imports limit substitution away from domestic production. Urban households therefore pay more for food without receiving the corresponding income gain. The burden is especially severe for informal workers, whose expenditure is most food-intensive and whose wages respond weakly to agricultural prices.

Persistent warming can consequently harm urban households proportionally more than rural households, narrowing the urban–rural real-wage gap and slowing both urbanization and structural transformation. This differs from a geographically concentrated shock. Local damage lowers productivity in the affected region while leaving most of the national food supply intact, encouraging migration towards unaffected locations. Under nationwide warming, food prices rise throughout the economy and the urban cost-of-living channel can dominate.

Greater formalization capacity does little to reduce the proportional loss from this national shock. In the most severe damage scenario in Appendix H, an extreme case rather than the central projection, national welfare falls by 55.9 percent under projection-consistent capacity and by 53.7 percent under current capacity, with urban losses exceeding rural losses in both regimes (Figure 6, panel (a)). These changes are measured relative to each regime's own zero-damage baseline and do not imply that weak formalization is protective. The higher-capacity economy begins with substantially greater welfare and productive activity and remains better off after warming, despite experiencing a similar percentage decline. This is notable because it contains substantially more formal urban employment and economic value exposed to the food-price channel.

Formalization therefore raises resilience in levels rather than providing proportional insurance against persistent warming, and cannot neutralize national agricultural damage. Climate vulnerability consequently cannot be inferred from agricultural exposure alone. In economies with large informal urban sectors and costly food trade, agricultural damage can become an urban cost-of-living crisis and an obstacle to structural transformation.

9.1.2 Extreme events, migration, and formalization capacity

Local droughts and other extreme events create a different resilience problem. Temporary agricultural losses displace rural workers and accelerate migration, whether they occur along a low- or high-warming path. Because moving is costly and urban labor-market attachment persists, many displaced workers do not return after rural productivity recovers. Transitory shocks can therefore produce lasting urbanization. Formalization capacity determines whether this reallocation moves workers into productive employment or leaves them accumulating in the informal queue.

To isolate this mechanism, I impose temporary drought shocks of varying duration and geographic breadth on rural agricultural productivity and trace the resulting migration and labor-market adjustment. In the all-zone episode, national welfare rises by 2.4 percent under projection-consistent capacity but by only 1.1 percent under current capacity, as stronger capacity converts displacement into more productive reallocation. Welfare rises at all because the drought's productivity damage is transitory while the reallocation it forces is permanent. The shock front-loads a movement out of agriculture that the baseline delivers more slowly. As in the conflict experiments below, such per-capita welfare movements reflect reallocation and composition, not a benefit of the shock. Urban-worker value nevertheless falls by approximately 5.3 and 5.5 percent, respectively, because receiving labor markets bear the congestion costs. Formalization improves the aggregate absorption of displaced workers without eliminating losses for urban incumbents.

Stronger capacity also stabilizes the long-run transformation. Under agricultural-price volatility, all simulated economies continue to urbanize and formalize, but the 10–90 percentile band of the terminal formal-employment share is 2.2 percentage points under projection-consistent capacity, compared with 5.9 points under current capacity (Figure 6, panel (b)). When absorption is weak, adverse agricultural shocks leave formal employment lower for longer.

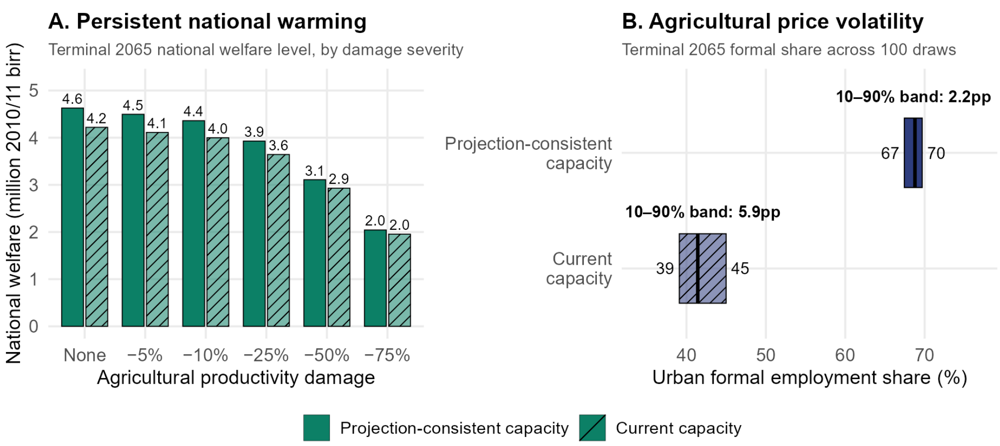


Figure 6: Formalization capacity preserves welfare in levels under persistent warming and narrows the spread of formalization outcomes under agricultural volatility.
Notes: Panel (a) reports the population-weighted national lifetime value in 2065 under persistent agricultural-productivity losses of increasing severity. Panel (b) reports the median and 10–90 percentile range of the 2065 urban formal employment share across 100 draws of recurring agricultural world-price shocks. Solid bars denote projection-consistent capacity and hatched bars current capacity. Welfare is expressed in constant 2010/11 birr. Source: author's computation.

Finally, I embed the model in three Shared Socioeconomic Pathway scenarios. They describe successful mitigation, high warming, and high warming combined with more frequent extreme events. Moving from successful mitigation to high warming lowers 2065 urban-worker lifetime value by a further 4.5 percentage points under projection-consistent capacity and 4.1 points under current capacity. Both figures are changes in the percentage deviation from each regime's own no-damage baseline. Adding more frequent extreme events costs a further 0.2 and 0.3 points on the same basis. Limiting mean warming remains the first-order objective, but formalization capacity governs the labor-market consequences of the displacement that cannot be avoided.

Climate resilience in perspective. Formalization capacity complements climate policy rather than substitutes for it. Its resilience value is strongest alongside competitive export industries and reliable trade networks that let households import food when domestic agriculture is impaired. Climate preparedness therefore requires stronger absorptive institutions alongside agricultural adaptation, food security, trade access, urban housing, and protection for informal households.

9.2 Conflict, displacement, and urban absorption

Conflict provides a complementary test of the economy's capacity to absorb reallocation. Persistent warming damages much of the agricultural system simultaneously. Conflict is instead concentrated in particular regions and can displace large numbers of workers toward unaffected cities. The central question is whether those receiving labor markets, housing markets, and food systems can turn forced migration into productive reallocation rather than persistent congestion.

I model conflict as a temporary regional deterioration in amenities, rural and urban productivity, and public employment, followed by recovery. The experiments vary the affected region, severity, onset, and recovery speed and are evaluated under both formalization-capacity regimes. The main result is a sharp distinction between national and local resilience. Spatially contained conflict can leave terminal national aggregates close to baseline even while conflict regions lose population persistently and receiving cities bear substantial welfare costs. Appendix H summarizes the broader experiment set, with complete regional decompositions in Online Appendix OA-7.

This distinction is consistent with the empirical conflict literature. Regional aggregates can recover after severe spatially concentrated destruction (Davis and Weinstein, 2002; Miguel and Roland, 2011), while local income losses, displacement, and household-level welfare effects can persist much longer (Abadie and Gardeazabal, 2003; Kondylis, 2010; Fiala, 2015; Ibáñez and Vélez, 2008). For Ethiopia, recent phone-survey evidence likewise documents substantial food-security losses concentrated among non-farm livelihoods (Abay et al., 2023).

9.2.1 National resilience and persistent displacement

When conflict remains regionally contained, unaffected parts of the economy provide a powerful absorption margin. Following severe conflict in Oromia, terminal national welfare is approximately 0.24 percent above the corresponding capacity-regime no-conflict baseline under projection-consistent capacity and 0.09 percent below it under current capacity. For Somali, the corresponding changes are $+0.70$ and $+0.58$ percent. National aggregates can therefore recover almost fully even after large local shocks

(Figure 7).

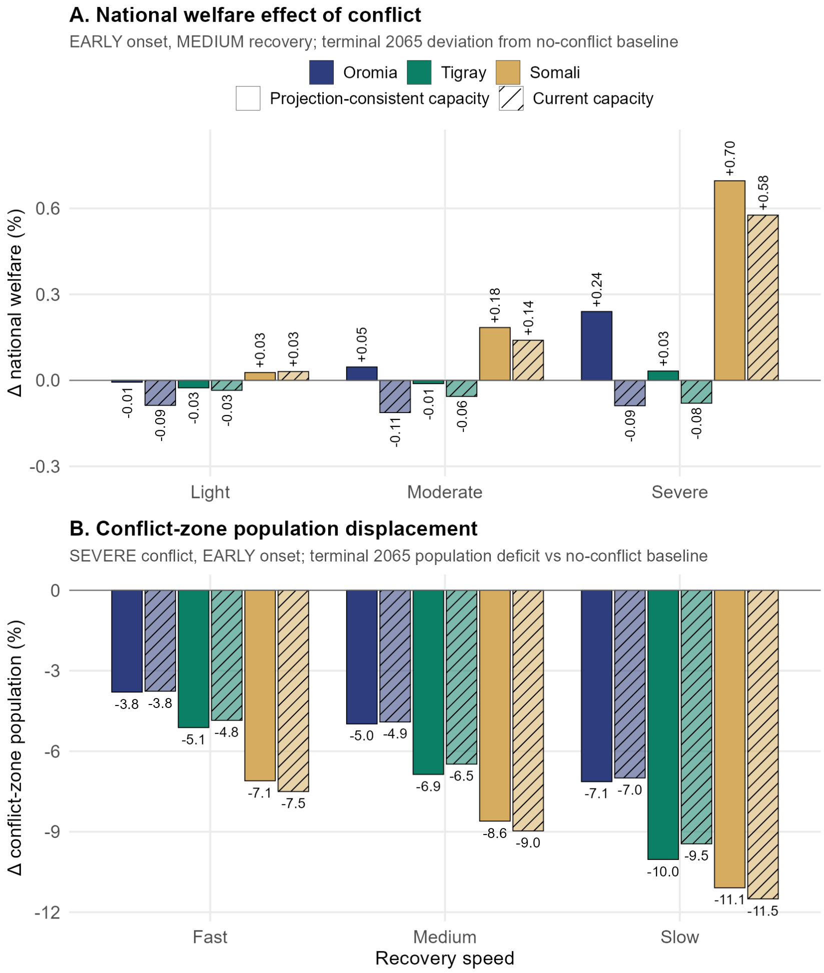


Figure 7: Spatially contained conflict leaves terminal national aggregates near baseline while receiving cities absorb the loss.

Notes: Terminal 2065 outcomes for regional conflict episodes in Oromia, Tigray, and Somali, relative to the no-conflict baseline. Panel (a) varies severity and panel (b) recovery speed, under projection-consistent and current capacity. National welfare excludes mortality and other non-economic costs. Appendix H and Online Appendix OA-7 report the full decompositions and extreme-tail cases. Source: author's computation.

This does not imply that conflict is economically benign. The aggregate combines recovery in the affected region with reallocation elsewhere and changes in the spatial composition of population. The model also excludes mortality, insecurity, unmeasured asset destruction, and other human costs. Positive terminal GDP or per-capita welfare therefore cannot be interpreted as a benefit of conflict.

The local consequences are much more persistent. Following severe episodes, populations in conflict regions remain roughly 5 to 9 percent below their baseline paths even after local fundamentals recover, with larger losses under slower recovery or repeated conflict. A temporary shock can therefore permanently alter where people live.

The persistence comes from displacement rather than permanent destruction. Evidence does not imply a sharp duration threshold, but shows that multi-year displacement can generate lasting labor-market re-sorting and non-return (Kondylis, 2010; Fiala, 2015). The model produces the same force. Once displaced workers have paid moving costs and entered destination labor markets, returning can remain unattractive even after conditions at home recover.

Formalization capacity determines what that displacement becomes. With stronger capacity, more displaced workers progress from informal entry into formal employment, allowing receiving cities to convert migration into productive urban growth. Under current capacity, the same inflow accumulates in informal employment, lengthens the queue, and places greater pressure on informal earnings, housing, and urban services.

These results rest on one assumption. Displaced workers enter destination labor markets under the same origin-specific entry rules as any other migrant and face the same formalization hazard. The first-order cost of displacement, a mass arrival that lengthens the queue, is therefore endogenous rather than assumed. Individual disadvantages of the displaced, such as lost networks, language, documentation, and trauma, would lower their absorption further. The congestion cost reported here is accordingly a lower bound, in line with the host-city evidence in Calderón-Mejía and Ibáñez (2016) discussed below. One simplification runs the other way. Displaced workers of urban origin enter destination markets at the destination's formal share, which is generous for workers who have just lost a job.

9.2.2 The local incidence hidden by national recovery

The receiving-city incidence is stark. In the severe Oromia experiment, all 35 cities outside the conflict zone gain population, but 33 experience lower per-capita welfare. Labor supply and housing demand rise immediately, while employment composition and housing supply adjust only gradually. National recovery can therefore coexist with losses in almost every city absorbing displaced workers.

Per-capita welfare within the conflict region can also rise after substantial population loss. This is a composition effect, not a gain from conflict. The remaining population has access to more local land and other productive factors, while displaced residents no longer enter the local denominator. Conflict outcomes must therefore be evaluated using displacement, population loss, host-city welfare, and unpriced human costs alongside GDP and per-capita measures.

The segmented urban labor market is central to this incidence. Forced migrants of rural origin enter informal employment and reach formal jobs only through the formalization process, while urban-origin migrants enter at the destination's current employment shares. When capacity is weak, informal workers in receiving cities bear most of the additional competition while formal incumbents remain partly insulated by restricted entry. A single urban labor market would conceal both who bears the loss and why.

This pattern mirrors evidence from actual displacement episodes. In Colombian cities, displacement-driven labor-supply shocks increased informal employment and reduced informal wages while leaving formal wages largely unchanged (Calderón-Mejía and Ibáñez, 2016). Syrian refugee inflows into Turkey displaced native workers primarily from informal rather than formal jobs (Tumen, 2016), while refugee arrivals in Tanzania imposed welfare costs on host populations, particularly in urban areas (Alix-Garcia and Saah, 2010). These findings are consistent with the model's central mechanism. Displaced workers initially compete in the informal market, while restricted formal entry partially insulates incumbents.

9.2.3 The limit of domestic absorption

At the catastrophic tail, the domestic absorption margin is exhausted. Severe shocks to the largest regions can displace more workers than unaffected cities can house and employ while also creating food demand beyond what the remaining agricultural system can accommodate. This boundary appears only when both the affected population and displacement response become very large.

The limit reflects the model's restricted external adjustment margins. Rural land is fixed, housing adjusts gradually, agricultural imports are capped, and international migration is excluded. It is therefore a domestic absorption limit rather than evidence that equilibrium would fail in the wider world. In practice, pressure beyond this boundary could instead produce cross-border displacement, emergency settlements, rationing, or other non-market responses. Greater formalization capacity expands the range of displacement that domestic cities can absorb productively.

Fear-driven migration matters more for this boundary than the direct loss of output. Holding productivity damage fixed, a larger deterioration in amenities generates much greater displacement and stronger pressure on receiving cities, consistent with evidence that fear of violence can drive migration beyond realized economic damage (Adhikari, 2013; Ibáñez and Vélez, 2008). Conflict resilience is therefore fundamentally an absorption problem. What matters is not only how much productive capacity is destroyed, but where displaced workers go and whether receiving labor, housing, and food markets can accommodate them.

Conflict resilience in perspective. Greater formalization capacity makes forced reallocation more productive by allowing receiving cities to absorb displaced workers into formal employment. It does not prevent violence or capture mortality, insecurity, asset loss, and other human costs outside the model. The resilience benefit is therefore narrower but economically important. Stronger absorption reduces the likelihood that forced migration becomes persistent informal congestion.

10 Robustness

The main conclusions survive a broad set of alternative parameters, dynamic paths, structural specifications, and migration assumptions. Stronger formalization capacity continues to produce a more formal and productive economy, the main welfare ordering across capacity regimes is preserved, and large rural–urban reallocations continue to generate national gains alongside losses for urban informal workers. Two mechanisms, nonhomothetic food demand and access to traded-goods markets, are more consequential. Table 7 summarizes the principal checks. Appendix F and Online Appendix OA-5 report the complete battery, including group-level welfare decompositions and alternative target trajectories.

Table 7: Robustness of the principal welfare and reallocation results

Check	Δ urban–rural value ratio, 2065	Conclusion
Structural parameters, $\pm 10\%$	-13.4% to $+6.0\%$	Group ordering preserved
θ–ψ_0 identification ridge	-0.3% to $+0.7\%$	Stable
Alternative structural specifications	-7.2% to $+3.1\%$	Stable
Literature-parameter substitutions	-30.4% to $+15.0\%$	Headline signs preserved
Productivity and amenity drift	-12.9% to $+17.1\%$	Headline signs preserved
Alternative demographic paths	-2.4% to $+2.7\%$	Stable
Calibration window and regional sample	0.0% to $+0.03\%$	Stable
Partial rural-to-formal entry	-16.6% to -23.0%	Reallocation result preserved
Homothetic demand or no subsistence floor	-85.5% to $+68.0\%$	Load-bearing
Near-autarky	-62.5%	Load-bearing

Notes: Changes are deviations of the 2065 population-weighted urban–rural lifetime-value ratio from its baseline value of 2.606 under projection-consistent capacity, $\theta = 3.25$, except the partial-entry row, which reports the urban-worker welfare effect. Reported ranges span all variants within each check. Appendix F describes each experiment and reports the complete outcome decomposition. Source: author's computation.

Local parameters and the identification ridge. The quantitative results are insensitive to most local parameter changes. Varying the principal structural parameters moves the 2065 urban–rural lifetime-value ratio by less than four percent in fifteen of sixteen cases. The main exception is discounting. Reducing β by ten percent lowers the ratio by 13.4 percent and substantially reduces lifetime-value levels. This largely reflects the mechanical effect of discounting on the value of future income and leaves the ordering of rural, informal, and formal workers unchanged.

The results are even more stable along the θ–ψ_0 identification ridge. Across this region, the urban–rural value ratio varies by less than one percent. The independent micro and cross-city evidence used to distinguish current from projection-consistent formalization capacity is therefore important for locating the economy within the ridge, but not for generating the aggregate welfare ordering.

Alternative functional forms preserve the main mechanisms as well. Freezing informal agglomeration, imposing symmetric trade substitution, varying housing-supply responsiveness, or replacing the baseline formalization hazard changes quantitative magnitudes without overturning the central distinction between migration into cities and access to formal employment. A pure-gravity migration specification does not generate an interior mobility response and is reported as an off-support boundary case in Appendix F.

Dynamics, targets, and calibration choices. Alternative productivity growth, amenity paths, demographic trajectories, and calibration targets change long-run magnitudes but not the direction of structural transformation. Across these exercises, the economy continues to urbanize and formalize and the ordering across formalization-capacity regimes remains intact. Larger changes in productivity or amenities naturally generate larger level effects, while the more empirically disciplined alternatives leave the main transition qualitatively unchanged.

Calibration choices matter little. Re-anchoring the productivity inversion to 2007 rather than 2014 changes it by only 0.03 percent, while excluding conflict-affected Tigray from the calibration objective is effectively immaterial. Across alternative benchmark trajectories, the selected calibration remains close to the best-fitting configurations and preserves the same long-run transformation.

Load-bearing economic mechanisms. Nonhomothetic food demand and integration into traded-goods markets matter much more. This sensitivity is economically informative because food prices and market access are central to the model's account of structural transformation, climate exposure, and spatial reallocation.

Replacing nonhomothetic demand with homothetic preferences reduces the 2065 urban–rural lifetime-value ratio from 2.606 to 0.379, reversing the urban premium. The logic runs through the composition of demand. With homothetic preferences the discretionary food share no longer falls as incomes rise, so productivity growth in cities raises formal output without raising the demand for it in proportion. Formal goods must then be absorbed at falling relative prices while food demand remains strong and supports agricultural earnings. Urban real earnings consequently fall below rural ones. The homothetic economy still urbanizes at close to the baseline rate (Table 30). It therefore moves workers into cities whose lifetime value lies below the countryside's and cannot reproduce the urban premium of Fact 2 (Section 5). The sensitivity validates the estimated demand system rather than exposing a fragility of the results.

Removing the subsistence requirement moves the ratio in the opposite direction, to 4.377. The subsistence floor obliges households to buy a fixed quantity of food before any other spending, which keeps food demand income-inelastic at low incomes and supports agricultural prices. Without the floor, spending shifts toward urban goods at every income level, so food prices and rural earnings fall. Urban households are at the same time relieved of a fixed food outlay at urban prices. Rural households bear the loss (Appendix F.3). These large effects are disciplined by the expenditure data. The food budget share declines with log expenditure at an estimated slope of -0.103 with a standard error of 0.005. The importance of food demand therefore comes from a measured feature of household expenditure rather than an assumption chosen to generate the headline results.

Trade integration is similarly important. Under near-autarky, the urban–rural lifetime-value ratio falls to 0.976 and remains below parity throughout 2015–2065. The mechanism works mainly through food prices. Cities can no longer import basic food, so a growing urban population must be fed from domestic agriculture and urban food prices rise. The formal-goods channel does not run through lost exports. The calibrated economy is a net importer of formal goods and begins far from export parity (Sections 6 and 8). Autarky therefore removes the ceiling that delivered import prices place on formal-goods prices, not an export outlet. Because food absorbs roughly three-quarters of household spending (Section 3.4), the food channel dominates. Urban households buy their food at the higher prices, while rural producers sell into a tighter food market. Urban informal and formal workers lose sharply, while rural households benefit from the change in relative prices. Literature-based alternatives for agricultural trade substitution and export capacity change the magnitude of these effects but preserve the conclusion that access to traded markets supports the urban productivity premium.

Alternative access to formal employment. The reallocation result does not depend on requiring every rural migrant to enter informal employment first. Allowing a direct rural-to-formal entry probability of up to 30 percent still leaves urban-worker welfare between 16.6 and 23.0 percent below the no-reallocation path. The urban loss therefore reflects the scale of migration relative to cities' capacity to absorb new workers, rather than a knife-edge assumption about migrants' initial employment state. Appendix F.2

reports the complete exercise.

Finally, the auxiliary identification exercises continue to support the current-capacity regime as a conservative description of present formal absorption relative to projection-consistent capacity. Appendix E.13 reports the underlying evidence and uncertainty.

The robustness exercises therefore separate quantitative magnitudes from the mechanisms of interest. Discounting, productivity growth, food demand, housing supply, and trade access can materially affect levels. The central distinction between migration into cities and access to productive urban employment, and the role of formalization capacity in governing that transition, survives the economically relevant alternatives.

11 Conclusion

Urbanization measures whether workers have reached cities. Structural transformation requires that they reach the productive labor markets within the cities. This paper has shown that migration into cities and access to productive urban employment are distinct transitions. The capacity to move workers from informal into formal employment governs whether urban growth translates into productivity, welfare, and resilience. I develop a dynamic spatial framework in which migrants enter an informal queue and reach formal work through an endogenous, congestible transition whose prospects feed back into migration. The framework connects the Lewis–Kuznets account of structural transformation and the Harris–Todaro logic of expected urban employment to modern spatial models of migration and reallocation (Lewis, 1954; Kuznets, 1955; Harris and Todaro, 1970; Fields, 1975; Redding and Rossi-Hansberg, 2017; Bryan and Morten, 2019; Tombe and Zhu, 2019; Morten and Oliveira, 2024). It further places the formal–informal boundary documented in the informality literature inside a general equilibrium in which employment composition, prices, trade, housing, and location adjust jointly (La Porta and Shleifer, 2014; Meghir et al., 2015; Ulyssea, 2018).

The Ethiopian application shows how and why segmented labor markets matter in practice. I combine satellite and geospatial records with restricted access establishment, employment, household, demographic, and agricultural microdata to construct a spatial dataset covering 681 rural and urban units and quantify the model over 121 locations. The model reproduces the spatial structure of wages, rural incomes, market access, migration, and employment composition, while separately measured worker transitions and cross city informality discipline the formalization mechanism rather than the aggregate development path alone.

The applied model reveals a large gap between the pace at which Ethiopian cities currently move workers into formal jobs and the pace needed for urban growth to occur alongside a sustained decline in informality. At current capacity, roughly 2 to 4 percent of informal workers reach formal employment each year, implying an average wait of about 26 years. For informality to decline as the population urbanizes, that transition must rise to roughly 6 to 7 percent per year, shortening the expected wait to about 17 years. Moving from current capacity to this faster pace raises real GDP by 13.1 percent by 2065 and national welfare over the transition by 9.7 percent. The urban formal employment share rises from 41.1 to 67.5 percent, while the urban population share changes by less than one percentage point. Formalization capacity therefore determines what growing cities become far more strongly than whether they grow.

This gap places the economy on the wrong side of an informality trap. When workers leave the informal queue quickly enough, congestion falls and formalization becomes easier for those who remain. Under the economy's current capacity, migrant entry replenishes the informal pool faster than workers move into formal employment, so the queue lengthens even as cities continue to grow. Informality can then rise rather than fall with urbanization. Closing the capacity gap raises welfare through reallocation rather than uniform wage growth. Rural households gain as outmigration raises rural earnings, informal workers gain because access to future formal employment becomes more valuable, and formal incumbents lose part of the scarcity premium created by restricted entry. Medium and small cities account for about 70 percent of the increase in formal employment. The binding constraint is therefore the economy's capacity to move workers into formal employment, not simply the expansion of the largest city.

The policy counterfactuals show that formalization capacity conditions both the magnitude and the incidence of development policy. Policies whose gains require workers to change labor-market states depend most strongly on whether workers can move through the informal queue. Formal productivity, migration, roads, and external demand generate broader gains when absorption is stronger, while interventions that raise rural or informal productivity and household purchasing power reach workers directly when formalization remains slow. The mobility experiment makes the incidence especially clear. At current capacity, lowering migration costs raises long-run GDP and national welfare, yet lowers the value of entering urban employment and the welfare of informal workers as additional migrants accumulate in informal work and congest the market. National gains can therefore coexist with losses in the cities absorbing the reallocation. A model with one urban labor market would miss this incidence.

The broader implication is a sequencing logic rather than a ranking of policies. While formal absorption remains weak, policies that raise productivity and purchasing power where workers already are generate gains without relying on rapid formalization. Investments that expand access to formal employment relax the bottleneck itself. As the queue clears, mobility, infrastructure, and industrial policy translate more readily into productive formal employment, and a larger formal sector increases the value of external demand. Formalization capacity, productive firms, infrastructure, and export competitiveness are therefore complements in sustained structural transformation.

The climate and conflict results show that the same margin also shapes resilience. Persistent warming can impose especially large losses on urban households, particularly informal workers, because higher food prices partly support rural earnings while reducing the purchasing power of households that buy food. Greater formalization capacity still leaves the economy better off in levels, but it does not substantially reduce the proportional welfare loss from a nationwide agricultural shock. Its resilience role is stronger when shocks displace workers across locations. Under local climate shocks and conflict, formalization capacity determines whether displaced workers move into productive employment or accumulate in informal work. Spatially contained conflict can therefore leave national aggregates close to baseline while generating persistent population losses in affected regions and welfare losses in the cities that receive displaced workers. In the most severe scenarios, displacement exceeds the capacity of surviving labor, housing, and food markets to absorb it.

More generally, this paper contributes a portable spatial GE framework for multiple connected labor markets within locations. Existing spatial models are well suited to reallocating workers across places, but typically represent employment access within each destination through a single labor market. The framework separates location choice from labor market access, allowing workers in the same place to face different wages, institutions, entry conditions, and transition probabilities. Beyond informality, the same distinction applies to labor markets segmented by skill, migration or legal status, contract type, or restricted sectoral access.

The model quantifies the value of greater formalization capacity without separating the margins that produce it (Section 2). A central task for future work is to identify which of firm entry and expansion, vacancy creation, training and matching, and registration and enforcement most effectively relax the formalization bottleneck, and at what fiscal and administrative cost.

The central takeaway is simple. Movement between labor markets within places can be as consequential as movement across places. Capturing the demographic dividend and building resilience to future shocks requires more than moving workers from farms to cities. Cities must also be able to move workers into productive employment after they arrive. Formalization capacity is therefore not merely a consequence of structural transformation. It is one of the conditions that makes structural transformation possible.

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A Data Construction

This appendix documents the data construction underlying the quantitative analysis. I combine administrative boundaries, population and settlement data, satellite imagery, agricultural surveys, urban labor market microdata, household surveys, national accounts, price data, demographic sources, and transport networks to construct a common spatial and temporal framework for Ethiopia. The resulting data infrastructure contains 681 spatial units, comprising 126 urban centers and 555 rural units, observed over 2000–2020. For equilibrium computation, these units are aggregated to 121 locations, comprising 43 urban and 78 rural locations. The principal constructed objects are agricultural productivity and rural income, urban formal and informal employment and earnings, spatial and temporal price indices, bilateral travel costs, demographic dynamics, amenities, and migration moments.

Table 8 summarizes the principal source families. This appendix focuses on construction choices that matter for interpreting the empirical and quantitative results. More detailed construction mechanics for agriculture, travel times, demographics, and measured amenities are reported in Online Appendix OA-1. Additional measurement and harmonization detail is reported in Online Appendix OA-2.

Table 8: Principal data sources

Source	Coverage	Role in the analysis
Panel A. Administrative boundaries and population		
2007 woreda boundaries (CSA/USCB; Van Dijk concordance)	2007	Spatial backbone and common geographic reference
CSA administrative boundaries	2013–2020	Administrative concordances and geographic validation
WorldPop adjusted population surfaces	2000–2020	Annual spatial population estimates
CSA Population and Housing Census	2007	Urban population benchmark and calibration anchor
WorldPop/GRID3 settlement boundaries	2001–2020	Settlement validation
Panel B. Built environment and geography		
GHS-BUILT-S R2023A (JRC)	2000, 2005, 2010, 2015, 2020	Built-up component of urban delineation
GHS-UCDB R2024A (JRC)	Cross-section	External validation of delineated urban centers
SRTM elevation (NASA)	Static	Elevation and terrain measures
ESA CCI/MODIS land cover	2003, 2008, 2013	Cropland and land-cover measures

continued on next page

Table 8 continued

Source	Coverage	Role in the analysis
DMSP and VIIRS night lights (NOAA)	2000–2021	Urban activity and productivity validation
Panel C. Climate and agriculture		
CHIRPS v2.0	1981–2020	Rainfall levels, anomalies, and drought measures
ERA5 (ECMWF)	2000–2020	Temperature and degree-day measures
MODIS vegetation products (NASA)	2000–2020	Vegetation conditions and agricultural yield prediction
Agricultural Sample Survey (CSA)	11 usable waves through 2022	Woreda-level crop production, area, and yields
Ethiopian Socioeconomic Survey (World Bank/CSA)	2011, 2013, 2015, 2018	Crop prices, household expenditure, and validation
FAOSTAT agriculture	Multi-decade	National agricultural production benchmarks
Panel D. Urban labor markets and migration		
Urban Employment Unemployment Survey (CSA)	11 waves, 2003–2018	Formal and informal employment, wages, migration tenure
Labour Force Survey/National Labour Force Survey (CSA)	1999, 2005, 2013, 2021	Migration and employment benchmarks
Informal Sector Survey (CSA)	1996, 2003	Own-account and informal-enterprise income benchmark
Ethiopian Socioeconomic Survey	2011, 2013, 2015	Supplementary migration moments
Panel E. Prices, national accounts, and demographics		
National Bank of Ethiopia national accounts	2005–2021	Sectoral value added and national accounting aggregates
FAOSTAT CPI	2000–2025	Temporal deflation
World Development Indicators	Multi-decade	Macroeconomic benchmarks
HICES 2004/05 (CSA)	2004/05	National food expenditure share
Demographic and Health Surveys	2000–2016	Fertility and demographic transition
UN World Population Prospects	2000 onward	Mortality, fertility, and demographic benchmarks
Panel F. Infrastructure and amenities		
OpenStreetMap Ethiopia	2018 snapshot	Road network and access to health and education facilities
Ethiopian Roads Authority road network	2009	Supplementary trunk-road network

$PM_{2.5}$ estimates (Van Donkelaar et al.)	2018	Air-quality component of measured amenities

Notes: The table lists the principal source families entering the published data construction and validation exercises. Several sources contain multiple survey rounds, raster products, or administrative vintages. Detailed construction procedures for selected data pillars are reported in Online Appendix OA-1.

A.1 Spatial framework

The spatial construction separates urban labor markets from their rural hinterlands while retaining a common national geography. I first delineate annual urban footprints, then overlay these footprints on a common 2007 woreda grid. Urban areas form distinct spatial units, while the residual non-urban portions of the woreda grid form the rural units. Population is assigned consistently to both using census-calibrated WorldPop surfaces. This procedure produces 126 urban centers and 555 rural units.

A.1.1 Urban boundary delineation

I construct urban boundaries for 126 Ethiopian cities over 2000–2020 using population density and built-up surface. The procedure follows the logic of density-based urban definitions used by the OECD and the *Atlas of Urban Expansion*, while adapting the thresholds to Ethiopian settlement patterns (OECD, 2012; Angel et al., 2016).

Dual-mask definition. At 100-meter resolution, a cell is classified as urban when two conditions hold. First, population density must exceed 1,250 persons per square kilometer. This threshold is below the 1,500-person benchmark commonly used in higher-income settings because Ethiopian urban settlement is less spatially compact. Second, at least 25 percent of the cell must be built up according to GHS-BUILT-S R2023A (Pesaresi and Politis, 2023). The population threshold prevents dispersed structures from being classified as urban, while the built-up threshold prevents densely populated agricultural areas from entering the urban footprint.

The 25 percent built-up threshold was selected after comparing alternatives. A 5 percent threshold generates substantial over-detection in densely settled highland areas. A 50 percent threshold excludes substantial portions of Ethiopian towns characterized by relatively low building coverage. The intermediate threshold, together with the population-density condition, provides a substantially closer match to the census distribution of urban population.

Population density is calculated from census-calibrated WorldPop surfaces. GHS-BUILT-S is observed at five epochs, 2000, 2005, 2010, 2015, and 2020. Built-up fractions for intervening years are obtained by linear interpolation.

Spatial and temporal consistency. Four additional restrictions stabilize the panel. First, before applying the urban mask, cells are assigned to the nearest city seed using a Voronoi partition. This prevents neighboring cities from mechanically merging into a single footprint. Second, cities identified in the 2007 census calibration remain represented throughout the panel, avoiding artificial entry and exit caused by changes in remote-sensing quality. Third, urban land conversion is treated as persistent: once a cell enters an urban footprint, it remains urban in subsequent years. This restriction is consistent with the persistence of built development documented by Angel et al. (2016). Fourth, annual WorldPop estimates are smoothed with a three-year moving window and a 15 percent spike filter to reduce high-frequency variation generated by the population model rather than observed demographic change.

Highland exceptions. The general algorithm over-connects settlements in parts of the densely populated southern highlands. Four city footprints therefore require additional restrictions. Hawassa and Sodo use census-anchored boundary rules that prevent surrounding rural settlements from being absorbed into the city. Dessie and Kombolcha are separated because the general mask otherwise joins their continuously built corridor into a single urban area. These exceptions preserve the same underlying population and built-up criteria while preventing geographically implausible city mergers.

The resulting panel contains 126 urban centers observed over 21 years, or 2,646 city-year observations (Figure 8).

A.1.2 Rural spatial units

The rural geography begins from the 2007 woreda boundary system. Urban footprints are overlaid on this grid, and the non-urban remainder of each relevant woreda forms the corresponding rural spatial unit. This produces 555 rural units. Together with the 126 urban centers, the full spatial framework therefore contains 681 units.

Annual unit populations are calculated by integrating the census-calibrated WorldPop surface over the relevant geography. Urban and rural populations consequently use the same underlying population source and partition the national surface without double counting.

A.1.3 Validation of urban delineation

Table 9 compares the resulting urban system with external benchmarks. The constructed urban population share is 11.8 percent in 2007, below the 16 to 17 percent recorded

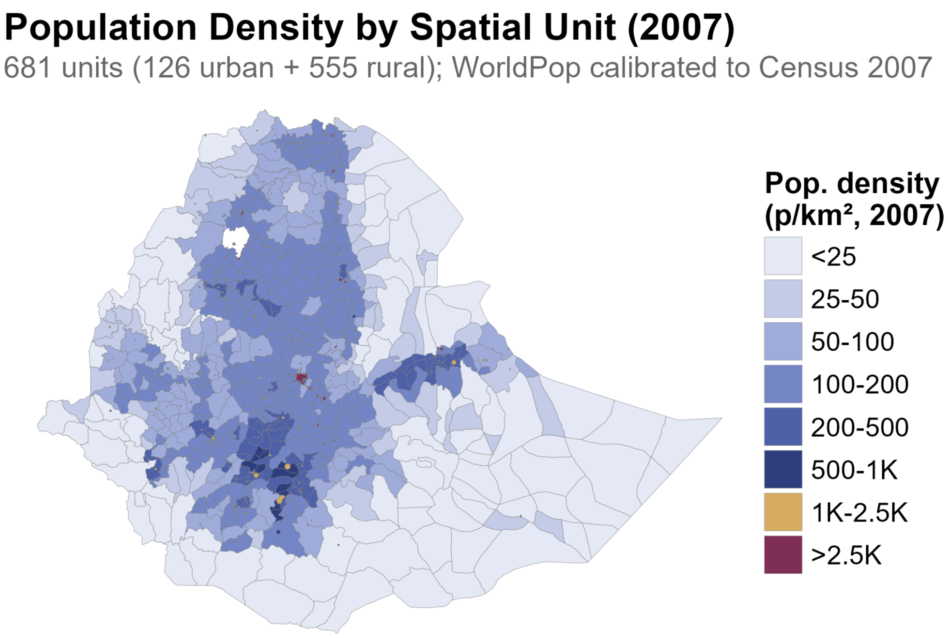

Figure 8: The spatial framework: urban and rural spatial units in Ethiopia.

Notes: Urban locations are shaded by population size. Urban boundaries require both population density of at least 1,250 persons per km^2 and a GHSL built-up surface share of at least 25 percent. The 681-unit partition covers 99.8 percent of national territory and is aggregated to 121 locations for the equilibrium computation. Source: author's construction from GHSL R2023A and WorldPop.

under the administrative national definition, as expected: the dual-mask criterion is deliberately stricter than administrative designation, and the same definitional ordering holds in 2011, when the constructed share of 12.1 percent lies below the World Bank national figure of 17.9 percent and the satellite-based DEGURBA figure of 20.8 percent (Appendix E.8). The procedure identifies 22 cities above 50,000 inhabitants and reproduces the census population of Addis Ababa closely. Eighty-nine percent of the delineated centers can also be matched to the independent GHSL Urban Centre Database.

A.1.4 Aggregation to model locations

The 681-unit geography provides the highest spatial resolution used in data construction. Solving the annual general equilibrium at this resolution would be computationally costly, so I aggregate the framework to 121 model locations, comprising 43 urban and

Table 9: Validation of the urban delineation

Outcome	External benchmark	Constructed value
Urban population share, 2007	16–17% (administrative)	11.8%
Cities above 50,000 inhabitants	Approximately 20	22
Total urban centers	Approximately 100–130	126
Addis Ababa population, 2007	2.7 million	2.74 million
Centers matched to GHSL UCDB	—	89%

Notes: The table compares the constructed urban geography with external demographic and settlement benchmarks. The urban population share uses census-calibrated WorldPop as the national population denominator; the external benchmark uses the administrative national definition, which is broader than the dual-mask criterion, so the constructed share is expected to lie below it (see Appendix E.8 for the full definitional comparison). The GHSL comparison reports the share of delineated centers that can be matched to an independently constructed GHSL urban center.

78 rural locations. Small urban centers with fewer than 15,000 inhabitants are combined with nearby urban locations, while rural units are aggregated to administrative zones. All underlying population, employment, income, and spatial characteristics are aggregated using definitions consistent with the corresponding economic object.

The aggregation preserves the margins central to the analysis, in particular the distinction between urban informal and formal employment, the spatial distribution of private formal wages, and variation in urban housing costs. The full 681-unit framework is retained for constructing inputs and for spatial validation; the 121-location geography is used for equilibrium computation.

A.2 Agricultural data

The agricultural construction combines eleven usable Agricultural Sample Survey waves, Ethiopian Socioeconomic Survey data, national agricultural accounts, and remotely sensed rainfall, temperature, vegetation, terrain, and land-cover measures. Administrative changes across survey waves are harmonized to a common woreda geography. Observed crop production and harvested area are then combined with the satellite and climate variables to construct a consistent panel of agricultural yields and productivity.

The Agricultural Sample Survey does not observe every woreda in every year. I therefore use an ensemble prediction model to interpolate agricultural yields in unsampled woreda-years. The prediction model is trained on observed survey yields and spatial and agro-climatic covariates. The resulting agricultural panel is used to construct agricultural value added per worker, the rural-income object entering the model, and the transitory productivity shock $\zeta^A_{i,t}$. The weather-based shock measure has a correlation of 0.758 with observed AgSS yields in the available survey cells; because AgSS information also disciplines other parts of the agricultural measurement, this comparison is a consistency check rather than fully independent validation. Online Appendix OA-1 reports the administrative concordance, crop and unit harmonization, prediction design, cross-validation, construction of agricultural employment, and sensitivity of the resulting productivity series.

A.3 Urban labor markets

The urban labor-market construction uses eleven waves of the Urban Employment Unemployment Survey between 2003 and 2018. The repeated cross-sections provide employment status, sector, earnings, worker characteristics, and, in selected waves, migration histories. Questionnaire coding changes substantially across waves, so variables are harmonized to a common employment and earnings classification before spatial aggregation. Survey weights are used throughout.

The 2020 UEUS wave is excluded because the available microdata are incomplete and omit entire regions, including Addis Ababa and Dire Dawa. The analysis therefore uses 2003, 2004, 2006, 2009, 2010, 2011, 2012, 2014, 2015, 2016, and 2018.

A.3.1 Formal and informal employment

Employment status is harmonized into six broad categories: government employees, private wage employees, employers, own-account workers, unpaid family workers, and domestic workers. The baseline informality measure assigns own-account employment primarily to the informal sector while allowing a small registered component. Let $L^I_{j,t}$ and $L^F_{j,t}$ denote informal and formal employment. The urban informality share is

$$\varphi_{j,t} = \frac{L^I_{j,t}}{L^I_{j,t} + L^F_{j,t}}, \tag{37}$$

where the baseline classification uses

$$L^I = 0.9 \times \text{Own account} + \text{Unpaid family} + \text{Domestic}, \tag{38}$$

$$L^F = \text{Government} + \text{Private wage} + \text{Employer} + 0.1 \times \text{Own account}. \tag{39}$$

The 90–10 split of own-account employment reflects the fact that a small share of self-employed enterprises are formally registered. All employment stocks are survey weighted. Because the harmonized formal category at this stage includes government employees, equation (37) defines an informality share among all urban wage employment. For the quantitative model, government employment is subsequently separated from private formal employment using the estimated government-employment share, and the model's *private* informality share applies the same classification to the remaining private formal stock. Across survey waves, the resulting national urban informality share ranges from 0.48 to 0.57, close to the approximately 0.55 benchmark from ILO statistics. A narrower enterprise-registration measure produces a substantially smaller share, approximately 0.21, illustrating the importance of distinguishing informal employment from informal-enterprise registration.

For the model itself, government employment is subsequently separated from private formal employment. The private formal wage therefore excludes government workers, while government employment and wages enter through the separate rule described below.

A.3.2 Own-account earnings

A central measurement problem is that UEUS wage questions are asked of employees but not of own-account workers. Own-account workers account for roughly 40 percent of urban employment, so a raw average of observed informal employee wages disproportionately represents domestic and casual wage workers and understates the earnings associated with self-employment. Across waves, this uncorrected procedure produces informal-to-formal earnings ratios between 0.14 and 0.31.

I use the 2003 CSA Informal Sector Survey to benchmark own-account income. The survey records enterprise profits for 16,866 informal enterprises in good and bad months. I define monthly enterprise income as

$$\text{profit}_{\text{monthly}} = \frac{\text{profit}_{\text{good month}} + \text{profit}_{\text{bad month}}}{2}. \tag{40}$$

The national survey-weighted mean is 121 ETB per month and the median is 90 ETB. Enterprises using unpaid family labor are adjusted for the imputed value of that labor using observed domestic-worker earnings.

To translate the ISS information into the UEUS earnings series, I construct a region-specific ratio between mean ISS enterprise income and the observed UEUS domestic-worker wage in 2003,

$$cf_r = \frac{\text{mean ISS enterprise income}_r}{\text{mean UEUS domestic wage}_r}. \tag{41}$$

The median correction factor across regions is 1.58. The pooled national estimate is 1.80 and is used where regional domestic-worker samples are too thin to support a stable region-specific estimate. The corrected informal-to-private-formal earnings ratio is approximately 0.43–0.58 across the reliable survey waves.

These magnitudes are more directly relevant for Ethiopia than wage-gap estimates based only on employees in substantially more formalized middle-income labor markets. In particular, the conditional employee gaps reported by Bargain and Kwenda (2014) are not treated as direct targets for the Ethiopian unconditional formal-to-informal earnings ratio.

A.3.3 The broader urban entry pool

For comparison with the Harris–Todaro and Fields tradition, I also construct a broader urban entry pool that combines informal employment with unemployment (Fields, 1975):

$$L_{I,\text{broad}} = L^I + U, \tag{42}$$

and

$$\varphi_{\text{broad}} = \frac{L_{I,\text{broad}}}{L_{I,\text{broad}} + L^F}. \tag{43}$$

Unemployment follows the survey's relaxed unemployment definition in the baseline series, with the stricter ILO search criterion retained as an alternative. The 2003 and 2004 surveys imply urban unemployment rates of 19.2 and 16.2 percent respectively, consistent with external estimates for Ethiopia during this period.

For descriptive Harris–Todaro comparisons, I benchmark earnings at the lower end of the informal-entry distribution using the twentieth percentile of 2003 ISS enterprise income, 29 ETB per month. The tenth percentile, 16 ETB per month, provides a lower-bound sensitivity check. Across UEUS waves, the broad urban entry-pool share ranges from approximately 0.58 to 0.68, compared with 0.48 to 0.57 for the narrower employment-based informality measure.

A.3.4 Government employment and wages

Government employment is modeled separately from private formal employment because it follows administrative staffing and national pay structures rather than the private labor-market mechanism. Using the UEUS zone-year panel, I estimate the government share of formal employment as

$$g_{j,t} = \beta_0 + \beta_{\text{pop}} \log(\text{pop}_{j,t-1}) + \beta_{\text{cap}} \mathbf{1}\{\text{regional capital}_j\}. \tag{44}$$

The estimated coefficients are $\beta_0 = 1.35$, $\beta_{\text{pop}} = -0.067$, and $\beta_{\text{cap}} = 0.051$. Government employment is therefore relatively more important in smaller cities and in regional capitals. The rule uses lagged population, making the government-employment component predetermined within each period of the equilibrium.

The government wage is considerably less spatially dispersed than private wages. Its UEUS median is approximately 1,800 ETB per month, or 21,600 ETB per year after annualization. Government workers are excluded from the private formal wage series used to recover formal-sector productivity and are retained as a separate employment category in the model.

A.3.5 Geographic assignment of labor-market data

The finest consistently available geographic identifier in the UEUS is the administrative zone. The underlying CSA frame contains roughly 76 zones, while the repeated survey waves provide usable information for approximately 50 distinct urban labor-market areas. I therefore map the 126 delineated cities to the corresponding UEUS zone where possible.

Of the 126 cities, 124, representing 99.4 percent of urban population in the spatial panel, can be assigned to a sampled UEUS zone. Fifteen have a one-to-one city-zone correspondence. For 21 additional cities, city names resolve otherwise ambiguous zone assignments. Six are the dominant city within a multi-city zone. The remaining 82 mapped cities inherit labor-market statistics from a zone containing multiple urban centers. Two cities lie outside UEUS coverage.

This geographic resolution places an important limit on interpretation. Labor-market variables may vary annually at the survey-zone level but should not be interpreted as independently measured city-level outcomes when several cities share the same zone. The descriptive relationship between informality and city size is negative, with a coefficient of approximately -0.016 per log point of population, but this relationship is not used as causal evidence about agglomeration.

A.3.6 City-level non-agricultural activity

Official national accounts provide sectoral value added but generally do not provide consistent city-level GDP outside Addis Ababa. I therefore construct city-level non-agricultural activity by allocating national sectoral value added across cities using observed sectoral employment. This produces an accounting measure that preserves national aggregates while introducing spatial variation from observed local labor allocation.

Let s index non-agricultural sectors, c cities, and t years. National accounts provide sectoral value added VA_{st}, while the UEUS and LFS provide city-sector employment L_{cst}. The baseline allocation assumes equal average value added per worker across cities within a given sector. The employment share of city c is

$$\omega_{cst} = \frac{L_{cst}}{\sum_{c'} L_{c'st}}, \tag{45}$$

and allocated sectoral value added is

$$VA_{cst} = \omega_{cst} VA_{st}. \tag{46}$$

City-level non-agricultural value added is then

$$NonAgVA_{ct} = \sum_{s \in \mathcal{S}_{nonag}} VA_{cst}. \tag{47}$$

By construction,

$$\sum_{c} NonAgVA_{ct} = \sum_{s \in \mathcal{S}_{nonag}} VA_{st}.$$

The employment surveys and national accounts use different sector classifications. I aggregate both to six broad groups: manufacturing, construction, trade and hospitality, transport and communications, public and social services, and other market services. This sacrifices fine industry detail in exchange for a stable concordance across survey years.

The equal-productivity assumption is relaxed in robustness exercises using night lights and formal wages as proxies for local productivity. In these specifications,

$$\widetilde{\omega}_{cst} = \frac{L_{cst}\Pi_{ct}^{\chi}}{\sum_{c'} L_{c'st}\Pi_{c't}^{\chi}}, \tag{48}$$

where Π_{ct} is the relevant productivity proxy and χ determines how strongly it affects the allocation. The baseline corresponds to $\chi = 0$. Because every specification preserves national sectoral totals, these exercises vary only the spatial distribution of non-agricultural activity.

I assess the resulting city rankings against independent night-light measures and compare their aggregate growth with national sectoral growth. These comparisons are validation exercises rather than independent measures of city GDP.

Formal and informal accounting components. For auxiliary accounting exercises, I further partition constructed non-agricultural value added using observed employment and earnings. This is not a directly observed national-accounts decomposition by formality status. It should therefore be interpreted as an accounting proxy rather than a measurement of formal and informal GDP.

Let Y_{ct}^{NA} denote constructed non-agricultural value added. For this accounting exercise, formal wage employment includes the protected wage-employment categories observed in the survey, including public employment. Denoting average formal earnings by w_{ct}^{F} and formal employment by L_{ct}^{F}, the formal wage bill is

$$WB_{ct}^{F} = w_{ct}^{F} L_{ct}^{F}. \tag{49}$$

The residual accounting component is

$$Y_{ct}^{INF} = Y_{ct}^{NA} - WB_{ct}^{F}, \qquad \widehat{y}_{ct}^{INF} = \frac{Y_{ct}^{INF}}{L_{ct}^{INF}}. \tag{50}$$

The corresponding accounting shares are

$$s_{ct}^{F} = \frac{WB_{ct}^{F}}{Y_{ct}^{NA}}, \qquad s_{ct}^{INF} = \frac{Y_{ct}^{INF}}{Y_{ct}^{NA}}. \tag{51}$$

This auxiliary decomposition differs from the private-formal wage object entering the structural model, which excludes government employment. It is used to assess the plausibility of the relative scale of formal and informal urban activity, not to treat observed wages as a complete measure of sectoral value added.

The residual construction is necessarily imperfect. Formal wages may differ from marginal products because of rents or public-sector wage premia, while national accounts may incompletely capture informal production. I therefore use alternative employment partitions and earnings definitions as sensitivity checks and compare the implied informal-income levels with household-survey evidence.

A.4 Price indices

Nominal income differences across space and time are converted to comparable real values using separate temporal and spatial price adjustments. The temporal component converts all monetary quantities to constant 2010/11 birr. The spatial component accounts for regional differences in food, housing, and transport costs.

A.4.1 Temporal deflation

Monthly FAOSTAT CPI observations are averaged over the Ethiopian fiscal year, July of year $t-1$ through June of year t, and rebased so that fiscal year 2010/11 equals 100. The deflator

$$d_t = \frac{100}{\mathrm{CPI}_t^{\mathrm{rebased}}} \tag{52}$$

converts nominal monetary values to constant 2010/11 birr. The resulting FAOSTAT series is essentially identical to the corresponding WDI CPI series: the calendar-year correlation is 1.000 and the maximum absolute percentage difference is 0.04 percent.

I infer a non-food CPI from the overall and food indices using the official 2016 consumption-basket weights,

$$\mathrm{CPI}_{\mathrm{overall}} = 0.54\,\mathrm{CPI}_{\mathrm{food}} + 0.46\,\mathrm{CPI}_{\mathrm{nonfood}}.$$

Urban and rural variants use food expenditure shares of 0.45 and 0.65 respectively, consistent with the substantially different consumption composition of Ethiopian urban and rural households (Dercon and Krishnan, 1998).

A.4.2 Spatial prices

I construct a spatial Törnqvist price index from ESS household unit values following Deaton and Zaidi (2002). For zone z,

$$\ln P_z = \sum_i \frac{w_{iz} + w_{i0}}{2} \ln\left(\frac{p_{iz}}{p_{i0}}\right), \tag{53}$$

where p_{iz} is the unit value of item i in zone z, p_{i0} is its national reference value, and w_{iz} and w_{i0} are expenditure shares. I use a common basket of 21 food items accounting for approximately 99 percent of observed food expenditure. Item-level unit values are trimmed at the first and ninety-ninth percentiles within each survey wave. I construct indices for 2013, 2015, and 2018 and interpolate between observed waves.

Food prices alone capture only part of spatial cost-of-living variation. In particular, the food-only index implies an Addis Ababa premium of 7–11 percent, compared with a substantially larger external cost-of-living benchmark. I therefore construct a composite index combining a 55 percent food component, a 20 percent housing component, a 7 percent transport component, and an 18 percent residual component treated as spatially common (Table 10). The housing component combines observed ESS rents with a population-density proxy. The latter uses a housing-cost elasticity of 0.15 following Combes et al. (2019).

Table 10: Spatial price indices by region

Region	Food-only index	Composite index	External benchmark
SNNPR	0.921	0.898	0.906
Amhara	0.929	0.911	0.949
Oromia	0.966	0.919	0.981
Addis Ababa	1.112	1.279	1.554
Somali	1.228	1.190	1.132

Notes: Regional price indices normalized around a national reference of one. The food-only index is constructed from 21 ESS food items. The composite index adds housing, transport, and other non-food expenditure. The external column reports the corresponding World Bank regional cost-of-living benchmark. ESS waves: 2013, 2015, and 2018.

The cross-region correlation with the external benchmark rises from 0.42 for the food-only index to 0.66 for the composite index. The remaining discrepancy is largest in Addis Ababa, where owner-equivalent rents and service prices are only imperfectly measured. Spatial prices are therefore informative about broad regional cost differences but should not be interpreted as precise city-level cost-of-living indices.

A.4.3 Income-level validation

After temporal and spatial adjustment, the median ratio of annual private formal urban earnings to rural agricultural value added per worker is 1.41. The denominator is an average product rather than an observed rural wage. In the model, agriculture has a land share $\alpha_A = 0.40$, so the corresponding labor marginal product is 0.60 times agricultural value added per worker. The implied formal-to-rural marginal-product ratio is therefore approximately 2.35, within the range documented for developing economies by Gollin et al. (2014).

Using the 2011 ICP conversion factor of 5.76 birr per international dollar gives rural agricultural value added per worker of approximately \$500–900 PPP and annual urban formal earnings of approximately \$2,000–4,000 PPP. These magnitudes provide an additional level check on the constructed income series.

A.5 Travel times

Bilateral travel times are constructed between all 681 spatial units and the international gateway. The network combines OpenStreetMap roads with the Ethiopian Roads Authority trunk-road layer and is converted to a friction surface calibrated against observed intercity journey times. The resulting least-cost travel times enter bilateral trade costs, migration costs, and market-access measures. Online Appendix OA-1 reports the construction of the friction surface, speed calibration, validation against observed routes, and limitations arising from the use of a fixed road-network snapshot.

A.6 Demographics

Location-level natural population growth combines the four full Ethiopian DHS waves from 2000 through 2016 with UN World Population Prospects vital rates. Regional fertility is converted to crude birth rates using separate urban and rural shares of women of reproductive age, and mortality is combined with births to construct natural population growth. These location-specific initial conditions discipline the demographic transition used in the forward model. Online Appendix OA-1 reports the fertility conversion and comparison with aggregate demographic benchmarks.

A.7 Measured amenities

I construct a measured amenity index combining access to health and education facilities, air quality, climate, and terrain for the 681-unit spatial framework. This index does not enter the equilibrium. Model amenities are instead recovered by inversion as described in Appendix C. The measured index provides an external benchmark for assessing whether the recovered amenity component is related to observable dimensions of local living conditions. Online Appendix OA-1 reports the component construction and alternative index weights.

A.8 Migration data

Migration evidence comes primarily from four LFS/NLFS rounds, the 2014 UEUS migration module, and supplementary ESS migration information (Table 11). These sources do not provide a complete annual bilateral migration matrix at the model's spatial resolution. I therefore use them to discipline and validate several distinct margins: the prevalence of migration, the importance of rural-origin migration, geographic distance and origin-destination patterns, and the relationship between time in the city and formal employment.

A.8.1 Sources and national migration moments

Table 11: Migration data sources

Source	Years	N	Main migration information
LFS/NLFS	1999, 2005, 2013, 2021	1,012,650	Duration, origin, rural/urban status, reason
UEUS	2014	70,083	Previous residence and duration in destination
ESS	2011	18,865	Birth region and lifetime migration
ESS	2013, 2015	6,906	Household out-migration information

Notes: Individual sample sizes and migration information available in the principal survey sources. LFS/NLFS denotes the Labour Force Survey and National Labour Force Survey; UEUS denotes the Urban Employment Unemployment Survey; ESS denotes the Ethiopian Socioeconomic Survey.

The earlier LFS waves report duration since migration in categories, which I convert to interval midpoints, while the later surveys record years directly. Individuals reporting residence in the current location since birth are treated as non-migrants.

Table 12 reports the corresponding national moments. The lifetime migrant share remains between 15 and 20 percent across rounds, while approximately 4–5 percent of the population reports a move within the previous five years. The recorded rural-origin share rises sharply across survey rounds. I use this pattern as evidence on the changing composition of internal migration rather than as a literal annual migration series.

The 15–20 percent lifetime-migrant share is close to the approximately 16 percent figure in the 2007 Census analytical report. The UEUS 2014 estimate that approximately 47 percent of urban residents are migrants is also close to the approximately 45 percent figure reported in the World Bank's Ethiopia Urbanization Review (World Bank, 2015).

A.8.2 Formalization by migration tenure

The 2014 UEUS contains sufficiently detailed migration histories to relate formal employment to years since arrival in the city. Table 2 in Section 5 reports the resulting

Table 12: National migration moments

Year	N	Migrant share	Moved within five years	Rural-origin share
1999	366,695	19.6%	4.3%	12.9%
2005	230,680	16.5%	4.7%	24.8%
2013	240,660	15.1%	4.8%	65.4%
2021	174,615	17.1%	5.2%	65.9%

Notes: Survey-weighted national migration moments from the four LFS/NLFS rounds. "Migrant share" is the share that previously lived elsewhere; the third column restricts to moves within five years; "Rural-origin share" is the share of migrants whose previous residence is reported as rural.

tenure profile, and Table 24 in Appendix E.12 reports the model-consistent estimation of the hazard curvature from the rural-origin profile.

A.8.3 Spatial migration information

The survey sources identify 161 distinct region-to-region migration corridors and 1,479 distinct zone-level corridors. Coverage is much sparser at the zone level than a complete national bilateral matrix would require. I therefore use these flows as spatial benchmarks rather than treating the observed matrix as a complete measure of bilateral migration.

The migration block is evaluated against the observed scale of internal mobility, the rural-origin composition of migration, and coarse origin-destination patterns. Distance between origins and destinations is measured using the travel-time construction of Section A.5. Because migration stocks and retrospective histories are more completely observed than annual bilateral flows, the data provide substantially stronger discipline on the overall migration margin than on a fully unrestricted bilateral migration elasticity.

A.8.4 Supplementary ESS validation

The Ethiopian Socioeconomic Survey provides an independent household-survey source for supplementary migration checks. I identify migrants from previous-residence information and, where the survey permits, distinguish rural-to-urban from other moves. Survey weights are applied to all resulting moments.

The ESS is particularly useful for comparing broad migrant shares and regional origin patterns with those obtained from the labor-force surveys. It does not provide a complete bilateral migration matrix at the model geography and is therefore not used to identify bilateral migration elasticities. Likewise, the tenure-to-formality profile used in the formalization analysis is taken from the UEUS 2014 migration module rather than inferred from the ESS. The ESS evidence is thus an independent plausibility check on the spatial allocation of migrants, not a separate source of identification for the formalization hazard.

Table 13: Principal constructed analysis datasets

Object	Spatial unit	Coverage	Principal use
Full spatial framework	126 urban, 555 rural	2000–2020	Geography, population, spatial construction
Agricultural panel	547 woredas	2000–2020	Yields, agricultural income, productivity shocks
Urban labor-market panel	UEUS zones/cities	2003–2018	Informality, wages, employment structure
Spatial price panel	Regions	2000–2021	Real-income adjustment
Travel-time matrix	681 spatial units	Static	Migration costs, trade costs, market access
Demographic panel	681 spatial units	2000–2020	Natural population growth
Measured amenity panel	681 spatial units	2000–2021	External amenity validation
Migration benchmarks	National, region, zone	1999–2021	Migration and formalization moments

Notes: Principal constructed objects used in calibration, validation, and equilibrium computation. The equilibrium is solved on an aggregation to 121 locations, comprising 43 urban and 78 rural locations.

A.9 Constructed analysis panels and limitations

The preceding construction delivers a set of mutually consistent spatial objects at different geographic resolutions. Table 13 summarizes the principal datasets entering the quantitative analysis without referring to their implementation-specific storage formats.

A.9.1 Measurement limitations

Several limitations of the data construction are important for interpretation.

1. **Agricultural yields are extensively gap filled.** Approximately 65 percent of woreda-year yield observations are predicted rather than directly observed, and eleven of the 21 panel years contain no observed AgSS yields. The prediction procedure exploits persistent cross-sectional yield gradients much more successfully than year-to-year variation. Agricultural productivity in non-survey years is therefore measured with substantially greater uncertainty. Online Appendix OA-1 reports the corresponding cross-validation exercises.

2. **Rural earnings are agricultural value added per worker.** Most Ethiopian agricultural workers are self-employed smallholders, so an individual rural market wage is not observed. The rural earnings object is agricultural value added per worker and should be interpreted as an average-product income measure rather than a directly observed wage (Gollin et al., 2014; Young, 2013).

3. **Agricultural area is self reported.** AgSS harvested area is farmer reported. Evidence from comparable surveys indicates that small-plot areas can be systematically overstated (Carletto et al., 2015; McCullough, 2017). This can bias measured

yield levels downward even when relative spatial patterns are more stable.

4. **Spatial prices are measured only at regional resolution.** ESS sample sizes are insufficient to construct stable Törnqvist indices at the zone or city level. Consequently, within-region cost-of-living differences remain unobserved. The housing component partly addresses this limitation but does not eliminate it.

5. **Infrastructure measures are partly static.** The travel network combines a 2018 OpenStreetMap snapshot with a 2009 Ethiopian Roads Authority layer. Health and school accessibility measures are likewise based on the available OpenStreetMap snapshot. These objects should therefore be interpreted as persistent spatial accessibility rather than a complete annual infrastructure panel. Sparse rural OpenStreetMap coverage may also overstate distances to some local facilities.

6. **Own-account earnings are imputed.** The UEUS does not collect wage information from self-employed respondents. The correction uses the 2003 Informal Sector Survey to recover a more representative informal-earnings benchmark. Because this adjustment is anchored in a single cross-section, changes in the relative earnings of employees and own-account workers over time are not separately observed.

7. **Inter-censal population is model based.** Annual population comes from census-calibrated WorldPop surfaces rather than annual enumeration. Measurement uncertainty is likely to be greatest in rapidly changing peri-urban areas, where settlement boundaries and population are also most economically important.

8. **Bilateral migration data are incomplete.** The labor-force and urban-employment surveys provide useful migration stocks and coarse origin-destination histories but not a complete national bilateral flow matrix at the model geography. Migration costs are therefore disciplined more strongly by aggregate mobility, distance, and destination patterns than by annual bilateral flows.

9. **The temperature-yield relationship is imprecise.** The within-woreda temperature coefficient in the agricultural counterfactual specification is approximately -7.7 percent per additional degree Celsius but is not statistically distinguishable from zero at conventional levels ($p = 0.13$). This reflects limited within-woreda temperature variation and is one reason the climate exercises are interpreted as model-based scenario analysis rather than reduced-form causal estimates of temperature damages.

These limitations differ in their implications. Several affect the precision with which levels are measured, especially rural income, informal earnings, and spatial prices. Others restrict the variation available to identify particular model components, especially bilateral migration and short-run agricultural shocks. The quantitative analysis therefore places greater weight on spatial rankings and moments that are directly observed, uses independent data where available for validation, and reports sensitivity to the principal constructed inputs in Appendices E and F and the corresponding Online Appendix sections.

B Descriptive Statistics

This appendix reports the descriptive evidence underlying the four empirical patterns in Section 5. All statistics in this appendix are constructed directly from the observed and harmonized data described in Appendix A; none is generated by the quantitative model.

The tables use two spatial representations. The full spatial framework contains 126 urban centers and 555 rural units and is used when describing the distribution of city size and the relationship between city size and informality. The equilibrium model aggregates this geography to 121 locations, comprising 43 urban and 78 rural locations. The sectoral wage series are reported on this model geography so that the descriptive levels correspond to the objects subsequently used in calibration. All monetary quantities are expressed in constant 2010/11 birr using the temporal and spatial price adjustments described in Appendix A.

The tables below report the private informality share against city size in the 2015 cross-section (Table 14), the city-size distribution (Table 15), and real earnings by sector and year (Table 16). Because the UEUS measures labor-market outcomes at the administrative-zone level rather than independently for every city, cities assigned to the same survey zone share the corresponding labor-market measure; Appendix A.3.5 describes this mapping and its limitations.

Table 14: Informal employment share by city size, 2015

Size tercile	Cities	Population range	Mean φ	Median φ
T1 (small)	42	2,987–37,418	54.6%	54.2%
T2 (middle)	42	38,051–69,048	56.3%	54.2%
T3 (large)	42	69,979–3,642,354	52.7%	51.3%

Notes: $\varphi = L^I/(L^I + L^F)$ is the private informal employment share, excluding government employment. Cities are divided into equal-count terciles by 2015 population. Informality is measured from the UEUS at the survey-zone level, so cities mapped to the same zone share the same underlying informality measure.

Fact 2 in Section 5 combines these observed wage and urbanization patterns with the migration incentives implied by the calibrated model. That exercise is therefore not reproduced as a purely descriptive table here. Section 5 reports the relevant comparison, while Appendix E documents the migration moments and calibration objects used to discipline the corresponding model margin.

Table 15: City-size distribution, 2015

Panel A. Ten largest urban units		
Rank	City	Population
1	Addis Ababa	3,642,354
2	Kefole	408,718
3	Adama	395,611
4	Bahir Dar	348,243
5	Harar	324,868
6	Gonder	289,982
7	Dire Dawa	287,262
8	Urban unit 12	266,740
9	Hawassa	261,434
10	Jimma	246,615

Panel B. Distribution across all 126 urban units	
Statistic	Population
Minimum	2,987
10th percentile	17,062
25th percentile	28,199
Median	49,127
Mean	106,230
75th percentile	89,521
90th percentile	193,337
Maximum	3,642,354

Notes: Population in 2015 for the 126 urban units in the full spatial framework. The equilibrium model aggregates these to 43 urban locations. One top-ten unit lacks a verified Latin-script place name and is therefore reported by its identifier. Population is based on WorldPop.

Table 16: Real earnings by sector, 2007–2015

	Rural		Informal		Formal		
Year	Mean	Median	Mean	Median	Mean	Median	w_I/w_F
2007	5,831	4,844	5,136	4,718	14,492	14,177	0.35
2008	5,990	4,663	5,342	5,221	13,141	12,949	0.41
2009	6,380	5,299	5,576	5,252	12,626	12,411	0.44
2010	7,136	6,158	5,695	5,785	12,619	12,589	0.45
2011	7,623	6,671	5,451	5,439	12,434	12,481	0.44
2012	7,574	6,583	5,362	5,260	11,976	11,921	0.45
2013	7,108	6,064	5,442	5,299	11,511	11,479	0.47
2014	7,093	5,481	6,370	6,306	12,340	12,309	0.52
2015	7,855	5,559	7,610	7,763	13,975	13,775	0.54

Notes: Annual real earnings in constant 2010/11 birr. Urban informal and formal measures are constructed from UEUS zone-level earnings; rural earnings are constructed from the agricultural income data. Series are smoothed using a three-year geometric moving average. Means and medians are taken across 43 urban locations for the informal and formal sectors and 78 rural locations for the rural sector. The final column reports the ratio of mean informal to mean formal earnings.

C Model Statement and Derivations

This appendix states the model in full and provides the derivations underlying Section 3. It is self-contained: each functional form is restated before it is used, while calibrated parameter values are deferred to Section 6. The purpose is to make the economic structure, equilibrium conditions, and dynamic transition transparent without mixing the derivations with numerical implementation details.

C.1 Notation, environment, and timing

Environment. The economy is a single country partitioned into $N = N_R + N_U$ locations, collected in the set $\mathcal{S} = \mathcal{S}_R \cup \mathcal{S}_U$. Rural locations $i \in \mathcal{S}_R$ produce agriculture only. Urban locations $j \in \mathcal{S}_U$ contain informal private, formal private, and government workers. I use ℓ as a generic location index. The sector index is $k \in \{A, I, F, G\}$ for agriculture, urban informal production, urban formal production, and government. Agriculture and the formal good are tradable across space and internationally, while the informal good is a non-tradable local service. Government produces no marketed output. Rural locations are endowed with arable land H_i^R, urban locations with a built-up envelope H_j^U, and each worker supplies one unit of labor inelastically.

Sector participation. In a rural location $i \in \mathcal{S}_R$, the entire resident population works in agriculture, so $L_i^A = L_i$ and $L_i^I = L_i^F = L_i^G = 0$. In an urban location $j \in \mathcal{S}_U$, agricultural employment is zero and $L_j = L_j^I + L_j^F + L_j^G$. The urban land envelope is shared by the two producing urban sectors, $H_j^I + H_j^F = H_j^U$. Government workers reside in the city but use no separate land input in production.

Timing. Time is annual and indexed by t, with the anchor year normalized to $t = 0$; its calendar value is reported in Section 6. Within a period, sectoral employment stocks $\{L_i^A, L_j^I, L_j^F, L_j^G\}$, land endowments, housing stocks, productivities, and world prices are predetermined. The within-period equilibrium in Section C.9 determines prices, wages, rents, and trade flows conditional on these objects. Between periods, the state evolves according to the operator in Section C.10. A worker relocates at most once per period and forms myopic expectations over destination values.

State and fundamentals. The time-invariant geographic fundamentals are

$$\mathcal{G} = \Big\{ \{A_\ell^k\}_{\ell,k}, \{H_i^R\}_{i \in \mathcal{S}_R}, \{\hat{a}_j\}_{j \in \mathcal{S}_U}, \{d_{\ell m}\}_{\ell,m}, \bar{L}^G \Big\}, \tag{54}$$

where A_ℓ^k are anchor-level productivity fundamentals, H_i^R are rural land endowments, $\hat{a}_j$ are recovered destination amenities, $d_{\ell m}$ is bilateral road distance, and $\bar{L}^G$ denotes the government-employment process. Bilateral distance determines both iceberg trade costs $\tau_{\ell m}$ in Section C.4 and migration costs $C_{\ell m}$ in Section C.6. This is the same geographic object defined in Section 3.7.

The period-t state is

$$S_t = \left\{ L^A_{i,t}, L^I_{j,t}, L^F_{j,t}, L^G_{j,t}, H^U_{j,t}, A^k_{\ell,t}, \zeta^A_{i,t}, p^{\text{world}}_{k,t} \right\}_{\ell,k}, \tag{55}$$

which collects sectoral employment, urban housing stocks, effective productivities, the agricultural shock $\zeta^A_{i,t}$, and world prices. The first five components coincide with the state $\mathcal{S}_t$ in Section 3.2; S_t additionally includes drifting productivities and time-varying exogenous drivers so that the transition operator acts on a single state object.

Two informality shares are used and must be distinguished. The private informality share

$$\varphi_{j,t} = \frac{L^I_{j,t}}{L^I_{j,t} + L^F_{j,t}}$$

excludes government employment and is the argument of the formalization hazard. The demand-relevant share

$$\varphi^D_{j,t} = \frac{L^I_{j,t}}{L^I_{j,t} + L^F_{j,t} + L^G_{j,t}}$$

includes government employment and enters the urban expenditure nest.

Notation. Table 17 collects the notation used in Section 3 and in the derivations below. Similar symbols are distinguished explicitly where they govern different economic margins.

Table 17: Model notation

Symbol	Meaning	Notes
Indices and sets		
$i,\ j,\ \ell$	rural location, urban location, generic location	
$k \in \{A, I, F, G\}$	sector: agriculture, informal, formal, government	
$\mathcal{S}_R,\ \mathcal{S}_U$	sets of rural and urban locations	$N_R,\ N_U$ elements
t	year, with anchor normalized to $t = 0$	calendar year in Sec. 6
Quantities and factors		

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Table 17 continued

Symbol	Meaning	Notes
L_i^A, L_j^I, L_j^F, L_j^G	sectoral employment stocks	predetermined within period
$L_j = L_j^I + L_j^F + L_j^G$	total urban employment	
$L^{\text{tot}} = \sum_\ell L_\ell$	national population	per-capita NX denominator
H_i^R, H_j^U	rural arable land, urban built-up envelope	H_i^R fixed; H_j^U adjusts dynamically
H_j^I, H_j^F	land allocated to informal and formal production	$H_j^I + H_j^F = H_j^U$
Y_ℓ^k	sectoral output	
Prices, wages, and rents		
p_i^A, p_j^F	origin prices of agricultural and formal goods	equilibrium unknowns
P_j^I	local informal price	non-tradable; equilibrium unknown
P_i^A, P_j^F, P_j^U	delivered Armington and urban-nest price indices	
P_ℓ	aggregate consumer price index	
w_ℓ^k	nominal sectoral wage	marginal product $\times$ origin price
$\widetilde{w}_j^k = (1 - s_j^H)\, w_j^k / P_j$	real disposable wage	net of housing and deflated
r_i^R, r_j^U	rural and shared urban land rents	
v_i^R, v_j^U	per-capita expenditure	wages, rents, and NX/L^{tot}
$\tilde{v}$	super-subsistence expenditure	$\max(v^{\text{goods}} - \bar{c}_A, 1)$
Technology and agglomeration		
A_ℓ^k	sectoral productivity fundamental	inverted from data
ζ_i^A	agricultural productivity shock	time varying
$\alpha_A, \alpha_I, \alpha_F$	land shares in production	
$\delta_j^I = (L_j^I)^{\eta_I}$	informal agglomeration externality	employment based
$\delta_j^F = (L_j^F + L_j^G)^{\kappa_F}$	formal agglomeration externality	employment based
η_I, κ_F	agglomeration elasticities	

continued on next page

Table 17 continued

Symbol	Meaning	Notes
$MA_j = (1/\tau_j^{\text{world}})/\overline{MA}$	normalized inverse gateway cost	enters as $MA_j^{\eta_{MA}}$
Preferences and trade		
μ_A, μ_U	outer-nest taste weights	
ρ	outer CES elasticity	
e_A, e_U	non-homotheticity parameters	$0 =$ homothetic
$\bar{c}_A$	Stone–Geary subsistence food term	
ν	inner urban-nest CES elasticity	
ω_j^I, ω_j^F	urban-nest demand weights	$\omega_j^I = \bar{\omega}_I \varphi_j^D / \varphi_{\text{ref}}$
σ_A, σ_F	Armington trade elasticities	
$\tau_{\ell m} = (1 + d_{\ell m}/d_{\text{ref}})^{\eta_{tr}}$	iceberg trade cost	d_{ref} fixed[14]
τ_ℓ^{world}	gateway iceberg cost to the international market	
ω_ℓ^k	Krugman variety weight	$\propto$ (employment)$^{\gamma_v}$
γ_v	variety elasticity	distinct from amenity γ
$s_x^k,\ \kappa_b^k$	export cap and band speed	Samuelson trade bands
Housing, migration, and formalization		
s_j^H	housing expenditure share	$\min\{\cdot, s_{\text{cap}}^H\}$
$\omega_H,\ \psi_H$	housing base share and curvature	
b_0, b_1, ϱ	Koyck intercept, short-run elasticity, persistence	
β	annual discount factor	
$\Pi_i^R,\ \Pi_j^U$	rural and urban net present values	
$\pi_{i\to j}$	migration probability	logit
ϑ	migration logit dispersion	distinct from θ
$\hat{a}_j,\ \gamma$	amenity and amenity coefficient	$\gamma = 1$; distinct from γ_v
C_{ij}	bilateral migration cost	eq. (85)
$\kappa_{\text{fixed}}, \kappa_{\text{dist}}$	fixed and distance migration-cost parameters	
$\eta_d,\ \kappa_s$	distance elasticity and destination-size discount	
$\varphi_j = L_j^I/(L_j^I + L_j^F)$	private informality share	hazard argument

continued on next page

Table 17 continued

Symbol	Meaning	Notes
φ_j^D	demand-relevant informality share	government included
$\lambda(\varphi_j)$	formalization hazard	Michaelis–Menten + brake
θ	hazard curvature	distinct from ϑ
$\underline{\lambda}$	formalization floor	distinct from dynamic drift parameters
ψ_0, ψ_{eff}	hazard saturation and effective saturation	distinct from ψ_H
φ_c, ζ_{brake}	brake midpoint and steepness	
Dynamics		
$g_s(t)$	sector-s TFP drift	logistic convergence with speed λ_d
$n_j(t)$	natural population growth	logistic transition
$\Lambda(x) = (1+e^{-x})^{-1}$	logistic function	distinct from σ_A, σ_F
$\hat{a}_j(t)$	amenity drift correction	constant urban drift g_a
g_j	government hiring share	
NX	aggregate net exports	distributed as NX/L^{tot}

C.2 Production: wage and rent first-order conditions

Firms are atomistic and perfectly competitive. Agglomeration is Marshallian: sector-level employment affects productivity, but each individual firm treats the externality as given (Combes and Gobillon, 2015). Factor payments therefore equal marginal products evaluated at the origin price of the sector's own output. Delivered Armington prices enter household real income and demand rather than firms' first-order conditions.

Rural agriculture. Agricultural production in rural location i is

$$Y_i^A = A_i^A\, \zeta_i^A\, (L_i^A)^{1-\alpha_A} (H_i^R)^{\alpha_A}, \tag{56}$$

[14] The reference distance d_{ref} in the iceberg trade cost is a fixed structural constant of the calibrated functional form; its value is reported in Section 6.

with land share $\alpha_A \in (0,1)$. A representative competitive farm sells output at the origin agricultural price p_i^A and solves

$$\max_{L_i^A, H_i^R} \left\{ p_i^A A_i^A \zeta_i^A (L_i^A)^{1-\alpha_A} (H_i^R)^{\alpha_A} - w_i^A L_i^A - r_i^R H_i^R \right\}.$$

Step 1. The labor first-order condition equates the marginal revenue product of labor to the wage,

$$w_i^A = p_i^A \,(1-\alpha_A)\, A_i^A \,\zeta_i^A \,(L_i^A)^{-\alpha_A} (H_i^R)^{\alpha_A}.$$

Step 2. Rearranging in terms of the land–labor ratio gives equation (8) of the main text,

$$w_i^A = p_i^A \,(1-\alpha_A)\, A_i^A \,\zeta_i^A \left(\frac{H_i^R}{L_i^A} \right)^{\alpha_A}. \tag{57}$$

Step 3. The land first-order condition gives

$$r_i^R = p_i^A \,\alpha_A \, A_i^A \,\zeta_i^A \left(\frac{L_i^A}{H_i^R} \right)^{1-\alpha_A}. \tag{58}$$

The two first-order conditions imply $w_i^A L_i^A + r_i^R H_i^R = p_i^A Y_i^A$, the constant-returns Euler identity. Because rural land is fixed, out-migration raises H_i^R / L_i^A and therefore raises w_i^A in (57). This diminishing-returns force limits rural depopulation. Rural land rents accrue to residents and enter per-capita income in Section C.9.

Urban informal. The informal agglomeration externality depends on own-sector employment, $\delta_j^I = (L_j^I)^{\eta_I}$, and production is

$$Y_j^I = A_j^I \,\delta_j^I \,(L_j^I)^{1-\alpha_I} (H_j^I)^{\alpha_I}. \tag{59}$$

An individual firm takes δ_j^I as given, sells the non-tradable good at the local price P_j^I, and chooses labor and land.

Step 1. The labor first-order condition is

$$w_j^I = P_j^I \,(1-\alpha_I)\, A_j^I \,\delta_j^I \left(\frac{H_j^I}{L_j^I} \right)^{\alpha_I}. \tag{60}$$

Step 2. The corresponding land condition, evaluated at the common urban rent r_j^U, is

$$r_j^U = P_j^I \,\alpha_I \, A_j^I \,\delta_j^I \left(\frac{L_j^I}{H_j^I} \right)^{1-\alpha_I}. \tag{61}$$

The firm's marginal product therefore carries the private exponent $1 - \alpha_I$, while δ_j^I shifts productivity at the sector level: increasing social returns without a departure from competitive factor pricing.

Urban formal. Formal agglomeration depends on formal plus government employment, $\delta_j^F = (L_j^F + L_j^G)^{\kappa_F}$. Government employment therefore contributes to the formal agglomeration base even though government produces no marketed output. Market access MA_j additionally raises formal productivity in locations with better access to the international gateway. Formal production is

$$Y_j^F = A_j^F \, MA_j^{\eta_{MA}} \, \delta_j^F \, (L_j^F)^{1-\alpha_F} (H_j^F)^{\alpha_F}. \tag{62}$$

Formal firms sell at the local origin price p_j^F, which may differ across cities; the aggregate price normalization is imposed separately in Section C.9.

Step 1. The labor first-order condition gives the formal wage in equation (8),

$$w_j^F = p_j^F \, (1 - \alpha_F) \, A_j^F \, MA_j^{\eta_{MA}} \, \delta_j^F \left(\frac{H_j^F}{L_j^F} \right)^{\alpha_F}. \tag{63}$$

Step 2. The corresponding land condition is

$$r_j^U = p_j^F \, \alpha_F \, A_j^F \, MA_j^{\eta_{MA}} \, \delta_j^F \left(\frac{L_j^F}{H_j^F} \right)^{1-\alpha_F}. \tag{64}$$

In the calibration, MA_j is absorbed into the inverted A_j^F because observed formal wages already reflect market access. When formal productivity is reported net of market access, I use $MA_j = (1/\tau_j^{\text{world}})/\overline{MA}$, the normalized inverse gateway trade cost, with $\overline{MA}$ chosen so that the market-access shifter has unit urban mean. Section 6 describes this normalization.

The same gateway cost τ_j^{world} that generates MA_j also determines the width of the Samuelson no-trade band in Section C.4. Market access and international openness therefore share a common geographic source and should not be interpreted as independent shifters.

Shared urban land rent. Informal and formal firms bid for the same urban land envelope. A common rent r_j^U allocates land across the two uses by equalizing its marginal value product.

Step 1. Constant returns imply that each sector's land bill is a fixed share of revenue, while revenue can be written as the wage bill divided by the labor share. From (60),

$$r_j^U H_j^I = P_j^I \alpha_I Y_j^I = \frac{\alpha_I}{1-\alpha_I} w_j^I L_j^I \quad \Longrightarrow \quad H_j^I = \frac{\alpha_I}{1-\alpha_I} \frac{w_j^I L_j^I}{r_j^U}.$$

Step 2. Symmetrically, (63) implies

$$H_j^F = \frac{\alpha_F}{1-\alpha_F} \frac{w_j^F L_j^F}{r_j^U}.$$

Step 3. Imposing land clearing, $H_j^I + H_j^F = H_j^U$, gives

$$r_j^U = \frac{\frac{\alpha_I}{1-\alpha_I} w_j^I L_j^I + \frac{\alpha_F}{1-\alpha_F} w_j^F L_j^F}{H_j^U}. \tag{65}$$

The rent increases with the urban wage bill and decreases with the built-up land envelope. Combining the two sectoral land demands also gives

$$\frac{H_j^I}{H_j^F} = \frac{\alpha_I(1-\alpha_F)}{\alpha_F(1-\alpha_I)} \frac{w_j^I L_j^I}{w_j^F L_j^F}.$$

C.3 The demand system

Preferences have two tiers. The outer tier is the non-homothetic CES system of Comin et al. (2021) over agriculture and an urban composite. The inner tier is a homothetic CES aggregator over informal and formal goods. I first characterize the outer expenditure shares and aggregate price index, then introduce the Stone–Geary subsistence term and the urban sub-nest. Throughout this subsection, P, P_A, P_U, and $\tilde{v}$ are evaluated separately at each location; location subscripts are suppressed where this simplifies notation.

Outer nest: non-homothetic CES. Let $\tilde{v}$ denote super-subsistence nominal expenditure and define the real expenditure index $U \equiv \tilde{v}/P$, where P is the aggregate consumer price index. Following Comin et al. (2021), using the convention in which $e_s = 0$ corresponds to homothetic preferences, P is defined implicitly by

$$\sum_{s\in\{A,U\}} \mu_s \left(\frac{P_s}{P}\right)^{1-\rho+e_s} U^{e_s} = 1, \tag{66}$$

which is equation (9) after substituting $U = \tilde{v}/P$. Here P_A is the agricultural price index, P_U is the urban composite price index, ρ is the outer substitution elasticity, and e_A and

e_U govern non-homotheticity.

Step 1. Expenditure shares. The demand system is specified directly in expenditure-share form,

$$\begin{aligned} s_s &= \mu_s \left(\frac{P_s}{P}\right)^{1-\rho+e_s} \left(\frac{\tilde{v}}{P}\right)^{e_s} \\ &= \mu_s \left(\frac{P_s}{P}\right)^{1-\rho+e_s} U^{e_s}, \qquad s \in \{A, U\}, \end{aligned} \tag{67}$$

and the aggregate index P is defined as the deflator for which the shares exhaust expenditure, $s_A + s_U = 1$. This is exactly the adding-up condition in (66). For agriculture, (67) gives equation (11) of the main text, while $s_U = 1 - s_A$ by construction. Marshallian demands $C_s = s_s\tilde{v}/P_s$ therefore satisfy $\sum_s P_s C_s = \tilde{v}$.

Step 2. Existence and uniqueness of P. Write the adding-up residual as

$$f(P) = \sum_{s\in\{A,U\}} \mu_s P_s^{1-\rho+e_s} \tilde{v}^{e_s} P^{-(1-\rho+2e_s)} - 1,$$

$$\frac{\partial f}{\partial \log P} = -\sum_s (1-\rho+2e_s)\, s_s(P).$$

Under the restriction $1-\rho+2e_s > 0$ for both nests, which is satisfied at the calibrated values, each term in $f(P)$ is strictly decreasing in P. Moreover, $f(P) \to \infty$ as $P \to 0$ and $f(P) \to -1$ as $P \to \infty$. A unique root therefore exists.

Step 3. Homogeneity. Replacing $(P_A, P_U, \tilde{v})$ by $(tP_A, tP_U, t\tilde{v})$ for $t > 0$, together with P by tP, leaves every term in (66) unchanged. The implicitly defined price index is therefore homogeneous of degree one in $(P_A, P_U, \tilde{v})$, while the expenditure shares in (67) are homogeneous of degree zero. Only relative prices and real expenditure matter. The ratio $U = \tilde{v}/P$ is the corresponding real-expenditure index.

Step 4. Non-homotheticity and the homothetic limit. When $e_A < 0$, $(\tilde{v}/P)^{e_A}$ declines with real expenditure, lowering the agricultural expenditure share as income rises. When $e_U > 0$, the urban share rises with real expenditure. Setting $e_A = e_U = 0$ reduces (66) to the standard homothetic CES price index

$$P = \left[\mu_A P_A^{1-\rho} + \mu_U P_U^{1-\rho}\right]^{1/(1-\rho)},$$

and (67) reduces to the standard CES expenditure shares.

Stone–Geary subsistence. Households first meet a subsistence food requirement before allocating discretionary expenditure. Let v^{goods} denote per-capita expenditure available for goods after housing expenditure, as defined in Section C.5. Super-subsistence expenditure is

$$\tilde{v} = \max\left(v^{\text{goods}} - \bar{c}_A,\ 1\right), \tag{68}$$

where $\bar{c}_A$ is the subsistence food term and the floor of one prevents the expenditure index from becoming degenerate. Discretionary expenditure $\tilde{v}$ is allocated according to (67). Agricultural consumption therefore combines subsistence and discretionary food demand,

$$C_A = \frac{\bar{c}_A}{P_A} + s_A \frac{\tilde{v}}{P_A}. \tag{69}$$

The subsistence component raises the effective food share at low income and reinforces the non-homotheticity generated by (67).

Inner urban nest. The urban composite is a homothetic CES aggregate of informal and formal goods with substitution elasticity ν,

$$C_j^U = \left[(\omega_j^I)^{1/\nu}(C_j^I)^{\frac{\nu-1}{\nu}} + (\omega_j^F)^{1/\nu}(C_j^F)^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}. \tag{70}$$

Step 1. Cost minimization of $P_j^I C_j^I + P_j^F C_j^F$ subject to (70) gives the dual price index

$$P_j^U = \left[\omega_j^I (P_j^I)^{1-\nu} + \omega_j^F (P_j^F)^{1-\nu}\right]^{1/(1-\nu)}, \tag{71}$$

which is equation (10).

Step 2. The conditional expenditure shares within the urban nest are

$$s_{k|U} = \omega_j^k \left(\frac{P_j^k}{P_j^U}\right)^{1-\nu}.$$

The corresponding unconditional shares are

$$\begin{aligned} s_I &= s_U\, \omega_j^I \left(\frac{P_j^I}{P_j^U}\right)^{1-\nu}, \\ s_F &= s_U\, \omega_j^F \left(\frac{P_j^F}{P_j^U}\right)^{1-\nu}, \end{aligned} \tag{72}$$

which reproduces equation (11), with $s_I + s_F = s_U$.

The demand weights vary across cities with the local demand-relevant informality share,

$$\omega_j^I = \bar{\omega}_I \frac{\varphi_j^D}{\varphi_{\text{ref}}}, \qquad \omega_j^F = 1 - \omega_j^I,$$

where

$$\varphi_j^D = \frac{L_j^I}{L_j^I + L_j^F + L_j^G}.$$

Thus cities with larger informal sectors place greater expenditure weight on informal goods. Rural households have limited access to informal goods through the nearest urban center at the corresponding iceberg-adjusted price. The residual informal share is redirected toward formal-goods demand, as described in Section C.9.

Marshallian demands. Conditional on the expenditure shares, Marshallian demand for good k is $C_j^k = s_k \tilde{v} / P_j^k$, with the additive subsistence component for agriculture given in (69). These demands enter the goods-market-clearing conditions in Section C.9.

C.4 Trade: Armington indices, variety weights, and Samuelson bands

Iceberg trade costs. Agriculture and formal goods are differentiated by origin and traded across locations subject to iceberg costs. Shipping one unit from ℓ to m requires dispatching $\tau_{\ell m} \geq 1$ units, where

$$\tau_{\ell m} = \left(1 + \frac{d_{\ell m}}{d_{\text{ref}}}\right)^{\eta_{tr}}, \qquad \tau_{\ell\ell} = 1, \tag{73}$$

which is equation (12). Here $d_{\ell m}$ is bilateral distance, d_{ref} is the fixed reference distance, and η_{tr} is the trade-cost elasticity. Urban locations additionally face an agricultural retail markup τ_{retail} on delivered food, capturing intermediation between agricultural producers and urban consumers.

Krugman variety weights. Origins receive Armington weights that depend on productive scale rather than symmetric weights of $1/N$. Following the variety logic of Krugman (1980), the mass of varieties supplied by an origin rises with its employment base:

$$\omega_j^F \propto (L_j^F + L_j^G)^{\gamma_v}, \qquad \omega_\ell^A \propto (L_\ell^A)^{\gamma_v}, \tag{74}$$

which is equation (13). The variety elasticity γ_v is distinct from the amenity coefficient γ in Section C.6. A multiplicative primate-city premium is applied to the largest formal producer. Relative to symmetric origin weights, employment-based weights allow larger production centers to supply a correspondingly larger mass of varieties.

Delivered price indices. Let p_ℓ^k denote the origin price of good k. Delivered CES price indices aggregate domestic varieties and a rest-of-world variety:

$$P_i^A = \left[\sum_\ell \omega_\ell^A (\tau_{\ell i}^{\text{ag}})^{1-\sigma_A} (p_\ell^A)^{1-\sigma_A} + \omega_{\text{world}}^A (\tau_i^{\text{world}} p_A^{\text{world}})^{1-\sigma_A} \right]^{1/(1-\sigma_A)}, \tag{75}$$

$$P_j^F = \left[\sum_\ell \omega_\ell^F \tau_{\ell j}^{1-\sigma_F} (p_\ell^F)^{1-\sigma_F} + \omega_{\text{world}}^F (\tau_j^{\text{world}} p_F^{\text{world}})^{1-\sigma_F} \right]^{1/(1-\sigma_F)}. \tag{76}$$

These are equation (17), with Armington elasticities $\sigma_A, \sigma_F > 1$, rest-of-world weights ω_{world}^k, and gateway iceberg costs τ_j^{world}. The bilateral expenditure share on origin ℓ is

$$\frac{\omega_\ell^k (p_\ell^k \tau_{\ell j})^{1-\sigma_k}}{(P_j^k)^{1-\sigma_k}}.$$

Samuelson no-trade band. International trade is governed by a Samuelson price band. A location trades with the international market only when its domestic origin price leaves the no-trade corridor implied by the gateway iceberg cost. The extensive margin follows from arbitrage, while trade volumes outside the band follow the reduced-form adjustment rule below.

Step 1. Export parity. To export one unit, a producer at ℓ must ship it to the gateway at iceberg cost τ_ℓ^{world}. The world-price value per unit dispatched is therefore $p_k^{\text{world}}/\tau_\ell^{\text{world}}$. Exporting is profitable when

$$p_\ell^k < \frac{p_k^{\text{world}}}{\tau_\ell^{\text{world}}},$$

or equivalently when $p_\ell^k \tau_\ell^{\text{world}} < p_k^{\text{world}}$.

Step 2. Import parity. An imported unit costs p_k^{world} at the gateway and $p_k^{\text{world}} \tau_\ell^{\text{world}}$ after delivery to location ℓ. Imports are profitable when

$$p_\ell^k > p_k^{\text{world}} \tau_\ell^{\text{world}}.$$

Step 3. No-trade band. Combining the two inequalities, there is no international trade when

$$\frac{p_k^{\text{world}}}{\tau_\ell^{\text{world}}} \leq p_\ell^k \leq p_k^{\text{world}} \tau_\ell^{\text{world}}.$$

The gateway cost therefore determines the width of the corridor. More remote locations face wider bands and require larger domestic-world price gaps before international trade occurs.

Step 4. Trade volumes. Inside the band, international flows are zero and domestic Armington clearing determines the local price. Outside the band, trade responds linearly to the price gap with speed κ_b^k, subject to the export cap s_x^k. Let marketed supply be $S_\ell^A = (1-h_A)Y_\ell^A$ in agriculture and $S_\ell^F = Y_\ell^F$ in the formal sector. Then

$$X_\ell^{k,\text{exp}} = \min\left\{\kappa_b^k \max\left(0,\, 1 - \frac{p_\ell^k \tau_\ell^{\text{world}}}{p_k^{\text{world}}}\right) S_\ell^k,\, s_x^k S_\ell^k\right\}, \tag{77}$$

$$M_\ell^{k,\text{imp}} = \kappa_b^k \max\left(0,\, \frac{p_\ell^k}{p_k^{\text{world}} \tau_\ell^{\text{world}}} - 1\right)(v_\ell L_\ell), \tag{78}$$

summarized in reduced form in Section 3.5. The export cap applies only to agriculture, so $s_x^F = \infty$, and the formal good has the larger adjustment speed, $\kappa_b^F > \kappa_b^A$. The agricultural world price p_A^{world} varies by agricultural zone between food and cash crops.

Equations (77)–(78) are a reduced-form representation of thin-market and export-capacity frictions rather than frictionless adjustment all the way to parity. Exports enter origin goods-market clearing as demand and imports as supply, as described in Section C.9.

Informal non-tradability. The informal good is non-tradable across locations. Its local price P_j^I is determined by local goods-market clearing in equation (15). Conditional on the remaining equilibrium objects, CES demand declines with P_j^I when $\nu > 1$, providing the downward-sloping demand side of the local clearing condition.

C.5 Housing

Housing expenditure. Urban workers devote a city-size-dependent share of income to housing,

$$s_j^H = \min\left\{\omega_H \left(\frac{L_j}{L^{\text{ref}}}\right)^{\psi_H},\, s_{\text{cap}}^H\right\}, \qquad v_j^{\text{goods}} = v_j^U(1 - s_j^H), \tag{79}$$

which is equation (19). The reference population

$$L^{\text{ref}} = \frac{\sum_\ell L_\ell^2}{\sum_\ell L_\ell}$$

is the employment-weighted mean city size. The base housing share ω_H therefore applies at $L_j = L^{\text{ref}}$, while s_{cap}^H limits expenditure shares in the largest cities. For $0 < \psi_H < 1$, the uncapped housing share is increasing and concave in city size.

Housing absorbs a share of income but is not a produced good in the goods-clearing system. It reduces expenditure available for consumption to v_j^{goods} and enters the real disposable wage

$$\widetilde{w}_j^k = \frac{(1-s_j^H)w_j^k}{P_j}.$$

Housing costs therefore provide a congestion force that partly offsets the productivity gains from urban agglomeration.

Koyck housing supply and the long-run elasticity. The urban built-up envelope adjusts gradually. Between periods,

$$\log H_j^U(t+1) = b_0 + a_j + b_1 \log L_j(t+1) + \varrho \log H_j^U(t), \tag{80}$$

which is equation (34). Here a_j is a city fixed effect, b_1 is the short-run population elasticity, and $\varrho \in (0,1)$ governs persistence.

Step 1. At a stationary population L_j, the housing stock converges to $H_j^{U,*}$ satisfying

$$\log H_j^{U,*} = b_0 + a_j + b_1 \log L_j + \varrho \log H_j^{U,*}.$$

Step 2. Rearranging gives

$$\log H_j^{U,*} = \frac{b_0 + a_j + b_1 \log L_j}{1-\varrho},$$

so the long-run population elasticity of housing supply is

$$\frac{\partial \log H_j^{U,*}}{\partial \log L_j} = \frac{b_1}{1-\varrho}. \tag{81}$$

Step 3. The same result follows from the geometric Koyck representation,

$$\log H_j^U(t+1) = \frac{b_0 + a_j}{1-\varrho} + b_1 \sum_{s\geq 0} \varrho^s \log L_j(t+1-s),$$

whose long-run population weight sums to $b_1/(1-\varrho)$.

The short-run elasticity b_1 is below unity, so a rapid population inflow initially outpaces expansion of the built stock. This raises housing pressure in the transition. Persistence ϱ gives the built environment an additional source of path dependence.

C.6 Migration: net present values and the logit

Rural value. A worker who remains in rural location i earns the real disposable agricultural wage $\widetilde{w}_i^A = w_i^A / P_i$ each period. With no rural housing expenditure, the stationary Bellman equation is $V_i^R = \widetilde{w}_i^A + \beta V_i^R$. Hence

$$\Pi_i^R = \frac{\widetilde{w}_i^A}{1-\beta}, \tag{82}$$

which is equation (24).

Urban value and the formalization queue. A newcomer to city j enters the informal sector and initially earns $\widetilde{w}_j^I$. In each subsequent period she formalizes with probability $\lambda_j \equiv \lambda(\varphi_j)$, as defined in Section C.7. Once formal, she earns $\widetilde{w}_j^F$ thereafter.

Step 1. Formal value. A formal worker satisfies $V_j^F = \widetilde{w}_j^F + \beta V_j^F$, so

$$V_j^F = \frac{\widetilde{w}_j^F}{1-\beta}.$$

Step 2. Informal value. An informal worker earns $\widetilde{w}_j^I$ today and next period either formalizes with probability λ_j or remains informal with probability $1-\lambda_j$:

$$V_j^I = \widetilde{w}_j^I + \beta\left[\lambda_j V_j^F + (1-\lambda_j)V_j^I\right].$$

Step 3. Solving for V_j^I. Collecting terms gives

$$V_j^I\left[1-\beta(1-\lambda_j)\right] = \widetilde{w}_j^I + \beta\lambda_j V_j^F,$$

and therefore

$$V_j^I = \frac{\widetilde{w}_j^I}{1-\beta(1-\lambda_j)} + \frac{\beta\lambda_j}{1-\beta(1-\lambda_j)}V_j^F.$$

Step 4. Substituting the formal value. Using $V_j^F = \widetilde{w}_j^F/(1-\beta)$, the value of entering city j, $\Pi_j^U \equiv V_j^I$, is

$$\begin{aligned}\Pi_j^U = {} & \frac{\widetilde{w}_j^I}{1-\beta(1-\lambda_j)} \\ & + \frac{\beta\lambda_j}{(1-\beta)\left[1-\beta(1-\lambda_j)\right]}\widetilde{w}_j^F,\end{aligned} \tag{83}$$

which is equation (25).

The first term is the expected present value of the informal spell. Survival in the informal state has effective discount factor $\beta(1-\lambda_j)$, so

$$\sum_{s\geq 0}[\beta(1-\lambda_j)]^s \widetilde{w}_j^I = \frac{\widetilde{w}_j^I}{1-\beta(1-\lambda_j)}.$$

The second term is the option value of eventual formalization, with coefficient

$$\frac{\beta\lambda_j}{(1-\beta)[1-\beta(1-\lambda_j)]}.$$

As $\lambda_j \to 0$, the formal component vanishes and the destination value is dominated by informal earnings. As λ_j rises, the formal wage receives greater weight. The hazard, and therefore its structural determinant θ, governs how strongly the formal wage prize enters migration incentives. Government wages do not enter Π_j^U because government positions are allocated through the separate administrative employment rule in Section C.10.

Logit location choice. A worker in origin i evaluates each destination using its systematic value plus an idiosyncratic taste shock. Define

$$u_{ij} = \vartheta\big(\log \Pi_j + \gamma \hat{a}_j - \log C_{ij}\big),$$

where Π_j is the destination net present value, $\hat{a}_j$ is the destination amenity, γ is its coefficient, C_{ij} is the migration cost, and ϑ governs responsiveness to systematic value differences. Realized utility is $u_{ij} + \varepsilon_{ij}$, with ε_{ij} i.i.d. Type-I extreme value.

Step 1. The standard Gumbel result (McFadden, 1974) implies

$$\pi_{i\to j} = \frac{\exp(u_{ij})}{\sum_\ell \exp(u_{i\ell})}.$$

Step 2. Substituting the systematic component gives

$$\pi_{i\to j} = \frac{\exp\big[\vartheta\big(\log \Pi_j + \gamma \hat{a}_j - \log C_{ij}\big)\big]}{\sum_\ell \exp\big[\vartheta\big(\log \Pi_\ell + \gamma \hat{a}_\ell - \log C_{i\ell}\big)\big]}, \tag{84}$$

which is equation (26). Amenities enter inside the component scaled by ϑ, additively with $\log \Pi_j$ and with coefficient γ, which is normalized to one in the baseline calibration. The economic value entering location choice is the net present value Π_j, not current flow income.

The taste shocks have unit scale, while ϑ multiplies the systematic component. Equivalently, ϑ is the inverse taste-shock scale. A higher ϑ makes location choices more responsive to differences in expected destination values.

Migration costs. Bilateral migration costs contain a fixed component and a distance component, together with a destination-size adjustment:

$$
\begin{aligned}
C_{ij} &= \left(\kappa_{\text{fixed}} + \kappa_{\text{dist}}\, d_{ij}^{\eta_d}\right)\left(\frac{L_j}{L^{\text{ref}}}\right)^{-\kappa_s}, \\
C_{ii} &= 1, \qquad L^{\text{ref}} = \frac{\sum_\ell L_\ell^2}{\sum_\ell L_\ell},
\end{aligned} \tag{85}
$$

which is the specification in equation (27).[15]

The parameter κ_{fixed} captures the fixed cost of relocation, $\kappa_{\text{dist}} d_{ij}^{\eta_d}$ generates the distance gradient, and κ_s lowers effective migration costs toward larger destinations, capturing network and information advantages. The self-cost is normalized to $C_{ii} = 1$.

C.7 Properties of the formalization hazard

The formalization hazard is the central friction governing movement from informal to formal employment. Restating equations (28)–(29), the annual informal-to-formal transition probability is

$$
\begin{aligned}
\lambda(\varphi_j) &= \underline{\lambda} + \frac{(1-\underline{\lambda})(1-\varphi_j)^\theta}{1+\psi_{\text{eff}}(\varphi_j)(1-\varphi_j)^\theta}, \\
\psi_{\text{eff}}(\varphi_j) &= \psi_0 \left[1 + \left(\frac{\varphi_c}{\varphi_j}\right)^{\zeta_{\text{brake}}}\right].
\end{aligned} \tag{86}
$$

Here $\varphi_j = L_j^I/(L_j^I + L_j^F) \in [0,1]$ is the private informality share, $\underline{\lambda}$ is the formalization floor, θ governs curvature, ψ_0 governs saturation, and $(\varphi_c, \zeta_{\text{brake}})$ govern the low-informality brake. Define $x \equiv (1-\varphi_j)^\theta \geq 0$. For $\theta > 0$, x decreases with φ_j. Conditional on $\psi \equiv \psi_{\text{eff}}$, the hazard can be written as $\lambda = \underline{\lambda} + (1-\underline{\lambda})x/(1+\psi x)$.

Limits.

Property 1. Fully informal city. As $\varphi_j \to 1$, $x = (1-\varphi_j)^\theta \to 0$, so $\lambda \to \underline{\lambda}$. The floor therefore permits some formalization even when the formal sector is initially arbitrarily small.

[15] The destination-size adjustment is defined relative to the employment-weighted mean city size L^{ref}. The reference distance d_{ref} appears only in the trade-cost function (73); migration costs use raw bilateral distance.

Property 2. Saturation without the brake. If $\psi_{\text{eff}} \equiv \psi_0$ and $\varphi_j \to 0$, then $x \to 1$ and

$$\lambda \to \underline{\lambda} + \frac{1-\underline{\lambda}}{1+\psi_0}.$$

The saturation term therefore bounds the transition probability below one even when the informal queue becomes small.

Property 3. Brake at low informality. With the brake active, $\varphi_j \to 0$ implies

$$\psi_{\text{eff}} = \psi_0 \left[1 + \left(\frac{\varphi_c}{\varphi_j}\right)^{\zeta_{\text{brake}}}\right] \to \infty.$$

Consequently, $x/(1+\psi_{\text{eff}}x) \to 0$ and $\lambda \to \underline{\lambda}$. The brake therefore prevents the hazard from remaining high when the remaining informal pool becomes very small.[16]

Monotonicity. Holding ψ_{eff} fixed, differentiating the hazard with respect to x gives

$$\frac{\partial \lambda}{\partial x} = (1-\underline{\lambda})\frac{(1+\psi x) - x\psi}{(1+\psi x)^2} = \frac{1-\underline{\lambda}}{(1+\psi x)^2} > 0.$$

Since $x = (1-\varphi_j)^{\theta}$ decreases in φ_j, this component of the hazard satisfies $\partial\lambda/\partial\varphi_j < 0$: a larger informal queue lowers the formalization rate through the absorption channel. The full derivative also incorporates the low-informality brake through $\psi_{\text{eff}}(\varphi_j)$, which is intentionally designed to modify the hazard as the informal share approaches zero.

Comparative statics in the structural parameters.

Property 1. Curvature θ. For an interior informality share,

$$\frac{\partial x}{\partial \theta} = (1-\varphi_j)^{\theta}\ln(1-\varphi_j) = x\ln(1-\varphi_j) < 0.$$

Since ψ_{eff} does not depend on θ,

$$\frac{\partial \lambda}{\partial \theta} = \frac{\partial \lambda}{\partial x}\frac{\partial x}{\partial \theta} = \frac{(1-\underline{\lambda})x\ln(1-\varphi_j)}{(1+\psi x)^2} < 0.$$

A higher θ therefore lowers the formalization hazard at every interior φ_j. Conversely, reducing θ raises formalization capacity and increases the weight placed on future formal earnings in the urban value (83).

[16] For numerical evaluation, φ_j is bounded below by a small positive constant inside the brake to avoid division by zero. This numerical bound does not change the functional form.

Property 2. Saturation ψ_0. Because ψ_{eff} increases with ψ_0,

$$\frac{\partial \lambda}{\partial \psi_{\text{eff}}} = -(1-\underline{\lambda})\frac{x^2}{(1+\psi_{\text{eff}}x)^2} < 0.$$

A higher ψ_0 therefore lowers the hazard by tightening the saturation constraint. The floor $\underline{\lambda}$ determines the limiting hazard at the two extremes and scales the interior transition term through $1-\underline{\lambda}$.

Figure 1 in Section 3 plots $\lambda(\varphi)$ and the associated expected waiting time $1/\lambda(\varphi)$ for the baseline and alternative values of θ. The comparative statics above provide the analytical counterpart to that figure.

C.8 Productivity and amenity inversion

Productivity fundamentals A_ℓ^k and destination amenities $\hat{a}_j$ are not directly observed. I recover them by inverting the equilibrium conditions at the calibration anchors. Productivity follows directly from the sectoral first-order conditions in Section C.2, while amenities are chosen to rationalize observed destination populations conditional on the remaining model objects.

Productivity inversion. Solving (57), (60), and (63) for productivity, conditional on observed wages, employment, land, prices, and agricultural shocks, gives

$$A_i^A = \frac{w_i^A}{p_i^A(1-\alpha_A)\zeta_i^A(H_i^R/L_i^A)^{\alpha_A}}, \tag{87}$$

$$A_j^I = \frac{w_j^I}{P_j^I(1-\alpha_I)(L_j^I)^{\eta_I}(H_j^I/L_j^I)^{\alpha_I}}, \tag{88}$$

$$A_j^F = \frac{w_j^F}{p_j^F(1-\alpha_F)(L_j^F+L_j^G)^{\kappa_F}(H_j^F/L_j^F)^{\alpha_F}}. \tag{89}$$

The urban land inputs in (88)–(89) follow from the common-rent allocation derived in (65). In particular,

$$r_j^U = \frac{\frac{\alpha_I}{1-\alpha_I}w_j^I L_j^I + \frac{\alpha_F}{1-\alpha_F}w_j^F L_j^F}{H_j^U},$$

with

$$H_j^I = \frac{\alpha_I}{1-\alpha_I}\frac{w_j^I L_j^I}{r_j^U}, \qquad H_j^F = \frac{\alpha_F}{1-\alpha_F}\frac{w_j^F L_j^F}{r_j^U}.$$

When formal productivity is reported net of market access, $MA_j^{\eta_{MA}}$ is additionally included in the denominator of (89), with $MA_j = (1/\tau_j^{\text{world}})/\overline{MA}$ as defined in Section C.2.

Two-anchor smoothing. Productivity fundamentals are inverted at the calibration anchors. For interior years, the corresponding geometric smoother is

$$A_i^k(t) = \left[A_i^k(t-1)A_i^k(t+1)\right]^{1/2}, \tag{90}$$

which averages neighboring values in logs. This reduces high-frequency measurement noise while preserving the anchored endpoints. The construction additionally applies spatial smoothing to the productivity series.

Amenity inversion. Destination amenities are recovered from a fixed point that matches predicted destination populations to their observed counterparts at the calibration transition, conditional on real destination values and migration costs. The procedure is

Step 1. Initialize $\hat{a}_j \leftarrow 0$ for all destinations.

Step 2. Evaluate the migration probabilities in (84) at the current amenity vector and aggregate the implied destination populations L_j^{pred}.

Step 3. Update each amenity according to

$$\hat{a}_j \leftarrow \hat{a}_j + \text{step} \cdot \frac{\log(L_j^{\text{obs}}/L_j^{\text{pred}})}{\gamma}.$$

Step 4. Mean-center the vector,

$$\hat{a}_j \leftarrow \hat{a}_j - \bar{\hat{a}},$$

which fixes the level normalization because only relative amenities are identified.

Step 5. Repeat Steps 2–4 until

$$\max_j \left| \log\left(\frac{L_j^{\text{obs}}}{L_j^{\text{pred}}}\right) \right| < 10^{-6}.$$

Conditional on the model's wages, prices, housing costs, migration costs, and formalization values, this procedure recovers the $N_U - 1$ relative urban amenity differences together with a mean-zero normalization. The recovered amenity should therefore be interpreted as a residual destination fundamental. It captures persistent differences in attractiveness not accounted for by the model's explicitly measured or endogenous channels and may reflect networks, public goods, climate, or other location characteristics. This interpretation is conditional on the maintained structure rather than a separate identification of the underlying amenity components (Ahlfeldt et al., 2015).

C.9 Within-period equilibrium

Equilibrium unknowns. Given the state S_t, the within-period equilibrium determines

$$\mathbf{x} = \Big\{ \{p_i^A\}_{i \in \mathcal{S}_R}, \{p_j^F\}_{j \in \mathcal{S}_U}, \{P_j^I\}_{j \in \mathcal{S}_U}, \{r_j^U\}_{j \in \mathcal{S}_U} \Big\}, \tag{91}$$

a vector of dimension $N_R + 3N_U$. There is one agricultural origin price for each rural location and, for each city, one formal origin price, one informal price, and one urban land rent. Conditional on $\mathbf{x}$, factor prices follow from Section C.2, delivered price indices from Section C.4, and expenditure shares and consumption from Section C.3.

Income accounting. Per-capita expenditure combines labor income, land rents, and an equal per-capita allocation of aggregate net exports:

$$v_i^R = \frac{w_i^A L_i^A + r_i^R H_i^R}{L_i^A} + \frac{\mathrm{NX}}{L^{\mathrm{tot}}}, \tag{92}$$

$$v_j^U = \frac{w_j^I L_j^I + w_j^F L_j^F + w_G L_j^G + r_j^U H_j^U}{L_j} + \frac{\mathrm{NX}}{L^{\mathrm{tot}}}. \tag{93}$$

These are equations (20)–(21). The government wage w_G is spatially uniform. Aggregate net exports NX sum the international trade flows in (77)–(78) and are distributed equally over national population $L^{\mathrm{tot}} = \sum_\ell L_\ell$. For urban households, expenditure available for goods is $v_j^{\mathrm{goods}} = v_j^U(1 - s_j^H)$, which enters the super-subsistence expenditure term in (68).

Market-clearing conditions. The equilibrium price vector $\mathbf{x}$ satisfies the following conditions.

(i) *Factor pricing.* Wages and rents equal marginal value products according to (57)–(58), (60), (63), and the common urban rent (65).

(ii) *Agricultural goods clearing.* For each rural origin i,

$$(1 - h_A)Y_i^A + M_i^{A,\mathrm{imp}} = \sum_m (\text{delivered domestic demand for } i\text{'s variety}) + X_i^{A,\mathrm{exp}}, \tag{94}$$

where domestic demand is generated by the Armington system and international flows follow (77)–(78). The analogous condition applies to each formal origin.

(iii) *Informal goods clearing.* For each city j,

$$Y_j^I = C_j^I, \tag{95}$$

which is equation (15). Total informal demand includes demand by city residents and the limited demand routed from the associated rural hinterland. This condition determines P^I_j jointly with the remaining equilibrium prices.

(iv) *Urban land clearing.* For each city j,

$$H^I_j + H^F_j = H^U_j, \tag{96}$$

which is enforced through the shared urban rent (65).

Numeraire. Only relative prices are determined. During the numerical solution, one city's formal origin price is fixed as the numeraire. The resulting price vector is then rescaled so that the population-weighted mean delivered formal price index equals one. Individual formal origin prices p^F_j remain heterogeneous across cities.

Numerical solution. The equilibrium system is solved in log prices, which imposes positivity, using quasi-Newton minimization of the squared equilibrium residuals with warm starts from adjacent years. In the calibration-window equilibria, the residual norm is approximately 10^{-15}. Appendix D reports the numerical implementation and alternative solution methods.

Local solution properties. I do not impose or claim a general theorem establishing global existence or uniqueness for the full equilibrium system. The nonlinearities generated by agglomeration, endogenous expenditure shares, housing, and international trade make such a result non-trivial. Conditional on the remaining equilibrium objects, the local informal-goods block has downward-sloping CES demand in P^I_j when $\nu > 1$. More generally, I assess numerical regularity at the equilibria used in the quantitative analysis through residual convergence, alternative initializations, and the local Jacobian. Appendix D reports these diagnostics. The quantitative results therefore rely on the computed equilibrium branch rather than on a claim of global uniqueness.

C.10 Between-period dynamics and sequential equilibrium

State transition. The state evolves according to the deterministic operator $S_{t+1} = \Phi(S_t)$. The ordering below is part of the model's timing convention. Demographic change precedes migration, and migration responds to the previous period's equilibrium location-choice probabilities.

Step 1. Demographics. Natural population growth is first applied to employment, $L^{\text{demog}}_j =$

$L_j(1+n_j(t))$, where

$$n_j(t) = n_j^{\text{floor}} + \left(n_j^{\text{base}} - n_j^{\text{floor}}\right)\left[1 - \Lambda\left(k_{\text{demog}}(t - t_j^{\text{mid}})\right)\right], \tag{97}$$

which is equation (22). Here $\Lambda(\cdot)$ is the logistic function, n_j^{base} is the initial natural growth rate, and urban and rural locations converge toward their respective long-run floors at the transition midpoints reported in Section 6.

Step 2. Migration. Population is redistributed using the previous period's migration probabilities from (84),

$$L_j' = \sum_i \pi_{i\to j} L_i^{\text{demog}}.$$

Workers therefore condition location choices on the destination values observed in the preceding equilibrium rather than on the equilibrium generated collectively by contemporaneous migration.

Step 3. Outflow adjustment. In cities experiencing net population decline, informal and formal employment stocks contract proportionally.

Step 4. Formalization. The hazard (86) is applied to each city's informal stock according to (100)–(101). Net migrant inflows enter the informal sector.

Step 5. Productivity drift. Sectoral TFP growth converges according to

$$g_s(t) = g_s^{\text{long}} + \left(g_s^{\text{init}} - g_s^{\text{long}}\right)\exp\left[-\lambda_d(t - t_0)/10\right], \tag{98}$$

which is equation (32). The parameters g_s^{init}, g_s^{long}, λ_d, and t_0 are reported in Section 6. Agricultural shocks $\zeta_{i,t}^A$ and world prices $p_{k,t}^{\text{world}}$ are also updated at this stage.

Step 6. Government employment. Government employment follows the exogenous share rule

$$\begin{aligned} g_j &= \beta_0 + \beta_{\text{pop}} \log L_j + \beta_{\text{cap}}\, \mathbf{1}\{\text{capital}_j\}, \\ L_j^G &= g_j(L_j^F + L_j^G), \end{aligned} \tag{99}$$

which is equation (33). The implied share is restricted to $[0,1]$ and is evaluated using lagged population. An expansion of government employment draws workers through the informal-to-formal-to-government sequence, while a contraction returns government workers to the private formal pool.

Step 7. Housing. The built-up envelope is updated according to the Koyck process (80).

Step 8. Equilibrium. The within-period equilibrium in Section C.9 is solved at the updated state. The resulting migration probabilities are then carried forward to the next period.

Employment-stock dynamics. The formalization step updates private formal and informal employment according to

$$L^F_{j,t+1} = L^F_{j,t} + \lambda(\varphi_{j,t})L^I_{j,t} + \text{inflow}_F + \text{govt return}, \tag{100}$$

$$L^I_{j,t+1} = \big(1 - \lambda(\varphi_{j,t})\big)L^I_{j,t} + \text{inflow}_I - \text{govt pull}. \tag{101}$$

These are equations (30)–(31). In the baseline transition, net rural-origin migrant inflows enter the informal sector, so $\text{inflow}_F = 0$ and $\text{inflow}_I = \max\{0, \Delta L_j\}$. This restriction is motivated by the tenure-formality profiles in the microdata. Changes in government employment generate the corresponding pull and return terms. New working-age population enters through demographic growth and is subsequently allocated under the same transition structure.

An additional amenity adjustment operates along the forward path. Beginning at re-inversion date t_r, urban amenities evolve according to

$$\begin{aligned} \hat{a}_j(t) &= \hat{a}_j(t_r) + g_a(t - t_r), && \text{for urban } j, \\ \hat{a}_\ell(t) &\leftarrow \hat{a}_\ell(t) - \overline{\hat{a}(t)}, && \text{for all } \ell. \end{aligned} \tag{102}$$

Rural amenities receive no direct drift, so this adjustment gradually raises urban amenities relative to rural amenities while preserving the normalization of the amenity vector. It is a reduced-form adjustment for changes in urban attractiveness not captured by the time-invariant inversion. The parameters g_a and t_r are reported in Section 6. This adjustment does not enter the welfare measure directly.

Sequential competitive equilibrium. Given geography $\mathcal{G}$ in (54), an initial state S_0, and parameter vector Θ, a sequential competitive equilibrium is a sequence of states $\{S_t\}_{t\geq 0}$ and within-period equilibrium objects such that, in every period, factor prices satisfy the production first-order conditions, agricultural and formal goods markets clear through the Armington trade system and international trade bands, informal goods markets clear locally, urban land clears, and the numeraire is imposed. Between periods, the state evolves according to $S_{t+1} = \Phi(S_t)$ through Steps 1–8 above, with migration governed by the lagged logit in (84) and formalization governed by (86).

Myopic expectations. The model links annual within-period equilibria using lagged destination values rather than solving a perfect-foresight transition path. This assumption is particularly useful for the mechanism studied here because the urban state includes both population and the composition of employment between informal and formal work. Migration changes the informal queue, which changes φ_j and hence the subsequent probability of formalization. The sequential formulation makes this feedback explicit: workers respond to currently observed destination values, and their location choices alter the state determining future absorption.

The distinction between myopic and forward-looking expectations primarily affects transition dynamics. Under conditions studied in related dynamic spatial models, steady states can be invariant to the expectation structure even when transition paths differ (Kleinman et al., 2023). Sequential forward solution is also widely used in quantitative spatial models with migration, trade, and endogenous local prices (Caliendo et al., 2019; Redding and Rossi-Hansberg, 2017). I therefore interpret the simulated transition conditional on the model's expectation rule rather than as a claim that alternative expectation structures would generate the same transition path.

Finally, amenities are held fixed after their calibration except for the common urban drift described above. Location-specific prediction errors are therefore not absorbed by repeated amenity re-inversion. Errors in migration, demographic change, housing, formalization, and equilibrium prices instead propagate into subsequent states. Section 6 uses this feature when comparing the forward simulation with later observed urbanization and informality.

C.11 The stylized one-location economy

This section derives the stylized one-location economy introduced in Section 3.1. The purpose is to isolate the interaction between the formalization hazard and migration by abstracting from trade, housing, agglomeration, geography, and richer demographic dynamics. The economy is used only to illustrate the mechanism and does not enter calibration. Parameter values appearing in Figure 9 are therefore illustrative.

Environment and functional forms. A unit mass of workers is divided between one rural region and one city, with

$$L^R + L^U = 1, \qquad L^U = L^I + L^F, \qquad \varphi = \frac{L^I}{L^U}, \qquad L^I = \varphi L^U, \quad L^F = (1-\varphi)L^U. \tag{103}$$

Here φ is the urban informality share. Rural production uses labor and a fixed unit land endowment,

$$Y^R = A_R (L^R)^{1-\alpha}, \qquad \alpha \in (0,1), \tag{104}$$

so the competitive rural wage is

$$w^R(L^R) = (1-\alpha) A_R (L^R)^{-\alpha}. \tag{105}$$

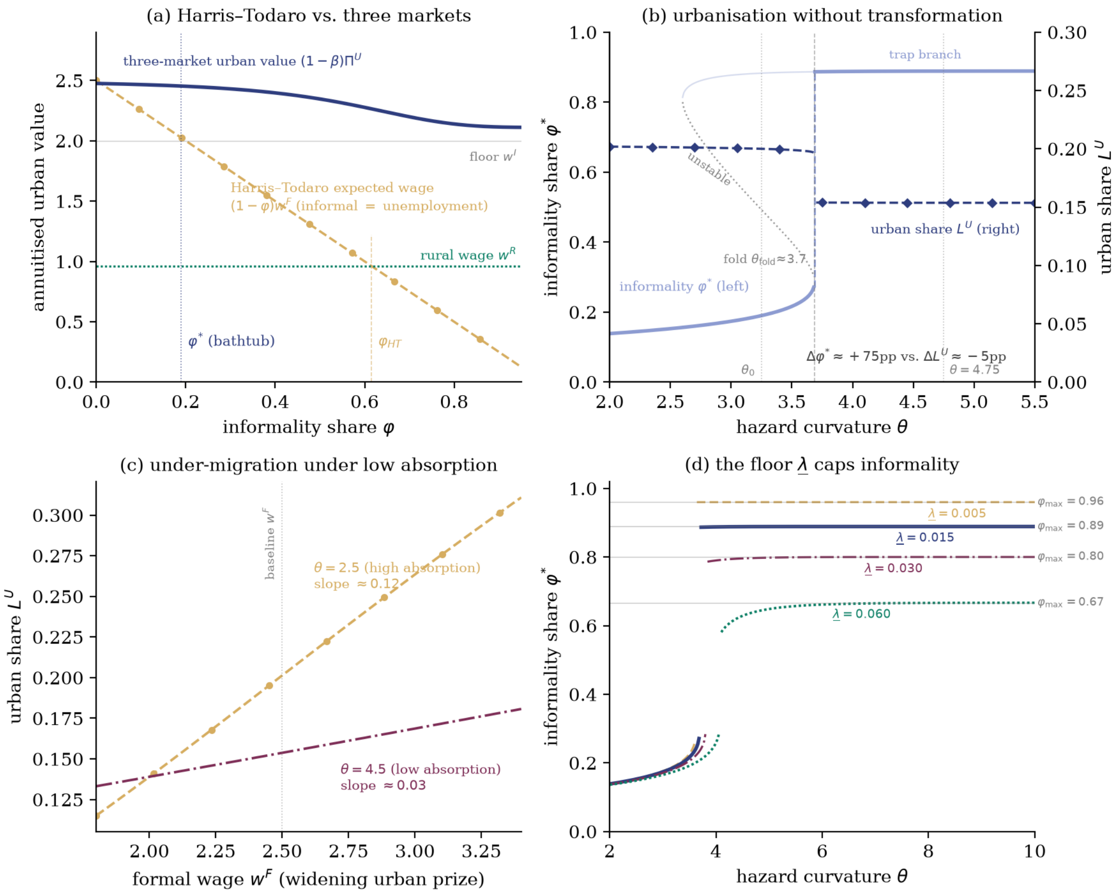

Figure 9: The stylized one-location economy.

Notes: Panel (a) compares the annuitized urban value with the Harris–Todaro expected wage as the informality share varies. Panel (b) plots the stationary informality share φ^* on the left axis and the urban share L^U on the right axis against the hazard curvature θ, including the fold at $\theta_{\text{fold}} \approx 3.7$ for the illustrative calibration. Panel (c) shows the urbanization response to a larger formal-wage prize under high and low absorption. Panel (d) shows how the hazard floor $\underline{\lambda}$ bounds stationary informality. Parameter values are illustrative. Source: author's computation.

The rural wage declines with rural employment and therefore rises with urbanization, since $L^R = 1 - L^U$. This diminishing-return force is the only equilibrating mechanism on the rural side of the stylized economy.

The city pays constant real wages

$$w^I < w^F \tag{106}$$

to informal and formal workers. In the full model these wages are endogenous marginal value products; here they are held fixed so that the only endogenous urban margins are composition φ and size L^U. Informal employment remains productive and paid rather than representing open unemployment.

Formalization follows the core absorption component of the full hazard,

$$\lambda(\varphi) = \underline{\lambda} + (1 - \underline{\lambda})(1 - \varphi)^{\theta}, \tag{107}$$

which declines from 1 at $\varphi = 0$ to the floor $\underline{\lambda}$ at $\varphi = 1$. The parameter θ governs curvature. Relative to (28)–(29), the stylized hazard omits the Michaelis–Menten saturation term ψ_0 and the low-informality brake $(\varphi_c, \zeta_{\text{brake}})$.

Value functions. Workers discount future income by $\beta \in (0, 1)$.

Step 1. Formal value. A formal worker earns w^F in perpetuity, so $V^F = w^F + \beta V^F$ and

$$V^F = \frac{w^F}{1-\beta}. \tag{108}$$

Step 2. Informal value. An informal worker earns w^I in the current period and then formalizes with probability $\lambda \equiv \lambda(\varphi)$ or remains informal with probability $1 - \lambda$:

$$V^I = w^I + \beta\big[\lambda V^F + (1-\lambda)V^I\big]. \tag{109}$$

Step 3. Solution. Collecting terms gives

$$V^I\big[1 - \beta(1-\lambda)\big] = w^I + \beta\lambda V^F.$$

Substituting (108), the urban value $\Pi^U \equiv V^I$ is

$$\begin{aligned} \Pi^U(\varphi) = & \frac{w^I}{1-\beta(1-\lambda)} \\ & + \frac{\beta\lambda}{(1-\beta)\big[1-\beta(1-\lambda)\big]} w^F. \end{aligned} \tag{110}$$

This is the same value expression as (83) after removing the housing adjustment. The rural value is

$$\Pi^R(L^R) = \frac{w^R(L^R)}{1-\beta}. \tag{111}$$

Multiplying (110) by $1 - \beta$ gives the annuitized urban value

$$(1-\beta)\Pi^U = (1-\omega_F)w^I + \omega_F w^F, \qquad \omega_F(\lambda) = \frac{\beta\lambda}{1-\beta(1-\lambda)} \in (0,1). \tag{112}$$

The coefficient ω_F is the discounted weight placed on future formal earnings. It approaches zero as $\lambda \to 0$, while $\omega_F \to 1$ as $\lambda \to 1$ and $\beta \to 1$. A low formalization hazard therefore substantially discounts the formal-wage prize from the perspective of a new urban entrant.

Stationary composition. Suppose a fraction $\delta \in (0, 1)$ of urban workers exits each period and is replaced by an entrant who begins in informal employment. Rural-origin migrants also enter the informal sector. A stationary urban composition requires formalization inflows to equal attrition from formal employment:

$$\underbrace{\delta L^F}_{\text{attrition}} = \underbrace{\lambda(\varphi)L^I}_{\text{formalization}} \iff \delta(1-\varphi) = \lambda(\varphi)\varphi \iff \varphi^* = \frac{\delta}{\delta + \lambda(\varphi^*)}. \tag{113}$$

Both flows are proportional to L^U, so the stationary composition condition is independent of city size. The stylized system is therefore recursive: (113) determines φ^*, after which the mobility condition below determines L^U.

Define

$$\mathcal{O}(\varphi) = \varphi\lambda(\varphi), \qquad \mathcal{I}(\varphi) = \delta(1-\varphi),$$

so stationary composition satisfies $\mathcal{O}(\varphi^*) = \mathcal{I}(\varphi^*)$.

Property 1. Existence. At the endpoints,

$$\mathcal{O}(0) = 0 < \delta = \mathcal{I}(0), \qquad \mathcal{O}(1) = \underline{\lambda} > 0 = \mathcal{I}(1).$$

Continuity therefore implies at least one interior stationary composition.

Property 2. Multiplicity. The outflow schedule is

$$\mathcal{O}(\varphi) = \underline{\lambda}\varphi + (1-\underline{\lambda})\varphi(1-\varphi)^\theta.$$

Its second component is single peaked, so the total outflow schedule can be non-monotone even though $\mathcal{I}(\varphi)$ is strictly decreasing. The two schedules can therefore intersect once or three times. For the illustrative calibration used in Figure 9, with $\theta = 3.25$, the three roots are

$$\varphi^* \in \{0.190,\ 0.493,\ 0.883\}.$$

Property 3. Local stability. Under the adjustment law

$$\dot{\varphi} = \delta(1-\varphi) - \lambda(\varphi)\varphi = \mathcal{I}(\varphi) - \mathcal{O}(\varphi),$$

a stationary point is locally stable when

$$\frac{d}{d\varphi}(\mathcal{O} - \mathcal{I}) > 0.$$

For the illustrative calibration, the low-informality and high-informality roots are locally stable, while the intermediate root is unstable.

Property 4. Trap appearance. Both saddle-node events are governed by the tangency system

$\mathcal{I}(\varphi) = \mathcal{O}(\varphi)$ and $\mathcal{I}'(\varphi) = \mathcal{O}'(\varphi)$. Eliminating the hazard level between the two conditions yields the closed-form tangency locus

$$\theta = \frac{\delta(1-\varphi)}{\varphi\,[\delta(1-\varphi) - \underline{\lambda}\varphi]}, \qquad (1-\varphi)^{\theta} = \frac{\delta(1-\varphi)/\varphi - \underline{\lambda}}{1-\underline{\lambda}},$$

whose two solutions bracket the bistable region. At the illustrative calibration ($\delta = 0.12$, $\underline{\lambda} = 0.015$), the high-informality trap appears at tangency composition $\varphi \approx 0.81$ with critical curvature

$$\theta^* \approx 2.60.$$

Below θ^* the stationary composition is unique and low-informality; above it a second stable high-informality steady state coexists with the transformation equilibrium. Because the tangency system involves only δ and $\underline{\lambda}$, the trap's existence is independent of the migration side of the economy, which determines its size and welfare cost instead. The window is moderately sensitive to the illustrative parameters: $\underline{\lambda} = 0.01$ gives $(\theta^*, \theta_{\text{fold}}) \approx (2.36, 3.65)$, $\underline{\lambda} = 0.03$ gives $(3.16, 3.80)$, and $\delta = 0.10$ gives $(2.85, 4.31)$.

Property 5. Regime threshold. As θ rises further, the low-informality and intermediate roots approach one another and disappear in the second saddle-node bifurcation of the same tangency system. In the illustrative calibration this occurs at tangency composition $\varphi \approx 0.29$ near

$$\theta_{\text{fold}} \approx 3.7.$$

Beyond this threshold only the high-informality branch remains. The economy is therefore bistable for $\theta \in (\theta^*, \theta_{\text{fold}}) \approx (2.6, 3.7)$, a window containing the calibrated baseline $\theta = 3.25$. This provides a stylized representation of how endogenous formalization can generate sharply different absorption regimes. In the full quantitative model, the saturation and brake terms of the complete hazard smooth this bistability into the regime boundary near $\theta \approx 4$ documented in Section 7.2; the analytic thresholds here are the stylized image of that boundary.

Property 6. Informality ceiling. As $\theta \to \infty$, $(1-\varphi)^{\theta} \to 0$ for every $\varphi > 0$, implying $\lambda \to \underline{\lambda}$. Equation (113) then gives

$$\varphi_{\max} = \frac{\delta}{\delta + \underline{\lambda}} < 1. \tag{114}$$

The hazard floor therefore bounds stationary informality away from one.

Location choice. Workers choose between the rural region and the city based on destination values net of a migration friction. With two-option logit dispersion ϑ and rural attachment or relocation wedge c, urbanization satisfies

$$L^U = \left\{1 + \exp\left[-\vartheta\left(\log \Pi^U(\varphi^*) - \log \Pi^R(1 - L^U) - c\right)\right]\right\}^{-1}. \tag{115}$$

The right-hand side decreases with L^U because rural wages rise as rural employment falls, while the left-hand side increases in L^U. The mobility condition therefore has a unique fixed point conditional on φ^*.

In the free-mobility limit $\vartheta \to \infty$, (115) converges to

$$\Pi^R(L^R) = \Pi^U(\varphi^*) \iff w^R(L^R) = (1-\beta)\Pi^U(\varphi^*). \tag{116}$$

Combining this condition with (105) yields

$$L^R = \left[\frac{(1-\alpha)A_R}{(1-\beta)\Pi^U}\right]^{1/\alpha}, \qquad L^U = 1 - L^R.$$

Finite ϑ dampens the spatial response. The analytical comparative statics below use the free-mobility expression where useful, while Figure 9 retains finite ϑ.

Harris–Todaro benchmark. In the classic Harris–Todaro environment, the rural wage equals the expected urban wage when a prospective urban worker obtains a formal job with probability p and otherwise earns zero:

$$w^R = p\, w^F.$$

Identifying p with the formal-employment share $1-\varphi$ gives

$$w^R = (1-\varphi)w^F. \tag{117}$$

Equation (117) is not obtained as a parameter limit of the Bellman equation (109). In particular, letting $\beta \to 0$ removes the value of future formalization and leaves the entrant with w^I. Instead, Harris–Todaro is recovered by replacing the dynamic queue with a static one-period employment lottery. If current urban income is

$$\mathrm{EW}^U = (1-\varphi)w^F + \varphi w^I,$$

then imposing $w^I \to 0$ and free-mobility indifference $\mathrm{EW}^U = w^R$ reproduces (117).

Three features distinguish the present three-market economy from this benchmark.

Departure 1. Informal work is paid. When $w^I > 0$, the annuitized urban value in (112) is bounded below by the informal wage rather than by zero. In the illustrative calibration it remains above 2.1 for $\varphi \in [0, 0.95]$, while $w^R \approx 0.96$. Migration indifference therefore does not determine the urban informality share.

Departure 2. Formalization is dynamic. The weight on the formal wage is

$$\omega_F = \frac{\beta\lambda}{1-\beta(1-\lambda)},$$

rather than the contemporaneous formal-employment share $1-\varphi$.

Departure 3. Composition and city size are distinct margins. The bathtub condition (113) determines φ independently of L^U, while the mobility condition determines L^U conditional on composition. Harris–Todaro instead combines the employment-composition and migration margins in a single expected-wage condition.

A separate benchmark within the stylized model is $\theta \to 0$. In this limit $\lambda \to 1$, so every informal worker formalizes immediately and

$$\varphi^* = \frac{\delta}{1+\delta}.$$

At the illustrative value $\delta = 0.12$, this gives $\varphi^* \approx 0.11$. Informality is therefore small but remains positive because new entrants begin in the informal sector.

Comparative statics. Define the stationary-composition residual

$$G(\varphi, \theta) = \varphi\lambda(\varphi; \theta) - \delta(1-\varphi),$$

with $G(\varphi^*, \theta) = 0$. On a stable branch,

$$\frac{\partial G}{\partial \varphi} > 0,$$

and

$$\frac{\partial G}{\partial \theta} = \varphi(1-\underline{\lambda})(1-\varphi)^{\theta}\ln(1-\varphi) < 0$$

for interior φ, since $\ln(1-\varphi) < 0$.

Result 1. Formalization capacity. The implicit function theorem gives

$$\frac{d\varphi^*}{d\theta} = -\frac{\partial G/\partial\theta}{\partial G/\partial\varphi} > 0.$$

A higher θ therefore raises stationary informality on a stable branch, while a lower θ increases formalization.

Result 2. Urbanization. A higher φ^* lowers the equilibrium formalization rate $\lambda^* = \lambda(\varphi^*)$

and therefore lowers the urban value through (112). The mobility condition then implies

$$\frac{dL^U}{d\theta} < 0.$$

The urbanization response is attenuated because the urban value remains bounded below by the positive informal wage w^I.

Result 3. Different sensitivities of composition and location. The parameter θ affects urban composition directly through the bathtub condition, while city size responds only indirectly through the resulting change in Π^U and is further dampened when ϑ is finite. In the illustrative calibration, this produces a much larger response of informality than of urbanization, mirroring the qualitative asymmetry emphasized in the full model.

Result 4. Response to the formal-wage prize. The migration response to a higher formal wage, dL^U/dw^F, is larger when formalization is easier. When absorption is poor, a new entrant assigns relatively little weight to w^F in (112), so a larger formal-wage prize has only a weak effect on the urban value and hence on migration.

Result 5. Hazard floor. Equation (114) implies

$$\frac{\partial \varphi_{\max}}{\partial \underline{\lambda}} = -\frac{\delta}{(\delta + \underline{\lambda})^2} < 0.$$

A higher formalization floor therefore lowers the maximum stationary informality share.

These results are intended to clarify comparative-static directions rather than reproduce the quantitative magnitudes of the full spatial equilibrium. The richer model additionally allows wages, prices, housing costs, migration frictions, demographics, and agglomeration to respond endogenously, so its distributional and quantitative results need not follow from the stylized economy alone.

D Computation and Solution Algorithm

This appendix describes the numerical solution and calibration of the model. Section D.1 presents the within-period equilibrium solver. Section D.2 describes the between-period transition operator. Section D.3 summarizes the calibration stages and their numerical scale. Parameter values and identifying moments are reported in Section 6 and Appendix E. Additional numerical diagnostics are reported in Online Appendix OA-3.

D.1 Within-period equilibrium solver

Within each period, the model solves a static spatial competitive equilibrium across 121 locations, comprising 43 urban and 78 rural locations. Sectoral employment, urban housing stocks, agricultural shocks, productivities, and world prices are predetermined within the period. The solver determines the price vector that jointly clears product and land markets.

Unknowns. The equilibrium contains 207 unknowns,

$$\mathbf{x} = \left\{ p_i^A \ (78),\ p_j^F \ (43),\ P_j^I \ (43),\ r_j^U \ (43) \right\}, \qquad \dim(\mathbf{x}) = 78 + 3 \times 43 = 207.$$

There is one agricultural origin price for each rural location and, for each urban location, one formal origin price, one local informal price, and one urban land rent. The sectoral land allocations H_j^I and H_j^F are not separate unknowns. They are recovered from the first-order conditions and the common urban land-clearing condition derived in Appendix C.

Residual system. Market-clearing conditions are expressed as log supply-demand ratios,

$$\begin{aligned}
R_i^A &= \log\left(\frac{S_i^A}{D_i^A}\right), && i = 1, \ldots, 78, \quad \text{agricultural goods,} \\
R_j^F &= \log\left(\frac{S_j^F}{D_j^F}\right), && j = 1, \ldots, 43, \quad \text{formal goods,} \\
R_j^I &= \log\left(\frac{Y_j^I}{D_j^I}\right), && j = 1, \ldots, 43, \quad \text{informal goods,} \\
R_j^H &= \log\left(\frac{H_j^I + H_j^F}{H_j^U}\right), && j = 1, \ldots, 43, \quad \text{urban land.}
\end{aligned}$$

Agricultural and formal market clearing incorporate international imports and exports through the Samuelson trade bands in Appendix C. Informal goods are non-tradable across cities and clear against local demand together with demand routed from the associated rural hinterland. For small deviations from equilibrium, $\log(S/D) \approx (S - D)/D$, so these residuals approximately measure proportional excess supply.

Numeraire. The equilibrium determines only relative prices. During the numerical solution, the formal origin price of one city is normalized to one, $p_1^F \equiv 1$. Solving in log prices simultaneously imposes positivity. After convergence, all nominal prices and incomes are rescaled so that the population-weighted mean delivered formal price index equals one. This normalization leaves all real allocations unchanged.

Solution method. The default numerical method is fixed-point iteration with Anderson acceleration. Newton, trust-region, and L-BFGS methods provide alternative solution routines, with L-BFGS minimizing

$$\frac{1}{2}\|\mathbf{R}\|^2.$$

Jacobians are evaluated by forward-mode automatic differentiation where required, and adjacent-period equilibria provide warm starts along the forward path.

The static-parameter grid converges for 423 of 432 configurations, or 98 percent. All configurations in the trade and productivity-drift searches converge. Non-convergent parameter configurations are excluded from selection. For converged calibration-window equilibria, the maximum market-clearing residual is below 10^{-14}.

D.2 Between-period transition operator

The within-period equilibrium is embedded in an annual transition operator that updates employment, productivity, government employment, and housing before solving the next equilibrium. The ordering is economically consequential because demographic change occurs before migration and migration responds to the previous period's destination values.

1. **Demographics.** Each location's population is updated using the natural-growth process described in Appendix C. Urban and rural growth rates follow separate logistic transitions toward their long-run values.

2. **Migration.** Population is redistributed according to the multinomial logit using the previous period's equilibrium migration probabilities $\pi_{i\to j}$. Migration therefore responds to lagged destination values rather than to a contemporaneous migration-equilibrium fixed point.

3. **Outflow adjustment.** In cities experiencing net population decline, informal and formal employment stocks contract proportionally, subject to the maximum annual decline imposed in the transition algorithm.

4. **Formalization.** Each city applies the transition hazard $\lambda(\varphi_j)$ to its informal employment stock. Net rural-origin migrant inflows enter informal employment.

5. **Productivity drift.** Sectoral productivity growth follows

$$g_s(t) = g_s^{\text{long}} + \left(g_s^{\text{init}} - g_s^{\text{long}}\right) \exp[-\lambda_d(t - 2014)/10] \,.$$

   A common urban productivity-growth process is applied to the informal and formal sectors. World-price drift is zero in the baseline forward path.

6. **Government employment.** Government employment follows the estimated share rule

$$g_j = \beta_0 + \beta_{\text{pop}} \log(\text{pop}_j) + \beta_{\text{cap}} \mathbf{1}\{\text{capital}_j\}.$$

   The resulting government employment stock is updated after private formalization.

7. **Housing supply.** The built-up urban envelope follows the Koyck process

$$\log H^U_{j,t+1} = b_0 + a_j + b_1 \log L^U_{j,t+1} + \varrho \log H^U_{j,t}.$$

   Housing therefore responds gradually to population changes and inherits persistence from the existing built stock.

8. **Equilibrium.** The within-period equilibrium is solved at the updated state. The resulting migration probabilities are retained for the following period's migration step.

Two timing conventions deserve emphasis. First, demographics precede migration. Second, migration operates on lagged equilibrium destination values. A period's migration flows therefore reflect the conditions observed before those flows alter employment composition, housing demand, and prices. Government hiring occurs after formalization and before the housing update.

From the 2025 amenity re-inversion onward, urban log amenities receive the constant drift and subsequent re-centering described in Appendix C.

Table 18: Calibration stages

Stage	Parameters selected	Configurations	Selected fit
Static structure	CES demand, housing, variety weights, and retail parameters	432	score 1.628
Trade channel	Samuelson-band parameters and world-market scaling	495	zero sign flips
Productivity drift	TFP convergence paths	34,056	score 0.013
Dynamic transition	Formalization, migration, and demographic parameters	1,763	loss ≈ 0.69

Notes: The static, trade, and dynamic-transition counts refer to distinct parameter configurations. The productivity-drift count refers to total equilibrium solves across the component searches. The dynamic objective is closest to its minimum along a θ–ψ_0 ridge. Section 6 and Appendix E.12 describe how cross-city informality dispersion provides additional discipline for selecting θ along this ridge. Source: author's computation.

D.3 Calibration architecture

Calibration proceeds in four stages. The first selects the static parameters governing demand, housing, varieties, and retail trade using the 2007–2014 cross-sections. The second selects the international trade parameters using observed trade patterns. The third selects the productivity-growth path. The fourth selects the parameters governing formalization, migration, and demographic dynamics against the forward path. At every candidate parameter configuration, the corresponding spatial equilibrium is solved rather than approximated by a partial-equilibrium response.

Table 18 summarizes the numerical scale and fit of the four calibration stages.

The stages are sequential in parameter selection but retain the full general-equilibrium structure at each stage. Static parameters and the trade specification are selected before the forward dynamic search. Conditional on these objects, every candidate productivity or dynamic parameter vector is evaluated by solving the complete spatial equilibrium along the relevant path. The dynamic calibration therefore incorporates the equilibrium effects of migration, formalization, prices, housing, and trade rather than evaluating these margins separately.

The exact parameter grids and additional numerical diagnostics are reported in Online Appendix OA-3.

E Calibration Targets and Corridors

This appendix provides additional detail on the calibration strategy described in Section 6. Section E.1 first collects the calibration and validation detail that the main text summarizes, in the order of the main text. I then document the parameters disciplined outside the quantitative model and the constructed fundamentals entering the calibration. I then describe the productivity and amenity paths, provide additional validation of the within-period equilibrium, and set out the aggregate moments used to discipline the forward simulation. The remaining sections examine the external comparison envelope, the θ–ψ_0 identification ridge, and the additional moments used to distinguish parameter combinations along that ridge. Search ranges for grid-searched parameters are reported in Online Appendix OA-4.

E.1 Additional calibration and validation detail

Production and urban labor markets. Appendix E.2 reports the empirical ranges for the factor shares and shows robustness to alternative shares within them. The model does not impose the formal–informal productivity gap directly. Location-sector productivity levels are recovered from observed earnings and employment, so the urban wage gap documented in Section 5 reflects the equilibrium productivity of the two labor markets rather than an arbitrary wage wedge. Workers are homogeneous, so the gap is a sector fundamental rather than a return to selection on ability. The model requires only that formal productivity exceed informal productivity within a city at the anchor.

Preferences and expenditure. The nonhomotheticity estimates $e_A = -0.103$ for food and $e_U = 0.109$ for urban goods imply that the food expenditure share declines with income while the urban-goods share rises. Their estimated standard errors are 0.005 and 0.014, respectively, rejecting the homothetic benchmark in both cases. The remaining expenditure weights come directly from observed consumption patterns. Rural households consume approximately 8 percent of agricultural production at home, giving $h_A = 0.08$. Within the urban composite, ESS expenditure shares imply weights of $\omega_I = 0.531$ on informal goods and $\omega_F = 0.469$ on formal goods. The upper-tier food weight is set to $\mu_A = 0.965$ so that the model reproduces the national food expenditure share of 0.76 measured in the 2004/05 HICES. Like all monetary quantities in the paper, the subsistence term $\bar{c}_A = 2{,}000$ birr is a real value in constant 2010/11 birr. It corresponds to roughly 40 percent of median annual rural or informal earnings per worker at the 2007 anchor and to a substantially larger share of per-capita income once dependants are accounted for, consistent with the importance of food needs at Ethiopian income levels. The elasticity $\nu = 8$ is disciplined by the observed expenditure split and relative-price variation.

Spatial fundamentals. Persistent location-specific productivity is recovered by inversion at the 2007 anchor rather than treated as a large set of free parameters. Given observed sectoral employment, wages, land, built surface, and prices, I invert the production first-order conditions to recover $A^A_{i,0}$, $A^I_{j,0}$, and $A^F_{j,0}$ following Allen and Arkolakis (2014). These fundamentals capture persistent spatial differences in agricultural potential, infrastructure, skills, and institutions that are not separately observed. The recovered agricultural fundamental is subsequently combined with the time-varying shock $\zeta^A_{i,t}$ constructed from MODIS vegetation and CHIRPS rainfall data, which has a correlation of 0.758 with observed AgSS yield measures.

Destination amenities $\hat{a}_\ell$ are recovered from the 2007 population distribution through the migration-choice system and normalized to have mean zero. They capture persistent location characteristics valued by households but not reflected in measured real earnings, including access to services, social networks, climate, and other local conditions. City-specific informal demand weights are scaled to the observed demand-relevant informality share, while formal market access is constructed from each city's cost of reaching the international gateway. The within-period parameterization in Table 3 is held fixed when evaluating the within-period equilibrium.

Fit within the calibration panel. The model closely reproduces the spatial ranking of all four outcomes in Panel A of Table 4. The Spearman correlation is 0.894 for private-formal wages, 0.981 for rural income, 0.940 for the local formal-to-rural wage premium, and 0.976 for migration-relevant market access. Because anchor wages help recover the location-specific productivities, the wage correlations are not fully independent validation. Instead, they show that the inverted fundamentals remain consistent with the observed spatial economy beyond the 2007 anchor.

Market access provides a more demanding check because it combines wages, local prices, housing costs, trade access, amenities, and formalization prospects into the attractiveness of alternative locations. Its strong spatial fit shows that these separately disciplined components reproduce the relative attractiveness of rural origins and urban destinations rather than only the wage levels used in the inversion.

Validation against an independent construction. Panel B of Table 4 breaks the common data-construction channel. Rather than using the city-level measures entering calibration, I aggregate the raw UEUS independently at the survey's native zone level and compare them with corresponding model locations. The strongest result is the private informality share, whose spatial ranking the model reproduces with a correlation of 0.982. Cross-city informality is highly persistent, so a model initialized at the 2007 distribution begins with much of the ranking already present. The result shows that four years of endogenous demand, migration, and formalization preserve that spatial structure rather than generating convergence toward a substantially different distribution.

The independent private-formal wage correlation is lower but remains substantial at 0.622. The informal-to-formal wage ratio is reproduced less successfully, with a correlation of 0.318. Informal earnings vary relatively little across locations and combine employee wages with own-account income from small zone-level samples, making their spatial ranking difficult to recover. Fit is therefore strongest for employment composition and relative location attractiveness, the objects central to the model, and weakest for informal earnings, the object measured with the least spatial precision in the underlying survey.

External transformation benchmarks. The urban share series is rescaled once to the model's fixed city definition at the common 2011 observation (Section E.8). The informality path is deliberately intermediate between the cross-country income–informality relationship of La Porta and Shleifer (2014) and the slower time-series decline among least-developed economies (International Labour Organization, 2018). No equally authoritative long-run projection exists for Ethiopia's formal employment share, and all three paths are transformation benchmarks rather than literal forecasts. Evaluated at these projected states, the equilibrium reallocates labor and demand smoothly, without discontinuous movements in prices, wages, expenditure shares, or trade, far outside the 2007–2014 calibration window.

Recursive dynamics. The recursive block moves the economy from one within-period equilibrium to the next through demographic change, migration, formalization, productivity growth, government employment, and housing adjustment. Most transition parameters are disciplined directly by demographic projections, migration data, observed productivity growth, and housing estimates. A smaller set jointly determines the pace and composition of the aggregate transition and is selected to reproduce the population, urbanization, and informality benchmarks.

Demographics. Local populations first evolve along separate rural and urban natural-increase paths before workers choose whether and where to migrate. The urban floor is closely benchmarked to the projected demographic transition, while the rural floor and steepness are selected within the corresponding projection corridor to reproduce the curvature of national population growth. These parameters govern the pace of demographic adjustment rather than initial population levels, which are taken directly from the spatial data.

Migration costs. Distance discourages movement, while larger cities provide denser networks, better information, and more frequent transport connections that reduce effective migration costs. The discount factor $\beta = 0.95$ follows annual values used in dynamic migration models (Lagakos et al., 2023).

Productivity corridor and amenity drift. The relatively high initial growth rates capture Ethiopia's rapid growth over the historical calibration period, while the lower terminal rates prevent that episode from being extrapolated indefinitely. The urban path is not separately identified from the short historical panel, so it is selected within a conservative catch-up corridor and disciplined jointly by aggregate output, urbanization, and employment composition. The urban amenity drift lets urban attractiveness improve gradually beyond the level recovered at the anchor, through infrastructure, public services, and technology, without introducing an unrestricted urban preference trend. The joint calibration penalizes drift values under which amenity drift accounts for less than 5 or more than 25 percent of projected urbanization over 2025 to 2065, and the selected value implies a share of about 15 percent. This band is a calibration restriction that keeps unmeasured local attractiveness a minor driver of urbanization relative to real earnings, formalization prospects, housing costs, and market access. The drift is selected jointly with the other transition parameters, kept deliberately small, and does not enter measured welfare.

Government employment and housing adjustment. Public employment follows the UEUS city-size and administrative-capital rule and expands local demand and the formal agglomeration base as cities grow. Built surface follows the GHSL adjustment equation with short-run elasticity $b_1 = 0.50$ and persistence $\varrho = 0.438$, so delayed construction raises urban costs when migration outpaces it.

Formalization. The calibration of the formalization block preserves three features of the mechanism. Formalization remains possible in highly informal cities, becomes easier as the formal employment base expands, and is bounded by institutional and firm-level throughput. The transition is therefore gradual and incomplete rather than an automatic consequence of urban growth (McCaig and Pavcnik, 2018; Ulyssea, 2018).

Joint forward performance. The joint fit in Figure 3 is more demanding than matching three independent trends because the target paths are linked by opposing feedbacks. Faster rural natural increase raises population but also migration pressure, migration raises urbanization but replenishes the informal queue, and faster formalization attracts additional migrants who must themselves be absorbed. The model reconciles these forces through wages, prices, housing costs, employment composition, and migration values in every year.

Spatial diagnostic on current capacity. Values below roughly $\theta = 4.4$ push cross-city informality dispersion below its 2014 level by 2065, and the projection-consistent value drives it close to zero, much faster than its historical persistence suggests (Table 25 in Section E.12). Because future dispersion is unobserved, this is a consistency check rather than direct evidence on current capacity. The implied slow pace also accords with persistent informality across much of the developing world (International Labour Organization, 2018). Higher worker-level transition rates reported elsewhere need not map directly into equilibrium formalization capacity because of classification changes and the additional informal entrants attracted by faster formalization (Danquah et al., 2021; Donovan et al., 2023). Even at $\theta = 0$, the annual formalization rate is capped near 11 percent by ψ_0, reflecting firm-level and institutional throughput constraints that remain when congestion disappears. Residual demand for informal goods also sustains a positive informal sector in equilibrium.

E.2 Layer 1: parameters disciplined outside the model

This subsection provides the sources and estimation procedures for the parameters summarized in Table 3 that are not selected by matching the model's equilibrium transition.

Production. The land shares are $\alpha_A = 0.40$ in agriculture (Gollin et al., 2014; Restuccia et al., 2008), $\alpha_I = 0.20$ in the urban informal sector (De Mel et al., 2008), and $\alpha_F = 0.10$ in the formal sector (Tombe and Zhu, 2019; Desmet and Rossi-Hansberg, 2014). The agglomeration elasticities are estimated from UEUS city cross-sections using sector employment as the scale variable. The resulting estimates are

$$\eta_I = 0.05, \qquad \kappa_F = 0.06,$$

for the externalities

$$\delta_j^I = (L_j^I)^{\eta_I}, \qquad \delta_j^F = (L_j^F + L_j^G)^{\kappa_F}.$$

The regressions include region and year fixed effects but no external instrument, so these estimates should be interpreted as conditional associations rather than causal agglomeration elasticities. Section 10 varies both parameters and shows that the principal counterfactual results are not sensitive to their baseline values.

Preferences and trade. The upper-tier substitution elasticity is $\rho = 0.50$. The non-homotheticity parameters are

$$e_A = -0.103\ (0.005), \qquad e_U = 0.109\ (0.014),$$

where standard errors are in parentheses. They are estimated from ESS expenditure data using the specification of Comin et al. (2021), with $e_s = 0$ denoting the homothetic case. The home agricultural consumption share is $h_A = 0.08$, measured from ESS crop own-consumption. The inner urban demand weights are $\omega_I = 0.531$ and $\omega_F = 1 - \omega_I = 0.469$, based on 2018 ESS expenditure.

The Armington elasticities are $\sigma_A = 4$ for agricultural goods (Simonovska and Waugh, 2014) and $\sigma_F = 6$ for formal goods (Broda and Weinstein, 2006). The distance elasticity of goods trade costs is $\eta_{tr} = 0.40$ (Atkin and Donaldson, 2015), entering

$$\tau_{ij} = \left(1 + \frac{d_{ij}}{600}\right)^{\eta_{tr}},$$

with reference distance $d_{\text{ref}} = 600$ km. Urban food additionally carries the retail wedge $\tau_{\text{retail}} = 0.15$, based on Minten et al. (2014).

Housing. The housing expenditure share is

$$s_j^H = \min\left\{\omega_H \left(\frac{L_j}{L^{\text{ref}}}\right)^{\psi_H}, 0.40\right\},$$

with $\omega_H = 0.35$ (Davis and Ortalo-Magné, 2011) and $\psi_H = 0.30$ (Combes et al., 2019). The upper bound of 0.40 is selected within the static calibration and is reported with the remaining calibrated housing parameters in Table 3.

The dynamic housing parameters are estimated from the GHSL built-up panel. The short-run population elasticity is $b_1 = 0.50$ and persistence is $\varrho = 0.438$. The implied long-run elasticity is

$$\frac{b_1}{1-\varrho} = 0.89.$$

Migration and discounting. The migration distance elasticity is $\eta_d = 1.3$, estimated from 2007 Census bilateral migration flows. This lies within the 1.1–1.5 range reported by Morten and Oliveira (2024). The annual discount factor is $\beta = 0.95$ (Lagakos et al., 2023). The remaining migration-cost parameters enter

$$C_{ij} = \left(\kappa_{\text{fixed}} + \kappa_{\text{dist}} d_{ij}^{\eta_d}\right) \left(\frac{L_j}{L^{\text{ref}}}\right)^{-\kappa_s}.$$

The distance coefficient is $\kappa_{\text{dist}} = 0.0025$, while κ_{fixed} and κ_s, together with the remaining dynamically calibrated migration parameters, are selected using the procedures described below and in Table 5.

Government employment and demographics. Government employment follows

$$g_j = \beta_0 + \beta_{\text{pop}} \log(\text{pop}_j) + \beta_{\text{cap}} \mathbb{1}[\text{capital}_j].$$

Estimating this relationship on the 2003–2018 UEUS zone-year panel gives

$$\hat{\beta}_0 = 1.35, \qquad \hat{\beta}_{\text{pop}} = -0.067, \qquad \hat{\beta}_{\text{cap}} = 0.051.$$

The government wage is $w_G = 21{,}600$ birr per year in constant 2010/11 prices. Government wages do not enter the migration value because workers cannot choose government employment as a migration destination state.

The demographic transition is anchored to the UN World Population Prospects 2024 medium variant. The urban natural-increase rate converges toward a floor of 0.6% per year with midpoint 2030, while the rural rate converges toward a floor of 2.0% with midpoint 2040. The rural floor and transition steepness are additionally disciplined by the aggregate population path described in Section E.7. They are therefore treated as calibrated transition parameters rather than purely externally imposed quantities.

E.3 Layer 2: constructed fundamentals and shifters

This subsection provides additional construction detail for the agricultural shock and market-access shifter entering the quantitative model.

Agricultural shocks. The agro-climatic factor $\zeta^A_{j,t}$ combines MODIS vegetation conditions and CHIRPS rainfall through

$$\zeta_j = B_j \left(\text{belg\_ratio}_j\right)^{0.30\,\text{bf}_j},$$

where B_j is the location-specific base, belg_ratio_j measures belg-season vegetation conditions relative to their long-run value, and bf_j determines local exposure to the belg season. The resulting series has a correlation of 0.758 with observed AgSS yields and reproduces the major agricultural downturns associated with the 2002, 2009, and 2015 drought episodes.

Market access. The formal-sector market-access shifter is constructed from gateway trade costs. Consistent with Appendix C, define

$$MA_j = \frac{1/\tau_j^{\text{world}}}{\overline{MA}},$$

where $\overline{MA}$ normalizes the urban mean, and formal productivity contains the term $MA_j^{\eta_{MA}}$ with $\eta_{MA} = 1$. Rural locations are assigned $MA = 1$. Gateway trade costs are

$$\tau_j^{\text{world}} = \left(1 + \frac{d_j^{\text{gateway}}}{600}\right)^{0.40},$$

with Addis Ababa assigned a gateway cost of 1.20 to reflect its role as the national air and customs hub. The same gateway wedge sets the international Samuelson price bands (Appendix C.2).

E.4 Productivity and amenity drift

The baseline productivity path allows sectoral growth rates to converge gradually toward long-run values. Rural productivity growth begins at

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

and converges toward

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

with the latter informed by Fuglie (2012). The informal and formal urban sectors share a common path beginning at

$$g_U^{\text{init}} = 0.040$$

and converging toward

$$g_U^{\text{long}} = 0.025.$$

All sectoral growth rates converge at $\lambda_d = 0.10$, which under the transition rule in Appendix C implies a half-life of approximately 69 years. Baseline world food and cash-crop prices have zero trend growth.

Beginning with the 2025 amenity re-inversion, urban log amenities additionally receive a linear adjustment of 0.006 per year. The amenity vector is re-centered after each adjustment.

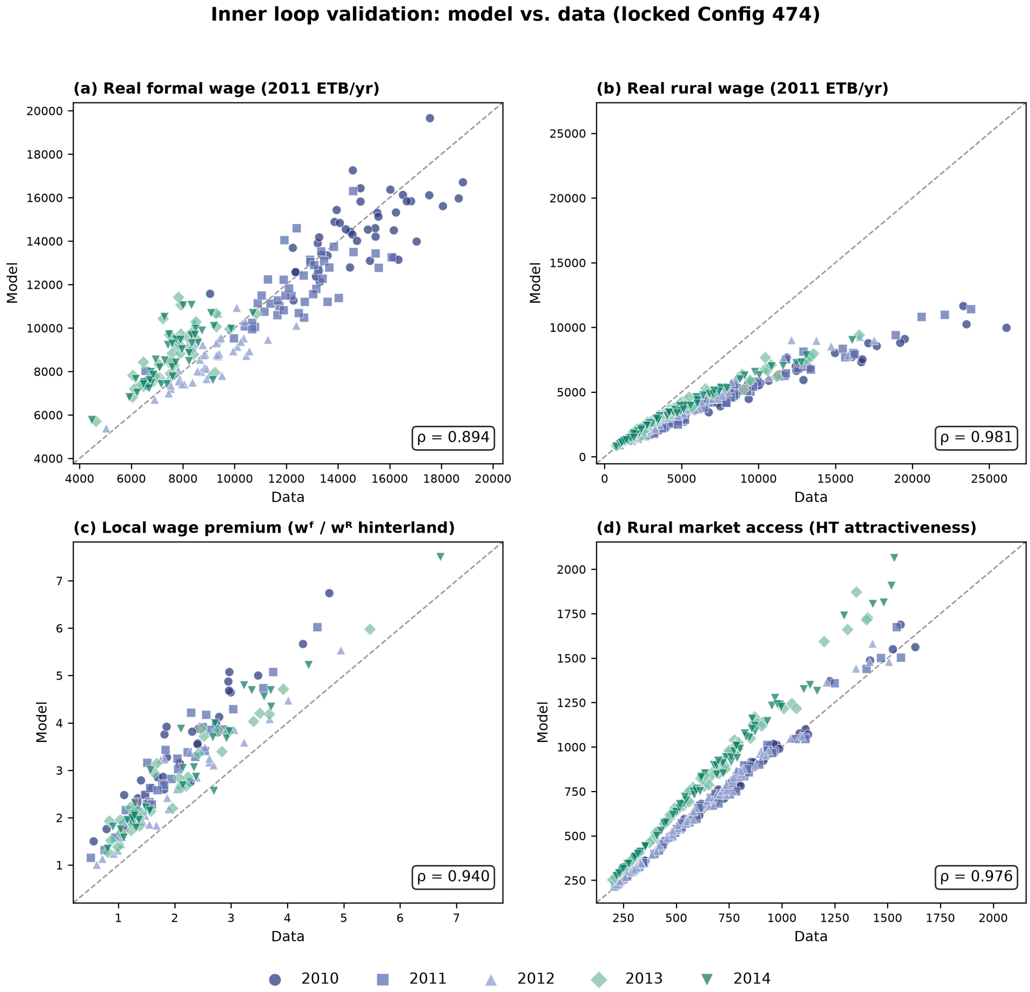

Figure 10: Within-period equilibrium: model and data, 2010–2014

Notes: Model outcomes are plotted on the vertical axis and their data counterparts on the horizontal axis. The dashed line is the 45° reference. Panels report private formal wages, rural income per worker, the local formal-to-rural earnings ratio, and migration-relevant market access. Pooled Spearman correlations are 0.894, 0.981, 0.940, and 0.976, respectively. Monetary outcomes are expressed in constant 2010/11 birr. Source: author's computation from CSA UEUS and AgSS data.

E.5 Additional validation of the within-period equilibrium

Figure 10 complements the rank correlations in Table 4 by comparing model outcomes with their data counterparts. The four panels examine private formal wages, rural income per worker, the local formal-to-rural earnings ratio, and migration-relevant market access. The first three comparisons are closely linked to the productivity inversions used in calibration and should therefore be interpreted primarily as checks on the internal consistency of the reconstructed equilibrium rather than independent out-of-sample validation. The market-access comparison combines wages with prices, housing costs, amenities, and formalization prospects and therefore provides a broader check on the equilibrium objects relevant for migration.

E.6 The dynamic scoring function

The forward calibration minimizes the composite loss in equation (36),

$$\text{score} = \sum_{t\in\mathcal{T}} \Bigg[\left|\text{urb}_t - \text{urb}_t^*\right| + \left|\varphi_t - \varphi_t^*\right| + \frac{\left|\text{pop}_t - \text{pop}_t^*\right|}{\text{pop}_t^*} \Bigg], \qquad \mathcal{T} = \{2025, 2030, 2040, 2050, 2060\}. \tag{118}$$

The three target families enter with unit weight as soft penalties rather than exact constraints. Urbanization and informality are measured as shares, while population enters as a proportional deviation from its target level. The weighting scheme is therefore a calibration convention rather than a statement that the three target series have identical statistical precision. The implemented grid objective evaluates the same three deviations at 2040, 2050 and 2060, averages them across those dates, and omits 2025 because amenities are re-inverted at that date. It scores 2030 through the fit of city population shares and ranks, the national urban share and city-level informality, and adds the amenity-drift band penalty described in Appendix E.1. Appendix E.14 describes their different evidentiary status, and the robustness analysis examines the sensitivity of the forward path to alternative calibration assumptions.

E.7 Population target: UN WPP 2024

The population path is the UN World Population Prospects 2024 medium variant (UN DESA, 2024). The target nodes are reported in Table 19.

The model geography does not cover the entire Ethiopian population because it excludes some remote rural areas and settlements below the delineation thresholds. In 2014, the 121 model locations contain 93.8 million people, compared with an interpolated WPP total of 101.2 million, giving a coverage ratio of

$$\frac{93.8}{101.2} = 0.927.$$

The population calibration therefore uses the WPP path to discipline population growth while maintaining a consistent treatment of the model's geographic coverage. The demographic transition parameters, rather than an independent population-level intercept, determine the shape of the simulated path. Table 19 reports the target series used in the forward calibration.

E.8 Urbanization target: WUP 2025 DEGURBA

The urbanization path is based on the UN World Urbanization Prospects 2025 revision (UN DESA, 2025). Its Degree of Urbanization classification defines "Cities" using contiguous one-kilometer cells with population density of at least 1,500 persons per square kilometer and a cluster population of at least 50,000. This concept is close to the density-based logic of the model's urban delineation but covers a broader set of settlements. In 2011, DEGURBA classifies 20.8% of Ethiopia's population as living in cities, compared with 12.0% under the model's fixed 126-city geography.

I map the external series into the model's urban definition using the 2011 ratio

$$\text{scaling} = \frac{\text{model urban}_{2011}}{\text{DEGURBA urban}_{2011}} = \frac{12.0}{20.8} = 0.578.$$

The model-equivalent target is therefore the DEGURBA series multiplied by 0.578. By construction, this procedure matches the model's 2011 urbanization level. The external information disciplines the subsequent growth rate rather than the initial level. The resulting model-equivalent urban share rises from 12.0% in 2011 to 24.1% in 2060, an average increase of approximately 0.24 percentage points per year. In the original DEGURBA units, the corresponding increase is approximately 0.41 percentage points per year.

The scaling factor is identified from the single year in which the two definitions can be directly compared. As a secondary benchmark, applying the same procedure to the World Bank national-definition urbanization series yields a scaling ratio of 0.672 and a similar qualitative growth path.

E.9 Formalization target: cross-country and ILO evidence

The formalization target is expressed as the national private informality share

$$\varphi = \frac{L_I}{L_I + L_F},$$

excluding government employment. Its forward path combines two external sources of discipline. The first is the strong negative cross-country relationship between informal employment and income documented by La Porta and Shleifer (2014). Using the corresponding income semi-elasticity of approximately -7 percentage points per log point of income implies substantially faster formalization than is observed in many low-income economies. The second source is the ILO evidence on changes in informal employment over time (International Labour Organization, 2018), which implies a much slower decline of approximately 1.4 percentage points per decade among least-

Table 19: Forward-simulation targets, 2025–2060

Moment	2025	2030	2040	2050	2060
Population (millions)	135.5	153.1	189.1	226.1	262.4
Urban share (model-equivalent)	0.150	0.163	0.192	0.216	0.241
Private informality share φ	0.450	0.425	0.400	0.376	0.355

Notes: The table reports the five target nodes entering equation (118). Population follows the UN World Population Prospects 2024 medium variant (UN DESA, 2024). The urban target is the UN WUP 2025 DEGURBA "Cities" series (UN DESA, 2025) mapped into the model's urban definition using the 2011 scaling ratio of 0.578 (Appendix E.8). Private informality is $\varphi = L_I/(L_I + L_F)$, excluding government employment, constructed as in Appendix E.9. The 2014 value $\varphi = 0.480$ is the model-consistent calibration anchor. Source: author's construction.

developed economies. This slower transition is consistent with persistent institutional and financial barriers to firm formalization (Ulyssea, 2018).

An Ethiopia-specific UEUS zone-panel regression produces a semi-elasticity of approximately -6.7 percentage points with respect to log income, close to the cross-country relationship. The calibration target lies between the income-based and historical time-series implications. The private informality share declines from 0.480 in 2014 to 0.355 in 2060, approximately 2.7 percentage points per decade on average, with a slower decline later in the horizon.

The 2014 value $\varphi_{2014} = 0.480$ is the model-consistent calibration anchor rather than a raw national survey mean. The forward decline is the external component used to discipline the transition parameters. Table 19 reports the five target nodes entering the scoring function.

E.10 Comparator-country trajectories

I benchmark the forward targets against observed transitions in countries that experienced substantial urbanization and structural change from broadly comparable development levels. These comparisons are intended to assess plausibility, not to identify Ethiopia's future path.

Table 20 reports the observed rates. Ethiopia's targeted urbanization pace of $+0.24$ percentage points per year is at or below every comparator shown, below Vietnam, Indonesia, Bangladesh, and Kenya, and marginally below India. The target therefore represents a deliberately gradual urban transition rather than a central value of the comparator distribution.

The formalization target is demanding in the opposite direction. Ethiopia's projected

Table 20: Comparator-country transition rates

Country	Urbanization (pp/year)	Change in informality (pp/decade)	Informality series and window
Vietnam	$+0.55$	-12.2	GSO/ILO informal employment, 2007–2019
Indonesia	$+0.86$	-4.8	BPS informal-sector share, 2000–2020
Bangladesh	$+0.38$	-1.3	ILO informal employment, 2010–2022
Kenya	$+0.43$	-0.2	ILO informal employment, 2008–2020
India	$+0.29$	-1.8	ILO informal employment, 2005–2020
Ethiopia (target)	$+\mathbf{0.24}$	$-\mathbf{2.7}$	model target

Notes: Urbanization is the annual percentage-point change in the national urban population share, World Bank WDI (SP.URB.TOTL.IN.ZS), 1990–2020. The informality column reports net changes in the stated series per decade. Series definitions differ across countries as listed and are not mixed within a row. Net share changes understate gross worker-level transition rates, which are mechanically larger (Appendix E.11). Bangladesh's magnitude is sensitive to a 2016/17 survey-methodology break, and Indonesia's 2000 baseline is a literature-based estimate. South Korea and Thailand are excluded for the data reasons discussed in the text. Ethiopia's $+0.24$ is the model-equivalent rate, and the corresponding DEGURBA rate is $+0.41$ percentage points per year. Ethiopia's entries are calibration targets rather than observed future outcomes.

decline in the informal employment share of approximately 2.7 percentage points per decade is faster than the near-stagnation observed in Bangladesh, India, and Kenya over the past two decades, below Indonesia's pace, and far below Vietnam's exceptional formalization during its export boom. The target therefore asks Ethiopia to leave the developing-country norm of stalled formalization and to approach the pace of the successful recent transformers, consistent with the reading in Appendix E.11.

South Korea and Thailand, prominent historical transformers, are deliberately absent from the table. No ICLS-comparable informal-employment series covers Korea's transformation decades. Its post-1990 self-employment share, the closest available proxy, fell by roughly 3 to 4 percentage points per decade from an already-transformed base, and its post-1990 urbanization is a plateau because the country was 74 percent urban by 1990. Thailand's informality series mix incompatible survey methodologies, and its WDI urban series contains a large reclassification break between 2017 and 2018. Both countries therefore enter the paper's narrative qualitatively, as transformation episodes, rather than as measured rates.

E.11 Formalization rates, waiting times, and international evidence

The capacity parameter θ has no natural units. This section translates every value of θ used in the paper into two observable quantities, the annual formalization rate λ and the expected waiting time for a formal job, and places them against the available international evidence (Table 21). Waiting times are reported as snapshot expectations, the wait a worker faces if the year's conditions persist, evaluated at the population-weighted national employment composition. They are not the path-integrated wait of a specific cohort, which differs when the hazard changes over time. Nor are they uniform across space, and this cross-city dispersion is itself one of the moments used to locate current capacity (Appendix E.13).

Table 21: The capacity parameter in rates and waiting times

θ	Annual formalization rate λ	Expected wait (years)	Role in the paper
1.00	10.1%	≈10	near-frictionless limit
3.25	6.7%	≈15	projection-consistent capacity
4.75	4.1%	≈24	current-capacity comparator
5.00	3.8%	≈26	micro estimate (minimum distance)
7.05	1.9%	≈53	micro estimate (maximum likelihood)

Notes: Hazards evaluated by the hazard formula at the 2015 national anchor composition ($\varphi = 0.48$) with all other hazard parameters at their calibrated values. Table 22 instead reports the population-weighted mean of city-level hazards along each baseline path, which is the basis for the queue labels used in the text and in Section 6.3. The two conventions differ slightly because the hazard is nonlinear in φ. Expected waits are $1/\lambda$, the snapshot expectation under the year's hazard. Source: author's computation from the locked model outputs.

Table 22: Waiting times along the two baseline paths

	$\theta = 3.25$ (projection-consistent)		$\theta = 4.75$ (current capacity)	
Year	λ	Wait (years)	λ	Wait (years)
2015	5.8%	17.1	3.8%	26.4
2035	6.7%	14.8	3.4%	29.6
2065	7.3%	13.7	2.6%	39.2

Notes: Population-weighted national hazard along each regime's baseline path. Source: author's computation from the locked model outputs.

The two paths diverge in opposite directions, and this divergence is the informality trap in observable units. Under current capacity the queue lengthens from roughly 26 toward 39 years as inflows outpace absorption. Under projection-consistent capacity it shortens from roughly 17 toward 14 years as formalization becomes self-reinforcing.

Three layers of evidence. *First, Ethiopia's own measured pace.* The tenure-to-formality profiles of rural-origin migrants (Section 6.3, Table 24) yield structural estimates of $\hat{\theta} = 5.00$ (minimum distance, confidence interval 3.9 to 6.25) and $\hat{\theta} = 7.05$ (maximum likelihood, confidence interval 5.8 to 9.55), implying current hazards between roughly 2 and 4 percent per year. Both confidence intervals exclude the projection-consistent value of 3.25, and the comparator $\theta = 4.75$ is conservative relative to both estimates. The one longitudinal Ethiopian study of this boundary, an urban worker panel for 1994 to 2004, is qualitatively consistent, documenting growing but persistently incomplete mobility between the formal and informal sectors alongside substantial state dependence in sector choice (Bigsten et al., 2013).

Second, worker panels elsewhere in the developing world. Panel studies report individual informal-to-formal transition rates of roughly 5 to 10 percent per year. The Indonesian labor force panel implies 6.8 percent between 2017 and 2018 (Sugiharti et al., 2022). Computed from the transition matrices of Danquah et al. (2021), annualized as $1 - (1-p)^{1/k}$ for a probability p observed over k years, the corresponding rates are 4.6 percent in Ghana (6.7 percent on the wage-employment margin), 9.0 to 9.5 percent in Tanzania, and 9.2 to 9.8 percent in Uganda.[17] These figures are best read as upper bounds on sustainable equilibrium capacity, for three reasons. Transition rates measured between two survey waves are inflated by classification error in employment status. They are individual probabilities conditional on the economy's existing queue, and do not measure the absorption a labor market could sustain once faster formalization attracts additional entrants. And gross worker flows in developing labor markets are systematically large relative to net outcomes (Donovan et al., 2023), so high measured individual mobility coexists with stagnant aggregate transformation.

Third, the aggregate transformation record. Informal employment shares across Sub-Saharan Africa and much of the developing world have been nearly flat for two decades (International Labour Organization, 2018), and near-term institutional assessments expect stagnation rather than decline. Against this record, the sustained net formalization of the successful transformers in Table 20 is the exception that the benchmark path asks Ethiopia to join.

Why the required gross pace is demanding. The model links the two margins that the empirical literature cannot connect. Along the projection-consistent path the hazard averages 6 to 7 percent per year, yet the national informality share falls by only about three percentage points per decade, because rural population growth and migration

[17]These annualized figures are computed from the published transition-matrix cells and initial employment shares in Danquah et al. (2021), Tables 1 and 2, and are not stated as such by the authors. Formality follows the ILO employment-based definition, registration for the self-employed and social-security contribution for employees.

continuously refill the informal pool. Gross absorption at the top of the internationally measured range is therefore required merely to deliver a modest net decline. Conversely, at current capacity the same inflows overwhelm absorption entirely and the share stalls. Net paces, the only quantity observable in most historical records, thus systematically understate the gross capacity that transformation demands. An economy matching the net record of the successful transformers must operate transformer-grade gross absorption for decades.

The frictionless limit is not an available anchor. Even at $\theta = 0$ the hazard is capped near 11 percent per year by ψ_0, so no value of θ eliminates informality (Section 6).

E.12 The θ–ψ_0 substitution ridge

The aggregate forward targets do not separately pin down the two parameters governing the curvature and saturation of the formalization hazard. The composite loss in equation (118) is minimized by grid search over the corridor $\theta \in [2, 8]$ and $\psi_0 \in [5, 12]$ documented in Online Appendix OA-4. Increases in curvature can be partly offset by weaker saturation while leaving the national informality path similar. Configurations that fit the aggregate targets comparably therefore lie on a diagonal ridge in (θ, ψ_0) space, along which ψ_0 falls as θ rises. Table 23 reports a set of configurations along this substitution ridge together with their 2065 outcomes.

Across D1–D5, which span $\theta \in [2.0, 4.0]$, the population-weighted urban-to-rural NPV ratio ranges from 2.597 to 2.624, the urbanization rate from 23.22 to 23.48 percent, and national informality from 0.325 to 0.346. The objective in equation (118) ranges from 0.454 at D2 to 0.582 at D5 and equals 0.481 at the projection-consistent pair, so D1 to D3 and that pair lie within 6 percent of the ridge minimum. The aggregate targets therefore discipline a combination of θ and ψ_0 considerably more tightly than either parameter individually. This is a parameter-identification limitation rather than evidence that all model outcomes are invariant to the location chosen along the ridge.

Point D6 is reported as an off-ridge diagnostic. At $(\theta, \psi_0) = (5.0, 5.0)$, national informality rises to 0.552 and urbanization reaches only 22.04 percent by 2065. The objective rises to 1.041, which is 2.3 times the ridge minimum. It therefore illustrates how sufficiently high curvature can produce qualitatively different formalization dynamics. D6 is not a formal upper bound on the identified set. Likewise, the current-capacity comparator used in the counterfactual analysis, $(\theta, \psi_0) = (4.75, 9.0)$, is not a continuation of the D1–D5 ridge. Holding $\psi_0 = 9.0$, that comparator produces national informality of 0.575 in 2065 and is treated separately below.

Table 23: Outcomes along the θ–ψ_0 substitution ridge

Configuration	θ	ψ_0	Urban share, 2065	φ_{2065}	NPV ratio (% Δ)	Objective
Projection-consistent	3.25	9.0	23.42%	0.325	2.606	0.481
D1	2.0	12.0	23.22%	0.344	2.621 (+0.6)	0.457
D2	2.5	10.5	23.26%	0.331	2.624 (+0.7)	0.454
D3	3.0	9.5	23.35%	0.326	2.613 (+0.3)	0.467
D4	3.5	8.5	23.48%	0.327	2.598 (−0.3)	0.503
D5	4.0	7.0	23.48%	0.346	2.597 (−0.3)	0.582
D6 (off-ridge)	5.0	5.0	22.04%	0.552	2.620 (+0.6)	1.041

Notes: Terminal 2065 outcomes for alternative combinations of the hazard parameters (θ, ψ_0). The NPV ratio is the population-weighted urban-to-rural lifetime-value ratio, with percentage deviations reported relative to the projection-consistent value of 2.606. D1–D5 trace the substitution ridge along which higher curvature is offset by weaker saturation. D6 is an off-ridge diagnostic and is not interpreted as an identified boundary. Objective is the value of equation (118) for each configuration, the sum over the five target dates of the absolute urban-share and informality deviations and the proportional population deviation from the targets in Table 19. The grid search selects the projection-consistent pair on the implemented objective of Appendix E.6, which also scores the 2030 city-level fit and the amenity-drift band, so that pair need not minimize this column.

Micro evidence on θ. I obtain an independent cross-check on the curvature parameter from UEUS 2014 tenure-to-formality patterns among rural-origin urban workers. This group provides the empirical analog of the model's migrant entrants. The estimation uses the same informal-employment definition as the aggregate calibration and holds $(\psi_0, \varphi_c, \zeta_{\text{brake}}, \underline{\lambda})$ fixed. The resulting estimates are therefore conditional estimates of θ, rather than a joint identification of the full hazard.

Table 24 reports two estimators. The structural MLE gives $\hat{\theta} = 7.05$ with a bootstrap interval of $[5.80, 9.55]$, while the two-step minimum-distance estimator gives $\hat{\theta} = 5.00$ with an interval of $[3.90, 6.25]$. Both place the central estimate above the projection-consistent value $\theta = 3.25$. The minimum-distance interval contains the current-capacity comparator $\theta = 4.75$, whereas the structural-MLE interval lies above it. These estimates therefore support examining substantially higher formalization frictions than those implied by the projection-consistent path, but they do not point-identify $\theta = 4.75$.

Cross-city dispersion. Cross-city dispersion provides a complementary diagnostic of the dynamic implications of θ. Panel A of Table 25 reports the 2014 UEUS benchmark.

Table 24: Micro-estimation of the hazard curvature θ

Estimator	$\hat{\theta}$	95% bootstrap interval	Replications	Covers 3.25?	Covers 4.75?
Structural MLE	7.05	[5.80, 9.55]	150	No	No
Two-step minimum distance	5.00	[3.90, 6.25]	2,000	No	Yes

Notes: Estimates use UEUS 2014 tenure-to-formality patterns among rural-origin urban workers and condition on $\psi_0 = 9.0$ and the remaining hazard parameters. The structural MLE fits the level and tenure gradient of the transition profile, while the two-step estimator matches zone-level transition hazards. Intervals are obtained from a zone-clustered bootstrap using the reported number of replications. Estimates are sensitive to the empirical definition of informal employment, so the same classification used in the aggregate calibration is maintained throughout.

The noise-corrected, population-weighted standard deviation of the private informality share is 0.106 across the full 75-zone sample. Panel B reports the corresponding model dispersion along the ridge.

All configurations share a 2014 model dispersion of approximately 0.110 because city-level initial informality is constructed from the same UEUS source and the hazard parameters do not determine that initial cross-section. The close match between 0.110 and the data benchmark of 0.106 is therefore largely mechanical and is not identifying evidence.

The forward profiles differ sharply. Under $\theta = 3.25$, the population-weighted standard deviation falls from 0.110 in 2014 to 0.015 in 2065. Under the current-capacity comparator $\theta = 4.75$, it instead rises to 0.135. Higher values of θ therefore generate substantially more persistent spatial heterogeneity in informality.

For reference, if one imposed the illustrative benchmark that the 2065 dispersion remained equal to the 2014 data level of 0.106, linear interpolation would imply $\theta \approx 4.4$. This calculation is useful for locating the region of the parameter space associated with persistent dispersion, but it is not an identifying moment because 2065 dispersion is not observed.

E.13 Interpretation of the capacity parameter

The evidence above plays three distinct roles. First, the aggregate forward targets select a projection-consistent path. At $\theta = 3.25$, the model generates a decline in national informality close to the external target, whereas the $\theta = 4.75$ comparator produces rising informality. The lower value should therefore be interpreted as the curvature required to deliver the projected formalization path, not as an estimate of current formalization capacity.

Table 25: Cross-city dispersion of the informal employment share

Panel A. UEUS 2014 benchmark

Sample	Zones	Mean φ	Raw SD	Noise-corrected SD
Full UEUS 2014	75	0.513	0.109	0.106
λ-consistent subset	39	0.484	0.107	0.105

Panel B. Model forward dispersion

θ (ψ_0)	Configuration	2014	2035	2050	2065
2.0 (12.0)	D1	0.110	0.052	0.018	0.006
2.5 (10.5)	D2	0.110	0.057	0.021	0.007
3.0 (9.5)	D3	0.110	0.069	0.029	0.010
3.25 (9.0)	Projection-consistent	0.110	0.076	0.038	0.015
3.5 (8.5)	D4	0.110	0.085	0.053	0.025
4.0 (7.0)	D5	0.110	0.104	0.091	0.074
4.75 (9.0)	Current capacity	0.110	0.114	0.122	0.135
5.0 (5.0)	D6	0.110	0.134	0.157	0.181

Notes: Population-weighted cross-city standard deviation of the private informal employment share φ. Panel A reports the UEUS 2014 benchmark, where the noise correction removes estimated sampling variance. Panel B reports model-implied dispersion at four horizons. The common 2014 model value is determined by the initial informality distribution and is therefore not informative about θ. The implied $\theta \approx 4.4$ obtained by matching the 2065 model dispersion to the 2014 data level is an illustrative persistence benchmark, not an observed future moment or a point estimate.

Second, the micro estimates cross-check current frictions. Conditional on the remaining hazard parameters, both estimators place θ above 3.25. Third, the dispersion profiles show that spatial dynamics are highly sensitive to θ even along the ridge where the aggregate objective is closest to its minimum.

Taken together, these results motivate the distinction used in the counterfactual analysis between a projection-consistent benchmark, $\theta = 3.25$, and a higher-friction current-capacity comparator, $\theta = 4.75$. They do not imply that either value is point-identified as the unique structural parameter governing current Ethiopian formalization.

E.14 Uncertainty in the forward targets

The forward targets are projections rather than forecasts. Three sources of uncertainty are particularly important. The population path assumes continued fertility decline, while recent DHS evidence points to a possible reversal in urban fertility. Population projections are also increasingly uncertain at horizons extending several decades beyond the observed data.

The urbanization target depends on a scaling factor of 0.578 estimated from a single 2011 cross-section. It therefore cannot capture future structural breaks associated with conflict, industrial development, or administrative reclassification. The formalization target similarly assumes that Ethiopia follows a developing-country relationship between structural transformation and informality that may be altered by its institutional and political environment.

The appropriate interpretation is therefore conditional. The targets define a disciplined forward path against which the model's mechanisms and counterfactuals are evaluated. They are not claims about the realized Ethiopian economy in 2065. The sensitivity exercises above show where the aggregate targets leave important structural uncertainty, and the counterfactual results should be read conditional on that uncertainty.

F Robustness and Alternative Specifications

This appendix reports the robustness exercises underlying Section 10. The full battery contains 214 forward simulations: a 125-configuration sensitivity analysis over the aggregate target paths, 81 parameter perturbations and alternative specifications, and eight exercises allowing rural migrants direct access to formal employment. Each exercise resolves the full spatial equilibrium through 2065. Online Appendix OA-5 reports the complete per-category results. The print appendix focuses on the assumptions most relevant for interpretation and then provides a consolidated summary of the remaining exercises.

Unless otherwise stated, outcomes are evaluated in 2065 relative to the baseline transition. The principal distributional objects are national welfare, rural welfare, informal-worker value, and formal-worker value, together with the population-weighted urban-to-rural NPV ratio and aggregate GDP. Monetary quantities are expressed in constant 2010/11 birr.

I report quantitative changes directly rather than assigning robustness labels mechanically from a single outcome. This matters because some specifications leave the urban-to-rural NPV ratio nearly unchanged while substantially altering formalization, urbanization, or distributional incidence.

F.1 Alternative formalization hazard

Appendix E.12 shows that the baseline Michaelis–Menten hazard admits a θ–ψ_0 ridge along which aggregate outcomes are relatively stable. A separate question is whether the quantitative results depend on that functional form itself. I therefore replace the baseline hazard with a logistic specification while holding the reported hazard parameters at their baseline values (Table 26).

The comparison is useful precisely because the conclusions differ across outcomes. The urban-to-rural value ratio changes relatively little, but the private informality share falls from 0.325 to 0.039. The baseline quantitative path of formalization therefore depends materially on the shape of the transition hazard even though the broad urban-rural value differential is much less sensitive. I treat the alternative hazard as a functional-form robustness exercise rather than as another point on the θ–ψ_0 identification ridge.

F.2 Partial rural-to-formal access

The baseline model assumes that rural-origin migrants enter urban labor markets through informal employment. This assumption is important for the incidence of

Table 26: Alternative formalization-hazard specification

Specification	Urban share, 2065	φ_{2065}	Urban–rural NPV ratio
Baseline hazard	23.42%	0.325	2.606
Logistic hazard	19.82%	0.039	2.509

Notes: Terminal outcomes under the baseline Michaelis–Menten formalization hazard and a logistic alternative evaluated at the same reported (θ, ψ_0) values. Source: author's computation.

Table 27: Partial rural-to-formal access under a 50 percent migration-cost reduction

Panel A. Aggregate outcomes					
θ	Direct formal access	Δ urbanization pp	$\Delta\varphi$ pp	Δ urban NPV %	Δ GDP %
3.25	0%	+11.6	+1.5	-20.7	+54.2
3.25	10%	+11.3	-3.5	-21.3	+55.8
3.25	20%	+11.1	-5.9	-22.1	+56.4
3.25	30%	+10.8	-7.9	-23.0	+56.2
4.75	0%	+9.8	+13.7	-22.3	+35.0
4.75	10%	+10.8	-2.7	-18.5	+55.2
4.75	20%	+12.5	-20.9	-16.6	+72.3
4.75	30%	+13.2	-30.5	-17.9	+80.7
Panel B. Welfare incidence					
θ	Direct formal access	Δ national %	Δ rural %	Δ informal %	Δ formal %
3.25	0%	+22.0	+47.0	-20.1	-20.2
3.25	10%	+21.3	+46.6	-21.2	-20.3
3.25	20%	+20.4	+46.0	-22.0	-20.2
3.25	30%	+19.2	+45.1	-22.9	-20.2
4.75	0%	+17.4	+38.7	-22.5	-0.4
4.75	10%	+24.6	+47.4	-18.5	-20.5
4.75	20%	+31.2	+56.8	-17.9	-24.7
4.75	30%	+32.5	+60.7	-20.4	-25.5

Notes: Deviations are measured in 2065 relative to the corresponding capacity-regime baseline under the 50% migration-cost reduction. Direct formal access is the share of rural movers allowed to enter formal rather than informal employment on arrival. Changes in urbanization and national private informality are percentage-point changes; all remaining outcomes are percentage deviations. Urban NPV is the value of an entering urban worker, combining informal earnings with the option value of subsequent formalization.

migration-cost reductions because a larger migrant inflow expands the informal queue before workers transition into formal employment. I relax the restriction by allowing 10, 20, or 30% of rural movers to enter formal employment directly.

The exercise is conducted under the 50% reduction in total migration costs analyzed in Section 8.3, and under both the projection-consistent capacity regime, $\theta = 3.25$, and the current-capacity comparison, $\theta = 4.75$. Table 27 reports the results. To keep the table readable, Panel A reports aggregate and urban outcomes and Panel B reports the welfare decomposition.

Allowing direct formal entry materially changes the composition of the resulting urban

Table 28: Engel-curve moments disciplining non-homothetic preferences

Moment	Estimate	Standard error
Mean food budget share	0.760	—
Mean non-food budget share	0.240	—
Food-share slope on log expenditure, all households	-0.1028	0.0049
Non-food-share slope on log expenditure, all households	+0.1088	0.0137
Food-share slope, urban households	-0.1385	0.0099
Food-share slope, rural households	+0.0045	0.0050
Households	6,694	—

Notes: Regressions relate household budget shares to log total expenditure in the pooled expenditure data. The food share declines strongly with expenditure in the full sample and among urban households, while the rural slope is statistically indistinguishable from zero. These moments discipline the non-homotheticity parameters of the upper expenditure nest. Source: author's computation.

workforce, especially when baseline absorption is weak. It does not eliminate the incidence result. Urban-worker value remains below its regime-specific baseline in every specification, with losses between 16.6 and 23.0%. National GDP and national welfare rise at the same time.

The result is therefore not mechanically generated by requiring every migrant to spend an initial period in informal employment. The precise incidence across formal and informal incumbents does depend on the entry rule, particularly under weak absorption, but the broader reallocation result survives substantial direct access to formal jobs.

F.3 Assumptions with large quantitative effects

Most local parameter perturbations leave the central quantitative results relatively stable. A smaller set of structural assumptions has much larger effects. I discuss two particularly important cases because they determine the level and incidence of the urban-rural value differential.

Non-homothetic demand. Replacing the non-homothetic upper-tier demand system with a homothetic CES specification lowers the 2065 population-weighted urban-to-rural NPV ratio from 2.606 to 0.379. Informal and formal worker values fall by 96.7% and 95.9%, respectively, compared with a 77.2% decline in rural value. Non-homotheticity is therefore quantitatively important for the relative valuation of urban and rural locations.

This preference structure is disciplined directly by household expenditure data. Table 28 reports the corresponding Engel-curve estimates.

Removing the subsistence term also has a large effect, raising the 2065 urban-to-rural NPV ratio from 2.606 to 4.377. Rural welfare falls by 28.5% relative to the baseline specification. Together, these exercises show that the treatment of subsistence consump-

Table 29: Trade integration and the urban–rural NPV ratio

Year	Baseline ratio	Trade-shutdown ratio	Below parity
2015	1.685	0.713	Yes
2020	2.206	0.817	Yes
2025	2.461	0.871	Yes
2030	2.673	0.920	Yes
2035	2.781	0.950	Yes
2040	2.846	0.972	Yes
2047	2.818	0.981	Yes
2050	2.788	0.981	Yes
2060	2.670	0.978	Yes
2065	2.606	0.976	Yes

Notes: Population-weighted urban-to-rural NPV ratio along the forward path under the baseline trade specification and the trade-integration shutdown used in the robustness battery. The shutdown ratio peaks at approximately 0.981. Selected years are shown.

tion and structural change in demand is quantitatively important for distributional comparisons between rural and urban households.

Trade integration. The trade-integration shutdown produces a second large change in the urban-rural value ordering. Under this specification, the population-weighted urban-to-rural NPV ratio remains below one throughout the simulated 2015–2065 path. Table 29 reports selected years.

The distributional response is nevertheless not summarized by this ratio alone. Under the shutdown, national welfare rises by 6.2% and rural welfare by 47.0%, while urban worker values fall substantially. This illustrates the importance of terms-of-trade and spatial-incidence effects: an aggregate welfare improvement need not imply gains for urban incumbents. The result also explains why the paper reports population-weighted rather than unweighted urban-rural value comparisons.

F.4 Consolidated robustness results

Table 30 summarizes the remaining robustness exercises. The complete 125-point target-path grid and the full four-way welfare decompositions for each robustness family are reported in Online Appendix OA-5. The table reports the terminal urbanization rate, national private informality share, population-weighted urban-to-rural NPV ratio, and percentage deviation of that ratio from the baseline value of 2.606.

The table deliberately excludes the micro-identification exercises reported in Appendix E.12, which are evidence on parameter discipline rather than robustness simulations. It also excludes the partial-access exercise in Table 27, because that exercise uses a different counterfactual baseline and would make the ratio-deviation column non-comparable.

Table 30: Consolidated robustness results

Specification	Urban share, 2065 %	φ_{2065}	NPV ratio	Δ ratio %
A. Representative target-path sensitivity				
Baseline target	23.34	0.319	—	—
Slow-φ target	23.42	0.357	—	—
Fast-φ target	23.29	0.290	—	—
Low-urbanization target	23.34	0.319	—	—
High-urbanization target	23.34	0.319	—	—
B. Local parameter perturbations				
Baseline reproduction	23.42	0.325	2.606	0.0
β -10%	23.40	0.325	2.256	-13.4
β $+10\%$	23.39	0.325	2.763	+6.0
η_d -10%	23.20	0.323	2.632	+1.0
η_d $+10\%$	23.55	0.327	2.592	-0.5
η_I -10%	23.47	0.326	2.583	-0.9
η_I $+10\%$	23.36	0.325	2.631	+1.0
η_{tr} -10%	23.45	0.325	2.611	+0.2
η_{tr} $+10\%$	23.38	0.325	2.601	-0.2
κ_{fixed} -10%	23.41	0.325	2.606	-0.0
κ_{fixed} $+10\%$	23.42	0.326	2.606	-0.0
$\underline{\lambda}$ -10%	23.43	0.329	2.603	-0.1
$\underline{\lambda}$ $+10\%$	23.41	0.322	2.609	+0.1
ν -10%	23.41	0.325	2.611	+0.2
ν $+10\%$	23.42	0.325	2.601	-0.2
ω_H -10%	23.41	0.325	2.645	+1.5
ω_H $+10\%$	23.42	0.326	2.569	-1.4
φ_c -10%	23.45	0.315	2.611	+0.2
φ_c $+10\%$	23.40	0.337	2.599	-0.3
ψ_0 -10%	23.41	0.311	2.616	+0.4
ψ_0 $+10\%$	23.42	0.340	2.597	-0.3
ψ_H -10%	23.44	0.326	2.586	-0.7
ψ_H $+10\%$	23.39	0.325	2.624	+0.7
σ_A -10%	23.50	0.327	2.692	+3.3
σ_A $+10\%$	23.33	0.323	2.501	-4.0
τ_{retail} -10%	23.48	0.326	2.691	+3.3
τ_{retail} $+10\%$	23.34	0.324	2.520	-3.3
θ -10%	23.32	0.318	2.624	+0.7
θ $+10\%$	23.47	0.341	2.592	-0.5
ϑ -10%	23.00	0.321	2.665	+2.3

continued on next page

Table 30 continued

Specification	Urban share, 2065 %	φ_{2065}	NPV ratio	Δ ratio %
ϑ +10%	23.80	0.327	2.548	-2.2
ζ_{brake} −10%	23.41	0.329	2.604	-0.1
ζ_{brake} +10%	23.42	0.322	2.607	+0.1
C. Hazard ridge and functional form				
D1: $\theta = 2.0,\ \psi_0 = 12.0$	23.22	0.344	2.621	+0.6
D2: $\theta = 2.5,\ \psi_0 = 10.5$	23.26	0.331	2.624	+0.7
D3: $\theta = 3.0,\ \psi_0 = 9.5$	23.35	0.326	2.613	+0.3
Baseline: $\theta = 3.25,\ \psi_0 = 9.0$	23.42	0.325	2.606	0.0
D4: $\theta = 3.5,\ \psi_0 = 8.5$	23.48	0.327	2.598	-0.3
D5: $\theta = 4.0,\ \psi_0 = 7.0$	23.48	0.346	2.597	-0.3
D6: $\theta = 5.0,\ \psi_0 = 5.0$	22.04	0.552	2.620	+0.6
Logistic hazard	19.82	0.039	2.509	-3.7
D. Alternative structural specifications				
Fixed informal demand weight ω_I	23.42	0.325	2.606	-0.0
Homothetic CES	24.26	0.355	0.379	-85.5
Symmetric Armington weights	23.65	0.327	2.687	+3.1
Housing elasticity $b_1 \times 0.5$	18.91	0.353	2.662	+2.1
Housing elasticity $b_1 \times 1.5$	27.12	0.303	2.419	-7.2
Pure-gravity migration specification	7.09	0.298	6.849	+162.8
E. Literature-based parameter alternatives				
$\alpha_A = 0.30$	25.49	0.335	2.406	-7.7
$\alpha_A = 0.50$	22.15	0.322	2.906	+11.5
$\eta_{tr} = 0.50$	23.33	0.325	2.594	-0.5
$\sigma_A = 5$	23.11	0.321	2.363	-9.3
$\sigma_A = 8$	22.57	0.322	1.869	-28.3
$\beta = 0.90$	23.42	0.325	2.373	-8.9
$\beta = 0.96$	23.41	0.325	2.678	+2.8
$\beta = 0.99$	23.32	0.325	2.996	+15.0
$\vartheta = 1.5$	21.12	0.299	2.927	+12.3
$\vartheta = 3.0$	24.12	0.327	2.501	-4.0
$\eta_I = 0.10$	22.91	0.322	2.910	+11.7
$s_x^A = 0.50$	24.24	0.332	1.813	-30.4
F. Calibration-window sensitivity				
Alternative 2007 anchor	23.41	0.325	2.607	+0.0
Excluding Tigray	23.42	0.325	2.606	-0.0
G. Productivity and demographic paths				
Rural TFP growth $\times 1.5$	25.91	0.353	3.052	+17.1
Rural TFP growth $\times 0.5$	22.28	0.323	2.369	-9.1
Urban TFP path $\times 1.5$	23.54	0.322	2.835	+8.8

continued on next page

Table 30 continued

Specification	Urban share, 2065 %	φ_{2065}	NPV ratio	Δ ratio %
Urban TFP path ×0.5	21.17	0.321	2.269	-12.9
Amenity drift ×1.5	24.59	0.333	2.421	-7.1
Amenity drift ×0.5	22.25	0.317	2.793	+7.2
Faster demographic transition	23.16	0.320	2.675	+2.7
Slower demographic transition	23.61	0.333	2.544	-2.4
H. Channel shutdowns				
No formalization response	22.88	0.299	2.710	+4.0
No housing congestion	23.11	0.321	3.153	+21.0
No migration	13.09	0.257	4.826	+85.2
No subsistence floor	18.80	0.293	4.377	+68.0
Trade-integration shutdown	23.58	0.341	0.976	-62.5
I. Amenity-drift sensitivity				
Amenity drift 0.000/year	21.15	0.309	2.980	+14.3
Amenity drift 0.003/year	22.25	0.317	2.793	+7.2
Amenity drift 0.006/year	23.42	0.325	2.606	0.0
Amenity drift 0.009/year	24.59	0.333	2.421	-7.1
Amenity drift 0.012/year	25.81	0.340	2.249	-13.7
Amenity drift 0.018/year	28.41	0.355	1.944	-25.4
Amenity drift 0.024/year	31.28	0.373	1.683	-35.4

Notes: The table reports representative target-path exercises and the parameter, specification, calibration-window, channel, and drift robustness exercises evaluated relative to the baseline transition. The baseline population-weighted urban-to-rural NPV ratio is 2.606. Dashes in Panel A indicate that those target-path exercises are evaluated through the calibration objective rather than through a directly comparable NPV-ratio statistic. The complete 125-point target grid and four-way welfare decompositions are reported in Online Appendix OA-5.

G Counterfactual Decompositions

This appendix provides the principal decomposition and incidence results supporting Sections 7 and 8. It complements the aggregate effects reported in the main text by showing how selected counterfactuals affect output, welfare, employment composition, and spatial incidence across worker groups and locations. Online Appendix OA-6 reports the complete dose-by-dose results for all policy instruments, horizons, capacity regimes, and spatial cuts.

For the formalization-capacity reform, I report the detailed decomposition relative to the current-capacity benchmark. For the policy counterfactuals, results are evaluated under both the projection-consistent capacity regime, $\theta = 3.25$, and the current-capacity benchmark, $\theta = 4.75$. Unless stated otherwise, welfare is the population-weighted lifetime value of workers across all locations and labor-market states, as defined in Section 7. Rural, informal, and formal worker values are reported separately where their incidence differs materially.

Spatial incidence groups. Spatial incidence is evaluated using a fixed set of terciles constructed before the counterfactuals are run. Rural locations are grouped by anchor agricultural productivity, population density, and market access. Urban locations are grouped by city size, population density, and gateway connectedness. Holding these bins fixed across experiments makes the incidence comparisons directly comparable. For variables expressed as costs, such as gateway travel costs, the tercile labels refer to the underlying cost measure: T1 denotes the lowest-cost and therefore most connected tercile.

The detailed instrument figures in Online Appendix OA-6 plot terminal 2065 deviations in output, urban-worker value, urbanization, and sectoral real wages across policy doses. All deviations are measured relative to the capacity-regime baseline corresponding to the same value of θ. The urban NPV is the population-weighted value of entering urban employment defined in equation (25); it is a worker-group value rather than a wage or national welfare measure.

G.1 Baseline spatial heterogeneity

Before turning to the counterfactuals, Figure 11 summarizes the cross-sectional structure implied by the baseline forward simulation. The figure shows how informality, formal wage premia, and cumulative growth differ across the 43 model cities as the economy evolves.

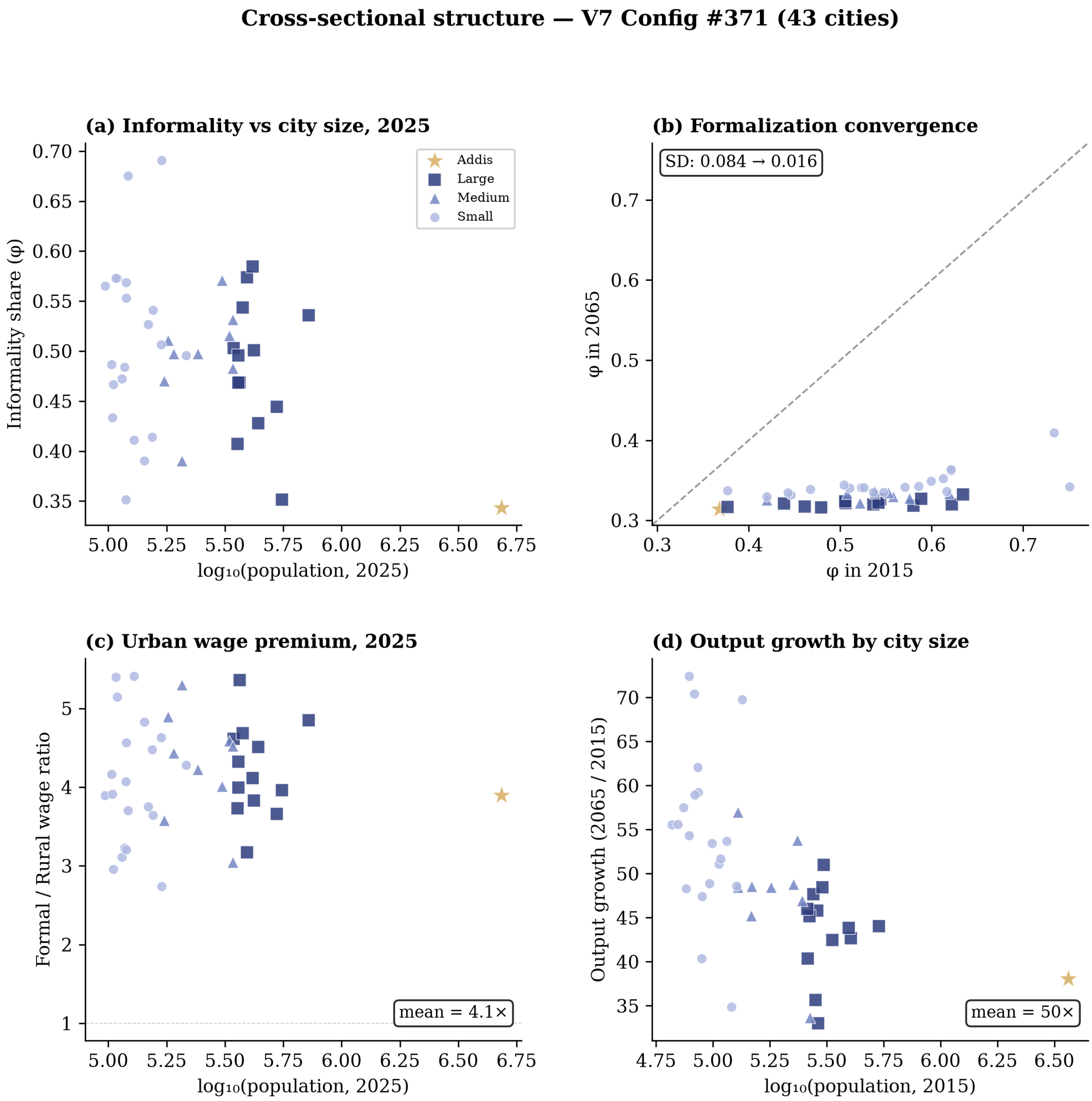

Figure 11: Model-implied baseline heterogeneity across cities

Notes: The figure reports outcomes across the 43 model cities along the baseline forward path. The upper-left panel relates the private informality share φ to city size in 2025. The upper-right panel shows the evolution of cross-city dispersion in informality, with the standard deviation declining from 0.084 in 2015 to 0.016 in 2065. The lower-left panel reports the formal-wage premium in 2025, averaging approximately 4.1 across cities. The lower-right panel reports cumulative city-level output growth; the cross-city mean is approximately 50 times initial output and the median approximately 35 times. These are model-implied outcomes rather than comparisons with observed data. Source: author's computation.

G.2 Formalization-capacity comparison and reform

Section 7 reports the headline comparison between the current- and projection-consistent capacity regimes over the full 2015–2065 transition. This subsection first documents that full-regime comparison and then reports a separate reform experiment in which both paths follow the projection-consistent path, $\theta = 3.25$, through 2025. From 2026 the reference path operates at current capacity, $\theta = 4.75$, while the reform path retains $\theta = 3.25$. The two exercises answer different questions and need not generate

Table 31: Full-regime capacity comparison: welfare incidence, 2015–2065

	Projection-consistent vs. current capacity
National welfare	+9.7%
Rural value, Π^R	+7.9%
Informal value, V^I	+4.3%
Formal value, V^F	−5.5%
Urban welfare (population-weighted)	+8.0%
Within-group share of national gain	82.9%
Reallocation share of national gain	17.1%

Notes: Entries compare the projection-consistent economy, $\theta = 3.25$, with the current-capacity economy, $\theta = 4.75$, each solved over the full 2015–2065 transition. National welfare is the population-weighted lifetime value of workers across all locations and labor-market states; group values are conditional values for workers occupying each state. The within-group and reallocation shares partition the national gain by location (rural and urban), so the within-group term contains the informal-to-formal reallocation occurring inside cities. Source: author's computation.

the same welfare incidence.

Table 31 summarizes the full-regime comparison underlying the headline results. It is the basis for the 9.7 percent national welfare gain and its group incidence, and for the decomposition of that gain into within-group value changes (82.9 percent) and reallocation across the rural–urban partition (17.1 percent) reported in Section 7.4.

The reform experiment in Tables 32 and 33 instead compares the projection-consistent value, $\theta = 3.25$, with the current-capacity benchmark, $\theta = 4.75$, from 2026 onward. Unlike the policy comparisons below, this is a reform relative to a single pre-reform capacity regime rather than a comparison of the same intervention under two values of θ. Both tables report deviations relative to the reference path that shares the same history through 2025 and operates at $\theta = 4.75$ from 2026, evaluated at the stated horizons. The smaller welfare effects relative to Table 31 reflect the shared pre-2026 history and the valuation of formal and government workers at the formal lifetime value, not a different model.

The decomposition highlights the distributional mechanism behind the aggregate gain. Formal incumbents lose part of the scarcity value associated with restricted access to formal employment, while rural households and many informal workers benefit from the reallocation toward more productive employment. The spatial incidence is also uneven. By 2065, informal-worker value falls by approximately 5.0% in the largest-city tercile but rises by approximately 2.6% in the middle tercile and 3.2% in the smallest-city tercile. The gains from greater formalization capacity therefore arise disproportionately outside the largest urban market.

Table 32: Formalization-capacity reform: output and welfare decomposition

	2035	2065
Panel A. Output		
GDP, total	+4.1%	+13.1%
GDP, rural	+3.7%	+12.1%
GDP, urban formal	+18.3%	+62.2%
GDP, urban informal	−15.8%	−43.9%
Government wage bill	+16.1%	+64.0%
Panel B. Welfare and lifetime values		
National welfare	+2.6%	+3.8%
Rural value, Π^R	+2.7%	+7.0%
Informal value, V^I	+0.1%	−2.1%
Formal value, V^F	−1.4%	−9.1%
Entrant surplus	+0.0%	−2.6%
Urban entrant NPV	+1.0%	+0.9%

Notes: Entries are percent deviations from the no-reform path when the formalization parameter falls from $\theta = 4.75$ to $\theta = 3.25$ beginning in 2026. The reform and no-reform paths share the same pre-2026 history. 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 33: Regional incidence of the formalization-capacity reform, 2065

Panel A. Rural locations

Characteristic	$\Delta\Pi^R$
Anchor agricultural productivity, T1 (low)	+5.8%
Anchor agricultural productivity, T2 (mid)	+6.9%
Anchor agricultural productivity, T3 (high)	+6.9%
Population density, T1 (low)	+3.6%
Population density, T2 (mid)	+7.0%
Population density, T3 (high)	+7.3%
Market-access cost, T1 (low)	+7.4%
Market-access cost, T2 (mid)	+7.6%
Market-access cost, T3 (high)	+5.2%

Panel B. Urban locations

Characteristic	ΔV^I	ΔV^F
City size, T1 (low)	+3.2%	−9.4%
City size, T2 (mid)	+2.6%	−14.7%
City size, T3 (high)	−5.0%	−9.2%
Population density, T1 (low)	+0.9%	−21.5%
Population density, T2 (mid)	+3.0%	−8.9%
Population density, T3 (high)	−6.0%	−4.1%
Gateway cost, T1 (low)	−2.3%	−1.8%
Gateway cost, T2 (mid)	+1.3%	−20.9%
Gateway cost, T3 (high)	−3.2%	−12.8%

Notes: Entries are percent deviations from the current-capacity baseline when the formalization parameter falls from $\theta = 4.75$ to $\theta = 3.25$ beginning in 2026. Terciles are fixed across counterfactuals. Rural outcomes report population-weighted Π^R; urban outcomes report population-weighted V^I and V^F.

G.3 Supply-side instruments

The supply-side experiments raise productivity in the formal, informal, or agricultural sector. A fourth experiment, reported in Online Appendix OA-6, combines formal and agricultural productivity. Each intervention is phased in over the decade beginning in 2026. Table 34 summarizes the principal aggregate and wage responses; the full group and spatial decompositions are reported online.

Table 34: Supply-side productivity: aggregate effects and wage incidence

	Formal productivity A_F	Informal productivity A_I	Agricultural productivity A_R
Panel A. Headline-dose welfare effects, 2065			
Headline TFP increase	25%	25%	30%
National welfare, $\theta = 3.25$	+13.6%	+2.0%	+10.7%
National welfare, $\theta = 4.75$	+9.6%	+6.6%	+9.4%
Urban NPV, $\theta = 3.25$	+8.7%	+4.7%	+11.8%
Urban NPV, $\theta = 4.75$	+5.2%	+8.6%	+11.0%
Urban-NPV capacity difference (pp)	+3.5	−3.9	+0.8
Panel B. Common 20 percent TFP increase, 2065, $\theta = 3.25$			
GDP	+16.7%	+4.8%	−0.6%
Formal real wage w_F	+12.9%	−2.0%	+8.2%
Informal real wage w_I	−6.6%	+17.9%	+8.7%
Rural real wage w_R	+9.6%	+3.4%	+5.5%

Notes: Each column raises one sector's TFP and re-solves the forward equilibrium through 2065. National welfare is the population-weighted lifetime value across all workers; urban NPV is the population-weighted lifetime value of an urban entrant. The capacity difference is the $\theta = 3.25$ effect minus the $\theta = 4.75$ effect in percentage points. Panel B uses a common 20% TFP increase to make GDP and wage responses comparable across sectors. Source: author's computation.

The capacity interaction differs across sectors. Formal-sector productivity has a larger effect on urban-worker value when formalization capacity is stronger because additional formal labor demand can be matched with workers moving through the queue. Informal productivity has the opposite capacity pattern because it directly raises earnings in a sector that contains a larger share of workers when formalization is weak. Agricultural productivity generates broad real-income gains through rural earnings and food prices and is comparatively insensitive to the formalization regime.

The wage decomposition also shows why sector-level incidence matters. Formal productivity raises formal wages but lowers informal wages at the common dose, whereas informal productivity strongly raises informal wages and slightly lowers formal wages. Agricultural productivity is the only one of the three experiments shown for which all three sectoral real wages increase at the common dose.

G.4 Demand-side instruments

The demand-side experiments operate through household purchasing power, demographic change, public employment, and direct support for formal employment rather than through sectoral productivity. Online Appendix OA-6 reports their complete output, welfare, and spatial-incidence decompositions.

Fiscal comparability. The counterfactual doses are not normalized to a common fiscal or resource cost. The food subsidy costs approximately 0.5% of GDP at the 10% dose and 1.5% at the 30% dose, while a 1.5-fold expansion of public employment costs approximately 3.0% of GDP under the model's accounting. Comparable fiscal costs are not available for the supply and infrastructure experiments. Cross-instrument welfare magnitudes should therefore be interpreted as effects of the stated policy doses rather than welfare per unit of public expenditure.

G.5 Infrastructure and spatial frictions

Infrastructure experiments affect migration costs, internal travel times, international trade barriers, or urban housing costs. The first two primarily operate through spatial reallocation, while trade integration and housing support raise purchasing power more directly within existing locations. The reallocation instruments generate the largest movement of workers and therefore the strongest interaction with formalization capacity. Their complete decompositions are reported in Online Appendix OA-6. Table 35 summarizes the principal in-place interventions.

Trade integration raises welfare and sectoral real wages under both capacity regimes while slightly reducing urbanization. Housing support is much more targeted. Reducing the informal housing burden primarily raises informal-worker purchasing power, while formal housing support primarily benefits formal workers. These interventions therefore operate differently from roads and migration-cost reductions, which induce larger spatial reallocations and can place additional pressure on the informal queue.

Table 35: In-place infrastructure interventions

Panel A. Welfare and urbanization, 2065			
Instrument	National welfare $\theta = 3.25/4.75$	Urban NPV $\theta = 3.25/4.75$	Δ urban share pp
Trade barriers -50%	$+8.1/+7.7\%$	$+11.5/+9.5\%$	-1.98
Informal housing burden -30%	$+0.3/+1.1\%$	$+3.0/+4.5\%$	-0.04
Formal housing burden -30%	$+5.4/+3.9\%$	$+7.0/+5.4\%$	-0.09
Panel B. Real-wage incidence, 2065, $\theta = 3.25$			
Instrument	w_R	w_I	w_F
Trade barriers -50%	$+9.2\%$	$+5.5\%$	$+13.8\%$
Informal housing burden -30%	≈ 0	$+10.53\%$	≈ 0
Formal housing burden -30%	≈ 0	≈ 0	$+10.59\%$

Notes: Each intervention is evaluated through 2065 relative to the corresponding capacity-regime baseline. Housing interventions reduce the relevant group's housing expenditure share proportionally by 30 percent (multiplier 0.70; for formal workers, approximately 6.5 percentage points at the baseline share). Panel A reports national population-weighted welfare, the population-weighted urban entrant value, and the percentage-point change in the national urban share. Paired welfare values report $\theta = 3.25$ first and $\theta = 4.75$ second. Panel B reports terminal sectoral real-wage effects under $\theta = 3.25$. Migration-cost and road interventions are omitted here because they operate primarily through reallocation and are reported in Section 8.3 and Online Appendix OA-6. Source: author's computation.

G.6 Scenario exercise: export competitiveness

The final exercise is a scenario analysis rather than one of the policy instruments in Section 8. It asks how greater external demand for formal-sector output interacts with domestic formalization capacity. I model the scenario as an exogenous increase in the effective world price of formal exports. The multiplier $m(t)$ rises linearly between 2026 and 2045 and remains constant thereafter. The experiment should therefore be interpreted as a change in external competitiveness or demand rather than as the effect of a specific implementable policy.

The large scenario magnitudes reflect the initial distance from export parity. Under the baseline trade structure, the most competitive city requires a formal export-price multiplier of approximately

$$m^{\star} = 2.58\text{–}2.71$$

over the forward horizon before formal exports become profitable, while the median city requires approximately

$$m = 4.6\text{–}4.7.$$

Smaller increases in export prices therefore leave the formal export margin inactive. I focus on $m = 3$ and $m = 4$, which cross the activation threshold for at least part of the urban system and are intended as scenario bounds rather than plausible point forecasts.

Table 36: Export-competitiveness scenarios: welfare, output, and formal employment

	$m = 3.0$ $\theta = 3.25/4.75$	$m = 4.0$ $\theta = 3.25/4.75$
National welfare	$+3.71/+1.73\%$	$+6.50/+3.05\%$
Rural value Π^R	$+1.95/-0.25\%$	$+4.48/+1.01\%$
Informal value V^I	$+3.56/+1.31\%$	$+6.40/+2.49\%$
Formal value V^F	$+5.09/+6.23\%$	$+9.32/+9.54\%$
Urban NPV	$+3.42/+1.49\%$	$+6.08/+2.59\%$
GDP	$+5.11/+2.21\%$	$+9.96/+5.18\%$
Formal employment L_F	$+4.28/+0.22\%$	$+5.14/+0.19\%$
Change in informality $\Delta\varphi$	$+0.01/+2.15$ pp	$-0.25/+2.35$ pp

Notes: The table reports terminal 2065 deviations from the corresponding capacity-regime baseline. Within each cell, the first number refers to $\theta = 3.25$ and the second to $\theta = 4.75$. All entries are percentage deviations except $\Delta\varphi$, which is the percentage-point change in the national private informality share. National welfare is the population-weighted lifetime value across worker groups, while urban NPV is the population-weighted lifetime value of an urban entrant. The export-price multiplier is phased in between 2026 and 2045 and held constant thereafter. Source: author's computation.

Export demand and formalization capacity. Table 36 reports the two pure export-price scenarios. The central result is a sharp distinction between the wage and employment responses. Higher external demand raises formal-worker value under both capacity regimes, but it creates substantially more formal employment when the informal-to-formal transition is less congested.

At $m = 4$, formal-worker value rises by approximately the same amount under the two regimes, 9.32% at $\theta = 3.25$ and 9.54% at $\theta = 4.75$. Formal employment, however, rises by 5.14% under stronger formalization capacity and by only 0.19% under the current-capacity benchmark. GDP displays the same asymmetry, increasing by 9.96% and 5.18%, respectively. Stronger external demand therefore translates into both higher returns and additional formal employment when workers can move through the queue. When absorption is weak, a larger share of the gain is capitalized into the value of existing formal positions.

The spillovers extend beyond formal workers. At $m = 4$, informal-worker and rural values rise under both capacity regimes. Export competitiveness is therefore not a purely sector-specific transfer in general equilibrium, although its employment effect is strongly conditioned by formalization capacity.

Entry into formal exporting. The interaction with capacity also appears in the timing of the national formal trade balance. Table 37 reports the first year in which formal-sector net exports become positive.

Greater formalization capacity brings the economy to export parity sooner. At $m = 3$, the formal trade balance turns positive in 2062 under $\theta = 3.25$ but remains negative

Table 37: First year of positive formal-sector net exports

Scenario	$\theta = 3.25$	$\theta = 4.75$
Export multiplier $m = 3.0$	2062	Never
Export multiplier $m = 4.0$	2048	2056
Corridor-assisted scenario	Never	Never
Migration costs -50% and $m = 4.0$	2044	2051
Migration costs -50% and corridor assist	2055	2065
Road travel times -25% and $m = 4.0$	2050	2060
Road travel times -25% and corridor assist	Never	Never

Notes: The table reports the first year between 2015 and 2065 in which national formal-sector net exports become positive. "Never" indicates that the formal trade balance remains negative throughout the horizon. The corridor-assisted scenario combines $m = 2.0$ with a 33% reduction in the world-gateway trade-cost wedge τ_{world}. Source: author's computation.

through 2065 under $\theta = 4.75$. At $m = 4$, the corresponding transition occurs in 2048 and 2056. Stronger capacity expands formal supply more rapidly and therefore allows external demand to translate into an export-oriented formal sector sooner.

The corridor-assisted experiment requires a different interpretation. It combines an export-price multiplier of $m = 2$ with a 33% reduction in τ_{world}. Because the same gateway wedge enters the international trade margins for both agricultural and formal goods, this experiment is not a formal-export intervention alone. Moreover, $m = 2$ remains below the formal export-activation threshold. Its gains therefore arise primarily from lower international trade costs and import prices rather than activation of the formal export margin. I retain the exercise because it clarifies the distinction between improving general international market access and raising external demand specifically for formal output.

Interactions with spatial reallocation. I next combine the export scenarios with the two reallocation instruments that generate the largest movement of workers: lower migration costs and improved roads. For each combination, Table 38 reports the total effect and, in parentheses, the interaction residual

$$\mathcal{I} = \Delta(\text{combined}) - [\Delta(\text{export}) + \Delta(\text{reallocation})] .$$

A positive value of $\mathcal{I}$ indicates that the combined intervention generates a larger effect than the sum of the two interventions evaluated separately.

The interaction effects are generally positive but modest relative to the levels of the combined interventions. National-welfare interaction residuals are positive in six of the eight combinations and close to zero in the remaining two, at -0.06 and -0.43

Table 38: Export competitiveness and spatial reallocation: interaction effects

Panel A. Projection-consistent capacity, $\theta = 3.25$			
Scenario	National welfare	Urban NPV	Informal V^I
Migration costs −50% and $m = 4.0$	+33.08 (+4.61)	−8.18 (+6.47)	−6.87 (+6.85)
Migration costs −50% and corridor assist	+25.85 (+2.96)	−15.06 (+3.20)	−14.30 (+3.32)
Road travel times −25% and $m = 4.0$	+18.00 (+0.53)	+**1.90** (+0.87)	+**3.21** (+1.04)
Road travel times −25% and corridor assist	+12.14 (+0.26)	−2.01 (+0.57)	−1.10 (+0.63)
Panel B. Current-capacity benchmark, $\theta = 4.75$			
Scenario	National welfare	Urban NPV	Informal V^I
Migration costs −50% and $m = 4.0$	+20.69 (+0.23)	−18.46 (+1.27)	−18.94 (+1.09)
Migration costs −50% and corridor assist	+18.15 (+0.24)	−20.25 (+0.33)	−20.58 (+0.45)
Road travel times −25% and $m = 4.0$	+10.97 (−0.06)	−2.65 (−0.41)	−2.51 (−0.50)
Road travel times −25% and corridor assist	+8.04 (−0.43)	−3.06 (+0.03)	−2.89 (+0.11)

Notes: Each cell reports the terminal 2065 deviation from the corresponding capacity-regime baseline, in percent, with the interaction residual $\mathcal{I}$ in parentheses, in percentage points. The export-only reference is the corresponding pure-price or corridor-assisted scenario, while the reallocation reference is the matching migration-cost or road intervention. National welfare is population weighted. Urban NPV and V^I are the urban-entrant and informal-worker lifetime values, respectively. The corridor-assisted scenario combines $m = 2.0$ with a 33% reduction in τ_{world}. Source: author's computation.

percentage points. The strongest complementarity appears when lower migration costs are combined with the $m = 4$ export scenario under stronger formalization capacity.

More important for the paper's mechanism is whether stronger external demand can offset the adverse urban incidence of a reallocation policy. Under $\theta = 3.25$, a 25% reduction in road travel times alone lowers urban NPV by 5.05% and informal-worker value by 4.24%. Combining the road improvement with $m = 4$ raises these outcomes to +1.90% and +3.21%, respectively. External demand therefore converts the road intervention from an urban-incumbent loss into a gain when formalization capacity is sufficiently strong.

The same rescue does not occur under $\theta = 4.75$: urban NPV and informal-worker value remain negative at −2.65% and −2.51%. Nor does the export scenario offset the much larger congestion generated by the 50% migration-cost reduction under either capacity regime. The result is therefore conditional rather than general. External demand can complement reallocation when the urban labor market has sufficient formalization capacity, but it cannot by itself clear an informal queue created by very large migration inflows.

Interpretation. Two qualifications bound the exercise. First, the export-price paths are exogenous scenarios, not forecasts or estimates of feasible policy effects. Their purpose is to identify how external demand interacts with formalization capacity. Second, the largest combined scenarios sit deliberately near the edge of the quantitative exercise. In particular, combining a 50% migration-cost reduction with $m = 4$ produces formal-sector net exports equal to approximately 11.3% of GDP under $\theta = 3.25$ by 2065. This outcome is best read as a scenario bound rather than a prediction.

The broader result is that formalization capacity and export competitiveness are complements. Stronger external demand can raise formal wages under either capacity regime, but it creates substantially more formal employment when workers can move through the informal queue. Successful formalization therefore increases the value of policies or external conditions that expand demand for formal output, while export demand can in turn support the wage and employment consequences of a larger formal workforce.

G.7 Incidence across the full counterfactual set

Figure 12 extends the main-text incidence figure to the complete policy and scenario set, reporting 2065 lifetime-value effects for rural, informal, and formal workers under both capacity regimes. Figure 13 reports the corresponding terminal real-wage incidence; comparing the two shows where current earnings and lifetime values move in opposite directions, most visibly for informal workers under policies that improve their formalization prospects while compressing informal wages.

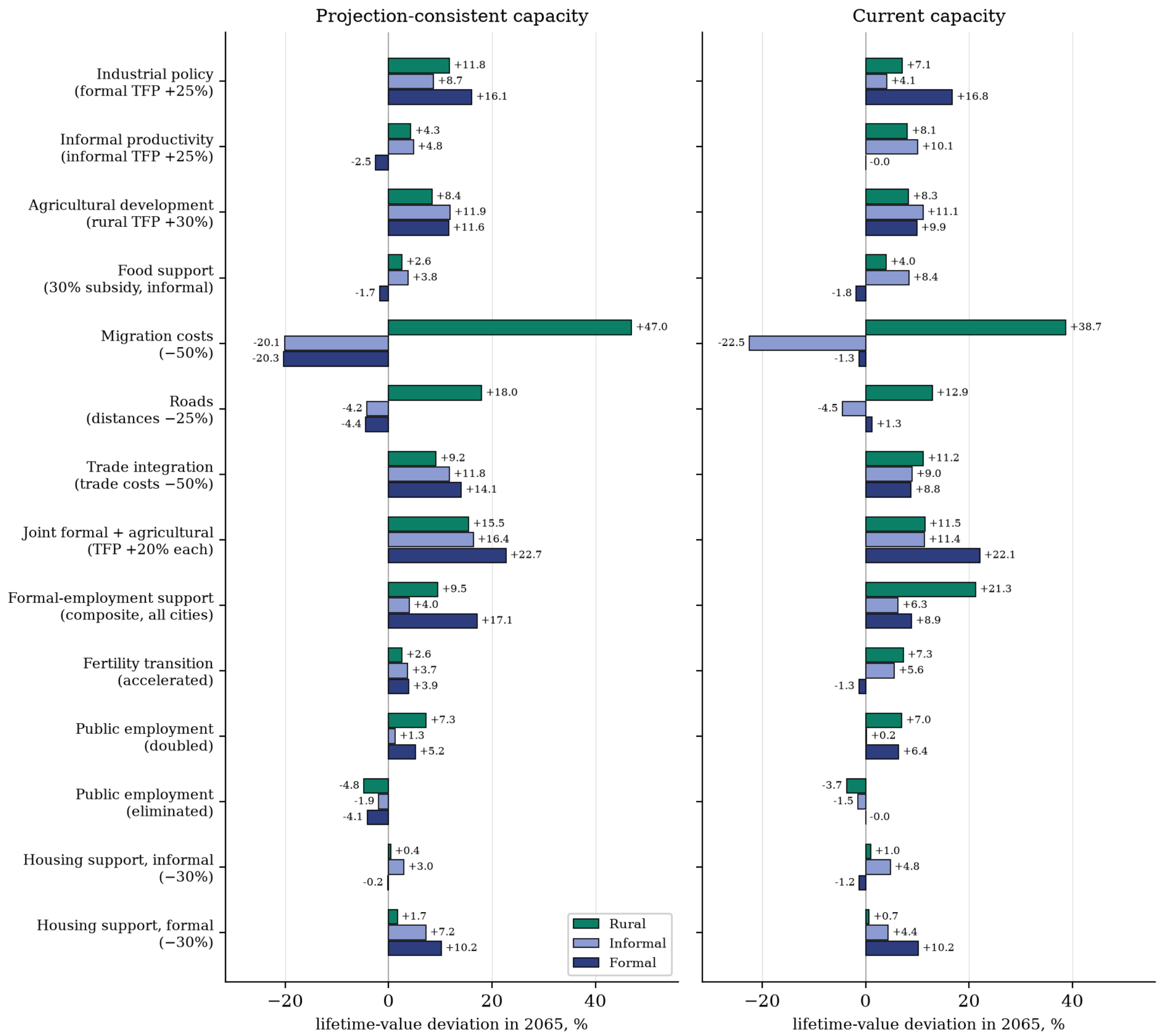

Figure 12: Lifetime-value incidence of the complete counterfactual set

Notes: Lifetime-value effects in 2065 for rural, informal, and formal workers, each measured against the no-policy baseline of the same capacity regime ($\theta = 3.25$ for projection-consistent and $\theta = 4.75$ for current capacity). The first seven experiments constitute the main-text set of Figure 5; the remainder are the additional counterfactuals summarized in this appendix. Fertility, public employment, and the joint productivity experiment are scenario or diagnostic exercises rather than costed policy instruments (Section 8). Source: author's computation.

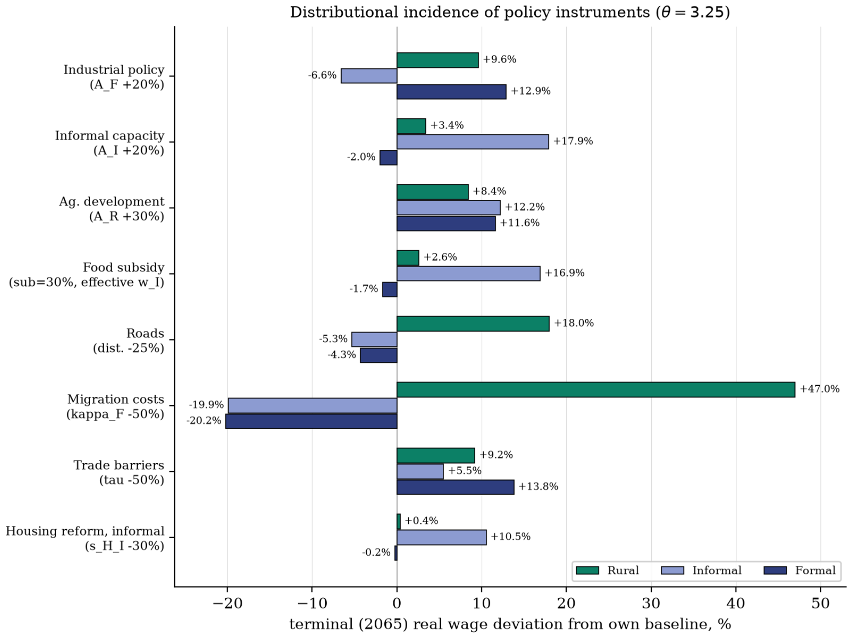

Figure 13: Real-wage incidence of the principal policy instruments

Notes: Terminal (2065) real-wage effects for rural, informal, and formal workers under projection-consistent capacity, $\theta = 3.25$, each measured against the no-policy baseline of the same capacity regime. Wage incidence differs from the lifetime-value incidence of Figure 12 because lifetime values also capitalize changes in formalization prospects. Source: author's computation.

H Climate and Conflict Scenario Decompositions

This appendix provides additional decomposition and incidence results for the climate and conflict exercises in Section 9. The purpose is to show how aggregate resilience outcomes are distributed across sectors, worker groups, and locations. Online Appendix OA-7 reports the complete results across climate scenarios, conflict episodes, horizons, capacity regimes, and spatial incidence groups.

The print appendix focuses on the Oromia conflict episode and the principal interpretation of the resilience exercises. The temperature-damage scenarios, the broader SSP exercises, and the corresponding Tigray conflict results are reported in Online Appendix OA-7. Unless otherwise stated, outcomes are evaluated under both the projection-consistent capacity regime, $\theta = 3.25$, and the current-capacity benchmark, $\theta = 4.75$.

Spatial incidence groups. The incidence decompositions use the fixed location groups and the tercile labeling convention defined in Appendix G, held constant across all policy and resilience exercises.

Baseline conventions. The decomposition tables in this appendix measure each scenario relative to the zero-intervention baseline corresponding to the same value of θ and the same year. This is the baseline convention used for the climate decompositions. The conflict results in Section 9.2 additionally report comparisons with a within-grid low-conflict reference scenario. Because these denominators differ, numerical deviations from the two presentations need not coincide even when they describe the same simulated conflict episode. I therefore state the comparison basis explicitly wherever the two are juxtaposed.

The climate scenario decompositions in Online Appendix OA-7 also distinguish between individual stochastic realizations and averages across simulation draws. Where a single realization is shown for incidence, it is labeled as such and should not be interpreted as the mean scenario effect reported in the main text.

Government employment is treated consistently throughout the decompositions. The government wage bill is reported as a supplementary accounting item and is excluded from market-price GDP.

H.1 Conflict: the severe Oromia displacement episode

The Oromia exercise provides the largest regional displacement experiment among the conflict scenarios considered in the model (Figure 14). The shock is severe but temporary, allowing the exercise to separate the short-run disruption generated by displacement from the economy's longer-run spatial adjustment.

Comparison basis and time profile. Table 39 measures the episode relative to the zero-conflict baseline at the same value of θ. On this basis, national welfare falls by 7.6% under $\theta = 3.25$ and 7.4% under $\theta = 4.75$ in 2035, when the displacement shock is near its maximum. By 2065, national welfare is approximately back to its baseline level, at +0.3% and −0.0%, respectively. GDP deviations are similarly small at the terminal horizon, at +0.5% and −0.2%.

Section 9.2 reports the same episode relative to a low-conflict within-grid reference scenario. Under that convention, terminal national-welfare deviations are +0.24% and −0.09%. The close terminal values mask a larger difference in the middle of the transition, when the choice of reference scenario matters more. The economic conclusion is therefore about the time profile rather than the precise terminal deviation: the model generates a large short-run national loss followed by substantial aggregate recovery after the temporary shock dissipates.

The urban entrant value remains slightly below its zero-conflict benchmark in 2065, at approximately −0.4% under both capacity regimes. Aggregate recovery therefore does not imply that every worker group returns exactly to its counterfactual path.

Table 39 reports the full output and welfare decomposition for the severe Oromia episode at the 2035 and 2065 horizons under both capacity regimes; Table 40 reports the corresponding regional-incidence cuts across the fixed location groups.

The decomposition shows that the principal welfare cost occurs during the displacement episode rather than at the terminal horizon. In the model, unaffected locations absorb part of the displaced population, allowing national employment and output to recover after the shock recedes. Formalization capacity influences how productively these workers are absorbed, but it does not eliminate the immediate costs of displacement.

The terminal spatial-incidence averages are comparatively small. Across the broad location bins reported in Table 40, most 2065 effects are approximately within one percentage point of the corresponding baseline. These averages should not be interpreted as evidence that every directly affected location has fully recovered. Tercile aggregation can conceal persistent local losses even when national and broad regional averages return close to baseline. The main resilience result is therefore that the national economy can absorb a severe but temporary concentrated shock without a comparably persistent aggregate loss, conditional on the model's domestic reallocation margins remaining operative.

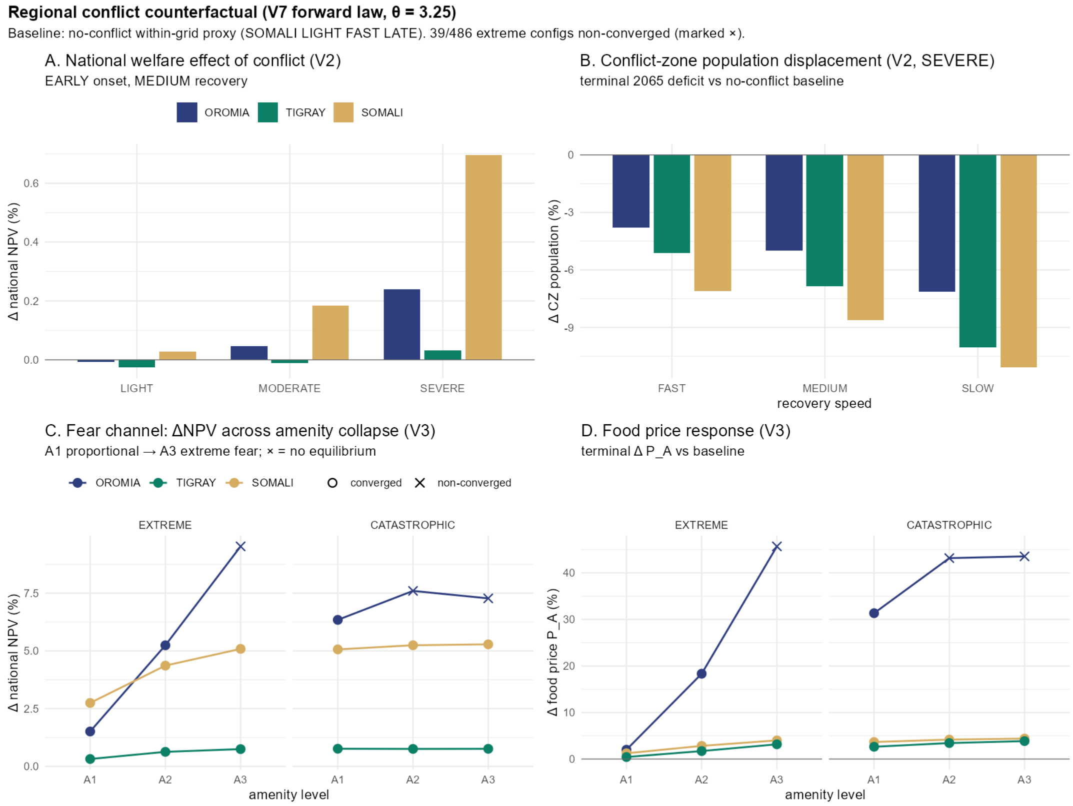

Figure 14: Conflict scenarios and terminal outcomes, $\theta = 3.25$

Notes: The figure reports terminal 2065 deviations from the zero-conflict baseline across the modeled conflict regions and severity levels under $\theta = 3.25$. Outcomes are total GDP, the population-weighted urban entrant value, urbanization, and sectoral real wages. The severe Oromia episode analyzed in Tables 39 and 40 is one point in this broader scenario set. Configurations for which the model does not admit a converged spatial equilibrium under catastrophic local collapse are omitted. The corresponding $\theta = 4.75$ figure and the detailed Tigray results are reported in Online Appendix OA-7. These are model-implied scenario outcomes rather than empirical estimates. Source: author's computation.

Table 39: Severe Oromia conflict: output and welfare decomposition

	2035		2065	
	$\theta = 3.25$	$\theta = 4.75$	$\theta = 3.25$	$\theta = 4.75$
Panel A. Output				
GDP, total	−1.7%	−1.5%	+0.5%	−0.2%
GDP, rural	−1.1%	−0.8%	+0.5%	−0.2%
GDP, urban formal	−3.6%	−3.2%	+1.0%	−1.9%
GDP, urban informal	−2.7%	−3.2%	−1.0%	+1.9%
Government wage bill	−10.4%	−10.3%	+0.6%	−2.3%
Panel B. Welfare and lifetime values				
National welfare	−7.6%	−7.4%	+0.3%	−0.0%
Rural value, Π^R	−6.7%	−6.5%	+0.6%	+0.1%
Informal value, V^I	−8.1%	−7.9%	−0.2%	−0.1%
Formal value, V^F	−7.2%	−7.0%	−0.4%	+0.1%
Entrant surplus	−8.0%	−8.1%	−1.0%	−0.6%
Urban entrant NPV	−7.6%	−7.6%	−0.4%	−0.4%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline for the severe Oromia 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 40: Regional incidence of the severe Oromia 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)	−0.4%	−0.8%
Anchor agricultural productivity, T2 (mid)	+1.0%	+0.5%
Anchor agricultural productivity, T3 (high)	+0.9%	+0.4%
Population density, T1 (low)	−0.2%	−0.5%
Population density, T2 (mid)	+0.3%	−0.1%
Population density, T3 (high)	+1.0%	+0.4%
Market-access cost, T1 (low)	+0.8%	+0.2%
Market-access cost, T2 (mid)	+0.8%	+0.3%
Market-access cost, T3 (high)	+0.0%	−0.3%

Panel B. Urban locations

	$\theta = 3.25$		$\theta = 4.75$	
Characteristic	ΔV^I	ΔV^F	ΔV^I	ΔV^F
City size, T1 (low)	−0.0%	−0.2%	+0.4%	−0.1%
City size, T2 (mid)	−0.1%	−0.3%	−0.2%	+0.6%
City size, T3 (high)	−0.3%	−0.2%	−0.1%	+0.1%
Population density, T1 (low)	−0.3%	−0.2%	−0.2%	+1.1%
Population density, T2 (mid)	−0.1%	−0.5%	−0.1%	+0.3%
Population density, T3 (high)	−0.3%	−0.3%	+0.1%	−0.3%
Gateway cost, T1 (low)	−0.4%	−0.4%	−0.0%	−0.4%
Gateway cost, T2 (mid)	−0.3%	−0.3%	−0.4%	+1.2%
Gateway cost, T3 (high)	−0.1%	−0.1%	−0.1%	+0.4%

Notes: Entries are percent deviations from the corresponding capacity-regime baseline for the severe Oromia 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.

I Guide to the Online Appendix

The Online Appendix provides supplementary methodological detail and the complete robustness, counterfactual, and resilience results underlying the paper. The main text and Appendices A–H contain the core arguments, principal evidence, and main quantitative results. The Online Appendix provides additional data-construction detail, numerical diagnostics, calibration information, and complete supporting tables and figures. It is distributed as a standalone companion document. Table 41 maps its seven sections to the corresponding appendices of the paper.

Table 41: Guide to the Online Appendix

Section	Title	Contents	Paper
OA-1	Data Construction Details	Additional construction, harmonization, and validation detail for agricultural outcomes, weather and environmental inputs, travel times, demographics, and the measured amenity index.	Appendix A
OA-2	Measurement and Harmonization	Supplementary detail on urban delineation, agricultural and labor microdata harmonization, construction of model-ready spatial variables, migration measures, and temporal and spatial price adjustment.	Appendix A
OA-3	Numerical Implementation and Diagnostics	Additional detail on the scale of the calibration searches, equilibrium solution methods, convergence performance, numerical accuracy, and reproducibility of the computed equilibria.	Appendix D
OA-4	Calibration Search Ranges	Search intervals, external and empirical discipline, and the role of numerically selected parameters, including additional discussion of the formalization-hazard ridge, productivity paths, and demographic parameters.	Appendix E
OA-5	Complete Robustness Results	Detailed results for alternative target paths, local parameter perturbations, the formalization-hazard ridge and alternative hazard form, alternative structural specifications, literature-based parameter values, calibration-window checks, productivity and demographic paths, channel shutdowns, and amenity-drift sensitivity.	Appendix F
OA-6	Complete Counterfactual Decompositions	Full transition paths and instrument-level output, welfare, employment, real-income, and spatial-incidence decompositions for the formalization-capacity sweep and the supply-side, demand-side, demographic, infrastructure, mobility, trade, and housing counterfactuals.	Appendix G
OA-7	Complete Climate and Conflict Scenario Results	Additional climate and conflict results, including uniform temperature damage, SSP and stochastic climate scenarios, localized agricultural damage, transitory drought episodes, agricultural world-price volatility, and the Tigray conflict exercise, with the corresponding welfare and spatial-incidence decompositions.	Appendix H

Notes: The paper and Online Appendix are designed to compile independently. References from the paper use the form "Online Appendix OA-*n*," while the Online Appendix refers to "Appendix X of the paper." Replication materials are distributed separately.