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Household State Transitions and Aggregate Adjustment under Hukou Reform

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Abstract

Household states shape aggregate adjustment through access to jobs, migration, social contributions, and consumption. We develop an open-economy agent-based stock-flow consistent model of hukou reform in which 600 households differ in skills, registration status, insurance coverage, and family integrity. State-dependent matching and return migration connect these differences to employment and household demand. After a permanent 10% traded-sector productivity increase, homogenizing initial skills and continuous citizenship attributes raises the five-year mean GDP response by 0.729 log percentage points and reduces the unemployment increase by 1.213 percentage points. Initial location-registration states and behavioral rules remain unchanged. Factorial reforms and channel ablations distinguish institutional access, social insurance, and family integrity: the social-insurance price effect operates mainly through contribution costs, with a smaller role for precautionary saving. In the attribute comparison, both price responses retain their signs: the CPI-based real exchange rate falls while the relative non-traded price rises. Pricing and demand experiments locate the conditions for these open-economy consequences across 6,912 simulations. The results describe conditional model mechanisms rather than estimated policy effects.

Keywords: agent-based macroeconomics; household states; labor-market interaction; hukou reform; migration; stock-flow consistency

JEL classification: E17; J15; O15; R23; F31

1. Introduction

Hukou reform changes who can obtain urban jobs, remain in cities, and participate in social insurance. These changes alter the household states through which productivity growth reaches employment and demand. In our model, assigning common initial skills and continuous citizenship attributes changes output and unemployment responses even when the signs of two aggregate price responses remain unchanged. The three reform margins operate through different mechanisms: better institutional access changes matching and migration, insurance changes contributions and saving, and family integrity changes return migration and consumption. Aggregate adjustment depends on these mechanisms jointly with firms' labor requirements and household income expectations.

We study this adjustment in a two-sector open-economy agent-based stock-flow consistent (AB–SFC) model with 600 households and 24 firms. Households move between rural, urban unregistered, and urban registered states. Workers encounter firms in random order, with state-dependent matching probabilities and reservation wages. Unregistered workers may return to rural production after repeated unemployment. These transitions change labor supply and household demand, which feed back into vacancies and employment. A government, consolidated bank, and foreign sector complete the accounts.

The attribute counterfactual provides the main comparison. After a permanent 10% traded-sector productivity increase, homogenizing initial skills and continuous citizenship attributes raises the five-year mean GDP response by 0.729 log percentage points and reduces the unemployment increase by

1.213 percentage points. The paired 95% simulation intervals are [0.375, 1.082] and [−2.166, −0.260], respectively. Initial location-registration states, behavioral rules, and interactions remain in place. The experiment quantifies how jointly homogenizing these attributes changes the response while holding the institutional structure fixed.

Factorial reforms and channel ablations explain why a common reform index would obscure the mechanisms. Social insurance has the largest individual reform effect on the CPI-based real exchange rate in the central calibration. Removing the employee and employer contribution channel reduces that effect from 0.652 to 0.085 log percent; removing the consumption-propensity response leaves 0.625. This comparison attributes most of the price effect to contributions. Reform also changes group composition: 42.86% of initially unregistered urban households become registered within five years, compared with no conversions in the paired baseline, while their return-to-rural share falls from 3.26% to 0.53%. Distributional changes trace how these transitions and employment responses reach households.

The model builds on the study of heterogeneous interacting agents (A. Kirman, 2006; A. P. Kirman, 1992) and macroeconomic models of production, credit, employment, and distribution (Delli Gatti et al., 2010; Delli Gatti et al., 2011; Dosi et al., 2010; Dosi et al., 2013). Following the AB–SFC accounting framework (Caiani et al., 2016; Nikiforos & Zezza, 2017), each transaction has an income, expenditure, asset, or liability counterpart. Our contribution combines registration-dependent job matching and conversion with rural–urban migration and return, and varies institutional access, insurance, and family integrity separately and jointly. The attribute counterfactual and channel ablations show which household differences and rules matter for aggregate adjustment. Table 1 summarizes these mechanisms.

The exchange-rate results are open-economy consequences of this adjustment. In the central productivity experiment, the CPI-based real exchange rate declines while the relative price of non-traded goods rises; attribute homogenization preserves both signs. The price-index relationship permits this divergence, and domestic traded-price adjustment produces it under incomplete world-price anchoring. The pricing experiments locate the conditions under which that sign pattern changes. This connects household adjustment to the Balassa–Samuelson mechanism (Balassa, 1964; De Gregorio et al., 1994; Samuelson, 1964) and work on rural-led appreciation and China's real exchange rate (Imai, 2018; Ju et al., 2020; Menzies et al., 2016; Menzies & Xiao, 2012; Tyers & Golley, 2008; Tyers & Zhang, 2014).

Public data motivate labor-market segmentation and selected initial conditions. The 6,912 simulations study mechanisms conditional on specified behavioral rules and parameter values. Section 2 summarizes the institutional setting and descriptive motivation. Sections 3 and 4 specify the model and paired experiments. Section 5 presents attribute homogenization, channel ablations, and household transitions; Section 6 traces their open-economy consequences and sensitivity. Sections 7 and 8 discuss interpretation and implications.

2. Institutional setting and descriptive motivation

2.1 Hukou, household states, and reform margins

China's hukou system distinguishes registration from residence. Access to urban employment and services can depend on local registration (Cai, 2011; Chan, 2010; Chan & Zhang, 1999; Meng & Zhang, 2001). This distinction motivates three household states: rural, urban unregistered, and urban registered. Households can migrate to cities, obtain registration, or return to rural production, changing both individual circumstances and group composition.

We use *citizenization* for changes in three related but distinct margins. Institutional access affects migration costs, matching, registration conversion, and wage formation. Social insurance affects contributions and precautionary saving. Family integrity affects return migration and consumption composition. Evidence on registration, settlement, insurance, and consumption motivates this distinction (B. Chen et al., 2015; X. Chen, 2018; Cheng et al., 2014; Dreger et al., 2015; Gao et al., 2012; Xie et al., 2021). The model specifies these responses separately. Better access can improve matching while expanding urban labor supply; insurance can support consumption while raising labor costs.

Permanent-resident and hukou urbanization were 58.52% and 42.35% in 2017, a gap of 16.17 percentage points. The gap was 17.86 points in 2023 (National Bureau of Statistics of China, 2018b, 2024). The 2017 accounts initialize the three population shares. The gap is a population-accounting proxy, not an individual measure of citizenship attributes or a migrant-worker count.

2.2 Descriptive evidence and model inputs

NBS migrant-worker reports, World Development Indicators, WIOD, and BIS indices describe the labor-market and price setting (Bank for International Settlements, 2026; National Bureau of Statistics of China, 2015, 2018a, 2025, 2026; Timmer et al., 2015; University of Groningen, 2018; World Bank, 2026). The migrant resident-services/manufacturing wage ratio falls from 0.905 in 2013 to 0.806 in 2025. WIOD comparisons show uneven movements in relative productivity, compensation, and sectoral prices. In descriptive first-difference regressions, positive relative-price coefficients coexist with negative narrow relative-compensation coefficients. The preferred samples contain only 14 WIOD and 25 World Bank differences. These patterns motivate incomplete wage transmission; they do not estimate a transmission elasticity or calibrate the model's behavioral parameters. Worker composition, imperfect tradability proxies, and the different coverage of WIOD compensation and employment limit interpretation. Online Resource 1, Section A, gives the data definitions, series, and regression table.

3. An open-economy AB–SFC model with household states

3.1 Agents and interaction sequence

The model contains 600 households, 12 traded-sector firms, 12 non-traded-sector firms, a government, a consolidated bank, and a foreign sector. Rural household production enters the traded account. Urban firms produce traded (T) and non-traded (N) goods with labor and fixed effective capacity in the central closure. Autonomous investment creates final demand and is financed from deposits or bank loans. Fixed-capital user costs are calibrated separately and do not vary mechanically with sales. The model focuses on medium-run demand and distribution under fixed effective capacity.

Each quarter has ten steps: interest accrual and bank-profit distribution; productivity and policy updates; migration, return migration, and registration conversion; wage and price adjustment; demand formation; vacancies and job matching; production and rationing; income, tax, and expenditure settlement; financial settlement; and accounting checks. Prices and wages are set before current demand and employment are known. Household consumption depends on expected disposable income. If desired output exceeds available labor, buyers are rationed proportionally and unspent balances remain with their owners. This sequence links household decisions and firm responses to aggregate prices, employment, and distributions.

Building on the AB–SFC accounting framework of Caiani et al. (2016), the model links household state transitions to job matching, demand, and financial settlement. Table 1 summarizes the mechanisms used to study this adjustment.

Table 1. Household interaction mechanisms within the AB–SFC framework. The experiments compare joint attribute homogenization and separate reform channels while retaining accounting consistency.

Mechanism in this model	Household or firm rule	Aggregate adjustment
State transitions	Migration into the unregistered urban pool, registration conversion, and return after repeated unemployment	Changes the composition of urban labor supply and rural production
State-dependent matching	Random-order encounters, registration-dependent match probabilities, skills, and reservation wages	Allocates employment and earnings across households
Three reform margins	Institutional access, insurance, and family integrity vary separately and in all combinations	Distinguishes matching and mobility from contribution costs and consumption responses
Household demand feedback	Expected disposable income and state-dependent consumption determine expenditure	Employment and contributions affect subsequent demand and vacancies
Open-economy accounting	Exports, imports, foreign interest, and net foreign assets have explicit counterparts	Transmits domestic adjustment to external balances and distinct price measures

3.2 Behavioral heterogeneity and state transitions

Household i has skill χ_i, a location-registration state, institutional access h_i, social-insurance coverage s_i, and family integrity f_i. Skills are drawn from a truncated lognormal distribution. Initial citizenship attributes differ by state. Their initial values are normalizations reported in Table 2. Registration conversion changes institutional access but does not automatically change insurance or family attributes, preserving the factorial interpretation.

Table 2. Initial household states and behavioral rules. Skill χ_i is heterogeneous across all states. The homogenized-attribute counterfactual sets $\chi_i = 1$ and assigns every household the initial population means of h_i, s_i, and f_i, while retaining initial states.

Rule or attribute	Rural	Urban unregistered	Urban registered
Initial institutional access h_i	0.00	0.25	1.00
Initial social-insurance coverage s_i	0.10	0.35	0.95
Initial family integrity f_i	0.80	0.30	0.90
Employment or activity	Own-account rural production	Firm matching; return migration possible	Firm matching with higher match probability
Registration conversion	First enters unregistered pool after moving	Stochastic conversion under identity reform	Already registered
Main reform-sensitive behavior	Migration net benefit	Reservation wage, matching, contributions, service share	Contributions and consumption composition

A rural worker compares expected urban labor income with the current rural return. The net-benefit index is

$$v_{i,t} = \frac{\bar{w}_t^u(1-u_t)(1-\tau_t) - w_{i,t}^R(1-\tau_t)}{\max(w_{i,t}^R, 0.08)} - m(z_t),$$

where $\bar{w}_t^u$ is the expected urban wage, u_t is urban unemployment, $w_{i,t}^R$ is rural labor income, τ_t is the labor-tax rate, and $m(z_t)$ is a migration cost that falls with institutional reform. The quarterly migration probability is

$$p_{i,t}^{move} = \text{clip}\big[b_0 + b_1 \max(v_{i,t}, 0), 0, 0.22\big].$$

New migrants enter the unregistered urban pool. Unregistered workers with repeated unemployment can return to rural production; their probability declines with family integrity. The three reform attributes adjust gradually over 12 quarters.

3.3 Matching and wage formation

Firms separate workers, lay off excess labor, and post vacancies. Unemployed urban workers encounter firms in random order. Matching probabilities are higher for registered workers and rise with institutional access for unregistered workers. Offers must exceed a reservation wage that depends on skill, sector, unemployment duration, and institutional status. Individual wages equal the firm offer multiplied by skill. These rules generate state- and skill-dependent employment and earnings.

Sector wage references evolve according to

$$\Delta \ln W_{j,t} = \text{clip}\big[\phi_j T_{j,t-1} + \eta_j \Delta \ln A_{j,t} + \psi_t(\ln W_{-j,t-1} - \ln W_{j,t-1}), -\bar{\Delta}_W, \bar{\Delta}_W\big],$$

where $T_{j,t-1}$ measures labor-market tightness and $\bar{\Delta}_W = 0.035$. The cross-sector coefficient is $\psi_t = \psi_0 + \psi_h \bar{h}_t^{\mu}$, with $\psi_0 = 0.0005$ and $\psi_h = 0.020$. Productivity pass-through is $\eta_T = 0.22$ and $\eta_N = 0.14$. The sensitivity experiment with $\psi_h = 0$ isolates the role of institutional access in cross-sector wage transmission.

3.4 Production, pricing, and two exchange-rate concepts

Firm sales are

$$Y_{f,t} = \min\left\{A_{f,t}\sum_{i\in f}\chi_i\,,\; D_{f,t}\right\},$$

where $D_{f,t}$ is desired real sales. Workers retained beyond short-run requirements create underutilization rather than free inventory. Rural household production is sold first within the traded market; urban traded firms meet residual demand.

The traded-price target combines an international price constraint and domestic cost:

$$\tilde{P}_{T,t} = \omega e_t P_t^* + (1-\omega)(1+\mu_{T,t})\left(\frac{W_{T,t}(1+\rho\bar{s}_t)}{A_{T,t}} + \kappa_T\right),$$

where e_t is domestic currency per unit of foreign currency, ρ is the employer social-contribution rate, $\bar{s}_t$ is mean employee coverage, and κ_T is fixed-capital user cost. The central weight is $\omega = 0.5$, with 0.6 as a longer-horizon alternative and 0, 0.25, 0.75, and 1 as boundary cases. This weight is not an estimated exchange-rate pass-through coefficient. Chinese import-price evidence motivates an incomplete-pass-through range, while firm-level export evidence warns against treating one economy-wide weight as identified (Bouvet et al., 2017; Burstein & Gopinath, 2014; Li et al., 2015; Shu & Su, 2009).

The non-traded target is

$$\tilde{P}_{N,t} = (1+\mu_{N,t})\left(\frac{W_{N,t}(1+\rho\bar{s}_t)}{A_{N,t}} + \kappa_N\right),$$

where $\mu_{N,t}$ responds to demand pressure and is bounded. Actual prices move partway toward their targets, with log changes capped at 3.5% per quarter. Imported goods cost $P_{M,t} = e_t P_t^*$. Export demand is

$$X_t = X_0\left(\frac{P_{T,t}}{e_t P_t^*}\right)^{-\epsilon_X}, \qquad \epsilon_X = 1.35.$$

The consumer price index is $P_t = P_{T,t}^{0.55} P_{N,t}^{0.32} P_{M,t}^{0.13}$, and the CPI-based real exchange rate is $Q_t = P_t/(e_t P_t^*)$. An increase denotes appreciation. We distinguish it from

$$p_t = \frac{P_{N,t}}{P_{T,t}}, \qquad r_t = \frac{P_{T,t}}{e_t P_t^*}, \qquad Q_t = p_t^{0.32} r_t^{0.87},$$

where the last equality uses $P_{M,t} = e_t P_t^*$. When r_t is fixed, p_t and Q_t move together. When traded prices respond to domestic costs, they can move in opposite directions. The baseline nominal exchange rate is anchored. Managed and floating alternatives respond to the lagged trade imbalance; they are sensitivity closures, not asset-market theories (Frankel, 2006).

3.5 Consumption, government, and external accounts

The nominal consumption budget is

$$B_{i,t} = \lambda\left[m_{i,t}Y_{i,t}^{e} + \omega_D D_{i,t-1}\right],$$

where $Y_{i,t}^{e}$ is expected disposable income, $D_{i,t-1}$ is deposits, and λ is a normalization. Expected income equals disposable income settled in the preceding quarter in the central closure. The propensity $m_{i,t}$ varies with state, insurance, institutional access, employment, and debt. Social coverage reduces precautionary saving. Consumption shares respond to family integrity, institutional access, insurance, and relative import prices. Reform therefore changes both the level and composition of demand.

A demand counterfactual replaces expected income after settlement with

$$\tilde{Y}_{i,t}^{e} = Y_{i,t}^{e}(A_{T,t}/A_{T,0})^{\chi},$$

so that the following quarter's budget reflects productivity-linked income expectations. The central model sets $\chi = 0$; the alternative sets $\chi = 0.5$. The alternative tests the sensitivity of demand to productivity-linked income expectations.

The government collects labor taxes, social contributions, corporate taxes, and output sales taxes net of input credits on domestically produced investment goods. It purchases goods and public services, pays benefits and interest, and finances citizenization. Debt, employer-surcharge, labor-tax-surcharge, and expenditure-reallocation financing are compared. The bank creates and retires deposits through lending and repayment. Foreign deposits and loans accommodate trade and cross-border interest. Net foreign assets are $F_t = L_t^R - D_t^R$. No independent capital-flow shock enters.

3.6 Stock-flow consistency

The consolidated balance-sheet identity is

$$L_t^F + L_t^H + L_t^R + B_t^G = D_t^H + D_t^F + D_t^G + D_t^R + E_t^B,$$

where the left side contains firm, household, and foreign loans plus government bonds, and the right side contains household, firm, government, and foreign deposits plus bank equity. Loan issuance creates matching deposits; repayment destroys them. Government bond issuance finances a negative government deposit. Bank profit changes equity, and dividends transfer equity to household deposits.

The model checks this identity and the nominal demand–output identity every period. Across the central and extended trials, the largest absolute residuals are 2.956×10^{-12} and 1.705×10^{-13}. The distribution trials have corresponding maxima of 4.775×10^{-12} and 1.705×10^{-13}. These residuals verify the numerical implementation of the accounting identities.

4. Calibration and experimental design

4.1 Calibration principles

The calibration separates data anchors, normalizations, and exploratory behavioral parameters. NBS population accounts initialize household shares. The migrant wage ratio is a descriptive reference rather than a fitted moment. Fiscal and external stocks are normalized relative to quarterly output. Chinese pass-through studies inform the range of the traded-pricing weight but do not identify it. Household and

wage responses without comparable evidence remain exploratory and are varied systematically. Table 3 distinguishes directly anchored inputs from exploratory behavioral values.

Table 3. Calibration map from public facts and external evidence to model objects. Initializations, descriptive references, normalizations, and exploratory parameters are distinct.

Object	Model value	External reference or calibration status
Rural population share	0.4148	Direct initialization from the 2017 NBS population account
Urban registered share	0.4235	Direct initialization from 2017 NBS hukou urbanization
Urban unregistered share	0.1617	Permanent-resident minus hukou urbanization; accounting proxy
Households / firms per sector	600 / 12	Numerical normalization
Initial / pre-shock W_N/W_T	0.846 / 0.901	NBS 2017 migrant ratio 3,022/3,444 = 0.877; descriptive reference
Initial government debt / annual GDP	0.405	Fiscal normalization close to 0.41
Initial trade balance / quarterly GDP	0.0022	Approximately balanced external-account normalization
Exchange-rate measures	Q and P_N/P_T	WIOD/WDI relative prices and BIS nominal–real divergence motivate separate reporting
Baseline traded/world-price weights	0.50 / 0.50	Incomplete Chinese import-price pass-through; 0.60 / 0.40 longer-horizon alternative (Shu & Su, 2009)
Productivity pass-through η_T, η_N	0.22, 0.14	Exploratory behavioral values; varied in sensitivity experiments
Wage linkage ψ_0, ψ_h	0.0005, 0.020	Exploratory values; unstable wage co-movement does not identify them
Productivity-linked income expectations χ	0; 0.5 counterfactual	Unestimated demand-closure comparison
Capital user costs κ_T, κ_N	0.411, 0.420	Fixed-capacity calibration
Labor, employee, employer tax/contribution rates	0.24, 0.06, 0.10	Fiscal-behavior normalization
Output sales-tax rate	0.08	Net of domestic investment-goods credits

Object	Model value	External reference or calibration status
Permanent productivity shock	10%	5% and 15% alternatives

The NBS wage categories are not identical to the model sectors, so the 0.877 ratio disciplines the initial wage neighborhood rather than imposing the pre-shock outcome. Baseline unemployment is a model diagnostic and is not compared with the official registered urban rate. The replication package reports baseline moments in `calibration_moments.csv`; Online Resource 1 presents stock diagnostics and additional simulation results.

4.2 Paired shocks and structural closures

The model runs for 90 quarters, with 20 burn-in periods and shocks beginning in quarter 30. The primary interpretation window is the medium-run transition five years after the shock; ten-year paths are stock-dynamics diagnostics. Three reforms generate a 2^3 factorial design with and without a permanent 10% traded-sector productivity shock. Each of the 16 factorial scenarios uses 32 paired seeds. Seventeen structural variants cover the four central scenarios with 16 seeds, and three alternative financing modes are compared with debt financing. This central design contains 1,792 trials and 161,280 quarterly records.

A separate extended design contains 4,480 trials and 403,200 quarterly records. It varies the world-price weight and shock size, demand formation, policy-cost timing, investment–capacity closure, social-insurance channels, and rural-production mapping. Together, the central and extended designs contain 6,272 trials and 564,480 quarterly records. Default extended closures reproduce the central contrasts.

The distribution design contains 640 trials and 57,600 quarterly records. It repeats all 16 factorial scenarios with 32 seeds and records household distributions. It also includes the four central scenarios with homogenized household attributes, using the same 32 seeds. Across all designs, we conduct 6,912 trials and 622,080 aggregate quarterly records, plus 172,800 state-by-quarter records.

Four contrasts answer different questions. Let B, P, R, and PR denote baseline, productivity-only, reform-only, and combined paths:

$$\Delta_Y^{P,0} = \ln Y^P - \ln Y^B, \qquad \Delta_Y^{R,0} = \ln Y^R - \ln Y^B,$$

$$\Delta_Y^{P,R} = \ln Y^{PR} - \ln Y^R, \qquad \mathcal{I}_Y = \Delta_Y^{P,R} - \Delta_Y^{P,0}.$$

The first is the productivity effect without reform, the second is the reform level effect, the third is the productivity effect after reform, and $\mathcal{I}_Y$ is the interaction. All contrasts are computed within seed before averaging. Log differences are multiplied by 100; unemployment is reported in percentage points. Reported 95% simulation intervals equal the paired mean plus or minus 1.96 times the sample standard deviation of the paired contrasts divided by the square root of the number of seeds. They measure Monte Carlo precision of the estimated mean at the specified parameters; they are not prediction intervals for individual runs and do not include data, parameter, or model uncertainty.

4.3 Distribution measures and homogenized attributes

For every household and quarter, the distribution calculations use real disposable income, real consumption, real saving, deposits, labor earnings, employment, and location-registration state. We calculate Gini coefficients and p90/p10 ratios for income and consumption, employed-wage dispersion,

and state-specific means. State-panel contrasts compare the same contemporaneous state across paired scenarios. Because households change states, these contrasts describe group composition and outcomes, not fixed-cohort welfare effects. Transition matrices compare each household's state immediately before the shock with its state five years later. Rural households count as active in own-account production; urban employment requires a firm match.

The homogenized-attribute counterfactual sets every skill to one and assigns every household the initial population means of h_i, s_i, and f_i. Initial location-registration states, firms, behavioral equations, and random seeds remain unchanged. The intervention changes the joint distribution of attributes across states. Setting skills to one need not preserve each seed's realized mean skill, so the comparison is not a pure dispersion experiment. For each seed, we compute the treatment-minus-baseline contrast in each setting and then subtract the heterogeneous-setting contrast from the homogenized-setting contrast. This paired difference measures how attribute homogenization changes the response to a given shock; its simulation interval uses the same calculation as the other paired means.

Implementation checks verify the balance-sheet and demand–output identities each period and identical pre-shock paths within each paired configuration. Aggregate contrasts from the runs with household-distribution recording agree with those from the central runs to within 9.0×10^{-14} at the seed level. Tests cover baseline behavior, alternative closures, and distribution accounting. We also inspect financial-stock accumulation and compare response signs across seeds and closures. These numerical checks are distinct from empirical validation of the behavioral equations.

5. Household states and aggregate adjustment

5.1 Attribute homogenization changes employment and output

The first counterfactual holds location-registration states, firms, behavioral rules, and paired seeds fixed while assigning common initial skills and continuous citizenship attributes. This compares responses to joint attribute homogenization within the same institutional structure. Figure 1 places output and employment beside the two price measures.

Homogenization changes the mean productivity-only GDP response from −0.165 to +0.564 log percent and reduces the unemployment increase from 3.265 to 2.052 percentage points. The GDP response in the heterogeneous setting has an interval that includes zero. The direct paired difference between settings is more informative: homogenization raises the mean GDP response by 0.729 log percentage points, with a 95% simulation interval of [0.375, 1.082], and lowers the unemployment response by 1.213 percentage points, with an interval of [−2.166, −0.260]. These paired comparisons show that joint attribute homogenization changes real adjustment at the specified calibration.

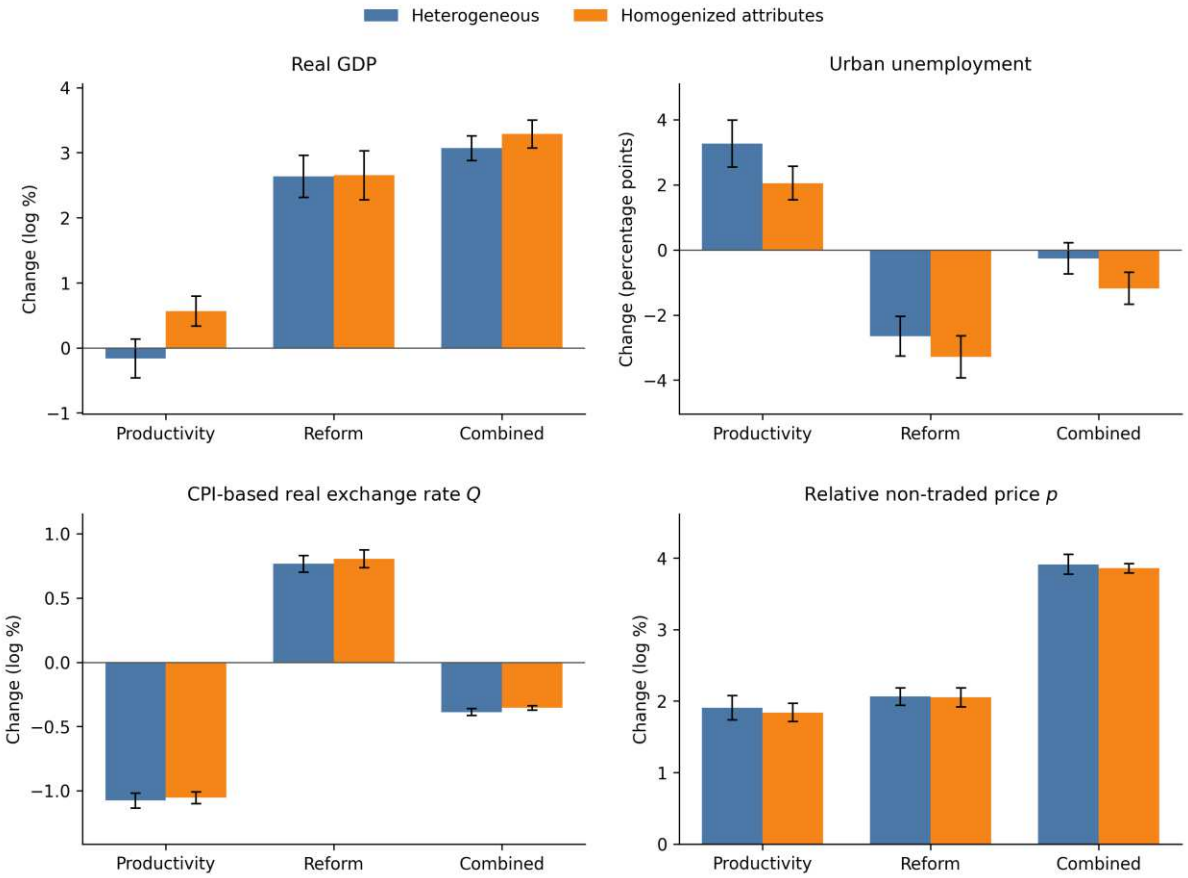


Figure 1. Attribute homogenization and aggregate adjustment at five years. Skills are set to one and continuous citizenship attributes to their initial population means; initial location and registration states remain. The upper panels report output and unemployment; the lower panels report prices. Bars are paired means with 95% simulation intervals across 32 seeds.

The attribute-homogenization counterfactual retains the signs of both price responses (Table 4). Productivity lowers Q by 1.054 log percent and raises p by 1.840. The combined scenario also retains CPI-based depreciation and relative-price appreciation. Thus the pricing rules can generate this divergence even when households start with common skills and continuous citizenship attributes. Initial location-registration states, behavioral rules, and interactions remain in this comparison.

The corresponding productivity-only differences in Q and p are 0.022 and −0.065 log percentage points; both intervals include zero. Under the combined scenario, homogenization lowers the unemployment response by 0.919 percentage points, with an interval of [−1.613, −0.225]. Table 5 reports all three scenarios. The price differences are small relative to the scenario effects, although the differences in Q for reform and the combined scenario have intervals above zero. The preserved signs should therefore not be interpreted as exact equality of the price responses.

Table 4. Homogenized-attribute counterfactual at five years. Skills are set to one and continuous citizenship attributes to their initial population means; initial states remain. Except for unemployment, entries are log differences multiplied by 100, with 95% simulation intervals. Unemployment is in percentage points.

Contrast and variant	Q	$p = P_N/P_T$	Real GDP	Unemployment
Productivity, heterogeneous	−1.076 (0.057)	1.905 (0.169)	−0.165 (0.299)	3.265 (0.726)
Productivity, homogenized	−1.054 (0.046)	1.840 (0.129)	0.564 (0.229)	2.052 (0.517)
Reform, heterogeneous	0.767 (0.065)	2.063 (0.120)	2.636 (0.322)	−2.653 (0.613)
Reform, homogenized	0.805 (0.070)	2.052 (0.133)	2.653 (0.376)	−3.288 (0.646)
Combined, heterogeneous	−0.388 (0.027)	3.911 (0.140)	3.068 (0.191)	−0.261 (0.476)
Combined, homogenized	−0.355 (0.018)	3.856 (0.065)	3.287 (0.216)	−1.180 (0.493)

Table 5. Change in the treatment effect after attribute homogenization. Each entry is the homogenized-minus-heterogeneous difference in treatment-minus-baseline contrasts, paired by seed. Parentheses contain 95% simulation-interval half-widths for the mean across 32 seeds. Price and GDP entries are log percentage points; unemployment entries are percentage points.

Contrast	Q	$p = P_N/P_T$	Real GDP	Unemployment
Productivity only	0.022 (0.027)	−0.065 (0.097)	0.729 (0.353)	−1.213 (0.953)
Reform only	0.038 (0.033)	−0.010 (0.134)	0.017 (0.268)	−0.635 (0.766)
Combined	0.033 (0.024)	−0.054 (0.096)	0.219 (0.296)	−0.919 (0.694)

The comparison changes skills and continuous citizenship attributes jointly. Separate interventions would be needed to distinguish their contributions. Differences in employment feed into expected income and subsequent demand, while the retained state-dependent rules continue to allocate jobs, contributions, and consumption across households.

5.2 Reform channels operate through different margins

The factorial experiments vary institutional access, social insurance, and family integrity separately and jointly. These margins change matching and mobility, contributions and saving, and the composition of consumption through different rules. Figure 2 compares their price effects and their interaction with the productivity shock. Institutional identity alone raises Q by 0.067 log percent at five years. Social insurance alone raises it by 0.652, while family integrity alone changes it by 0.014. Social insurance is the largest positive level channel in this calibration.

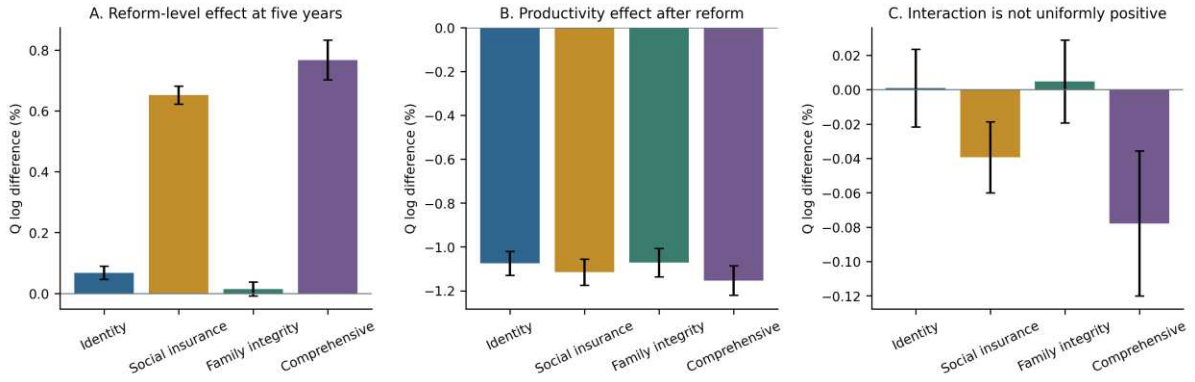


Figure 2. Citizenization channels at five years. Bars show means and 95% simulation intervals. Panel A is the reform-level effect; panel B is the post-reform productivity effect; panel C reports each reform's interaction with the productivity shock, calculated as panel B minus the no-reform productivity response.

Ablations identify the behavioral source. With all social-insurance mechanisms active, social-insurance reform raises Q by 0.652 and p by 0.696. Disabling the consumption-propensity response leaves corresponding effects of 0.625 and 0.556; disabling the service-share response leaves 0.650 and 0.670. Disabling employee and employer contributions reduces them to 0.085 and 0.236. Each comparison uses its corresponding ablated baseline. Contribution costs account for most of the exchange-rate level effect in this calibration. Removing contributions also raises real GDP by 1.193, compared with 0.642 in the full social-reform scenario, so price and real-economy interpretations must remain separate.

The productivity response after each single-channel reform remains negative: −1.076 after identity reform, −1.116 after social-insurance reform, and −1.072 after family reform. Removing the direct institutional wage-spillover term does not reverse the combined decline in Q. This experiment leaves the contribution of labor supply, demand composition, financing, and external adjustment to be traced through the remaining model rules.

5.3 State transitions and household distributions

Comprehensive reform changes the distribution of households across states. Five years after the shock, the unregistered urban group has 44.75 fewer households on average than in the paired baseline, while the registered group has 51.31 more and the rural group has 6.56 fewer. The group sizes change through migration and registration conversion.

The transition matrix shows the underlying mobility. In the baseline, 4.13% of initially rural households enter the unregistered state within five years, and 3.26% of initially unregistered households return to rural production. Under comprehensive reform, 42.86% of initially unregistered households become registered and only 0.53% return to rural production. Reform also creates a small direct rural-to-registered flow because conversion occurs after migration during the five-year window.

Table 6. Five-year state-transition shares from the pre-shock state to the post-shock state. Entries are means across 32 paired seeds. Reform changes both registration conversion and return migration.

Origin → destination	Baseline share	Comprehensive-reform share
Rural → rural	0.9587	0.9437
Rural → urban unregistered	0.0413	0.0417
Rural → urban registered	0.0000	0.0147
Urban unregistered → rural	0.0326	0.0053
Urban unregistered → urban unregistered	0.9674	0.5661
Urban unregistered → urban registered	0.0000	0.4286
Urban registered → urban registered	1.0000	1.0000

The household ledgers reveal a contrast hidden by aggregate output. Productivity alone raises the five-year income Gini coefficient by 0.00495 and the consumption Gini coefficient by 0.00594. Comprehensive reform lowers them by 0.00693 and 0.00326. Combining reform with productivity leaves income inequality 0.00385 below baseline but consumption inequality 0.00229 above it.

Table 7. Five-year paired changes in household Gini coefficients, with 95% simulation intervals in parentheses. Income and consumption are CPI-deflated. Gini changes are reported in levels.

Contrast	Income Gini	Consumption Gini
Productivity only	0.00495 (0.00120)	0.00594 (0.00104)
Reform only	−0.00693 (0.00104)	−0.00326 (0.00121)
Combined	−0.00385 (0.00084)	0.00229 (0.00101)

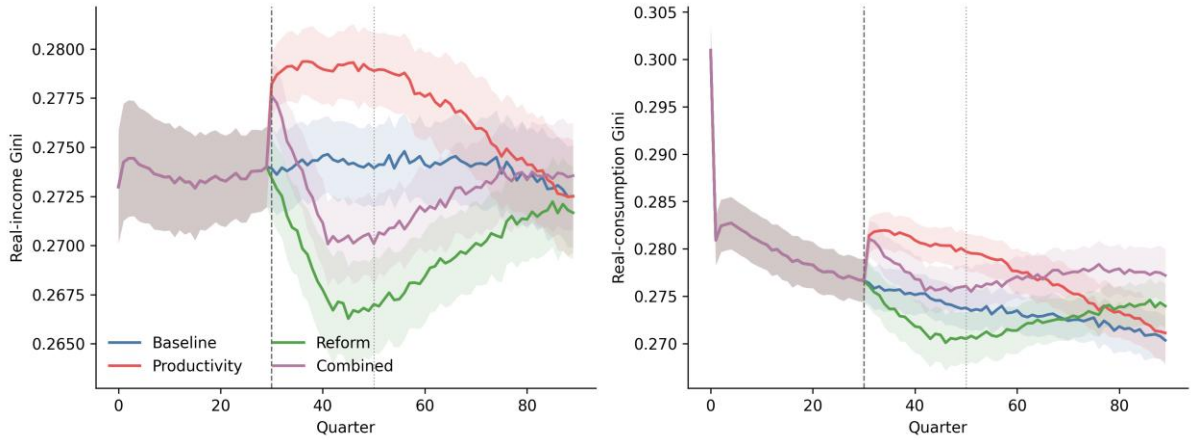


Figure 3. Household distributions along medium-run transition paths. Lines are seed means and shaded areas are 95% simulation intervals across 32 seeds. Shocks begin in quarter 30; quarter 50 is the five-year horizon.

State panels show how reform reaches households. Registered households experience mean income and consumption increases of 6.285 and 7.595 log percent. For unregistered households, consumption

rises by 10.230 log percent and employment by 3.022 percentage points, while the mean income response of 0.219 log percent has a wide simulation interval of ±1.919. Rural incomes rise by 1.132 log percent. Saving falls in both urban groups as consumption and state transitions adjust. These contemporaneous-state contrasts combine within-state outcomes with changing group composition; they should not be read as fixed-cohort gains.

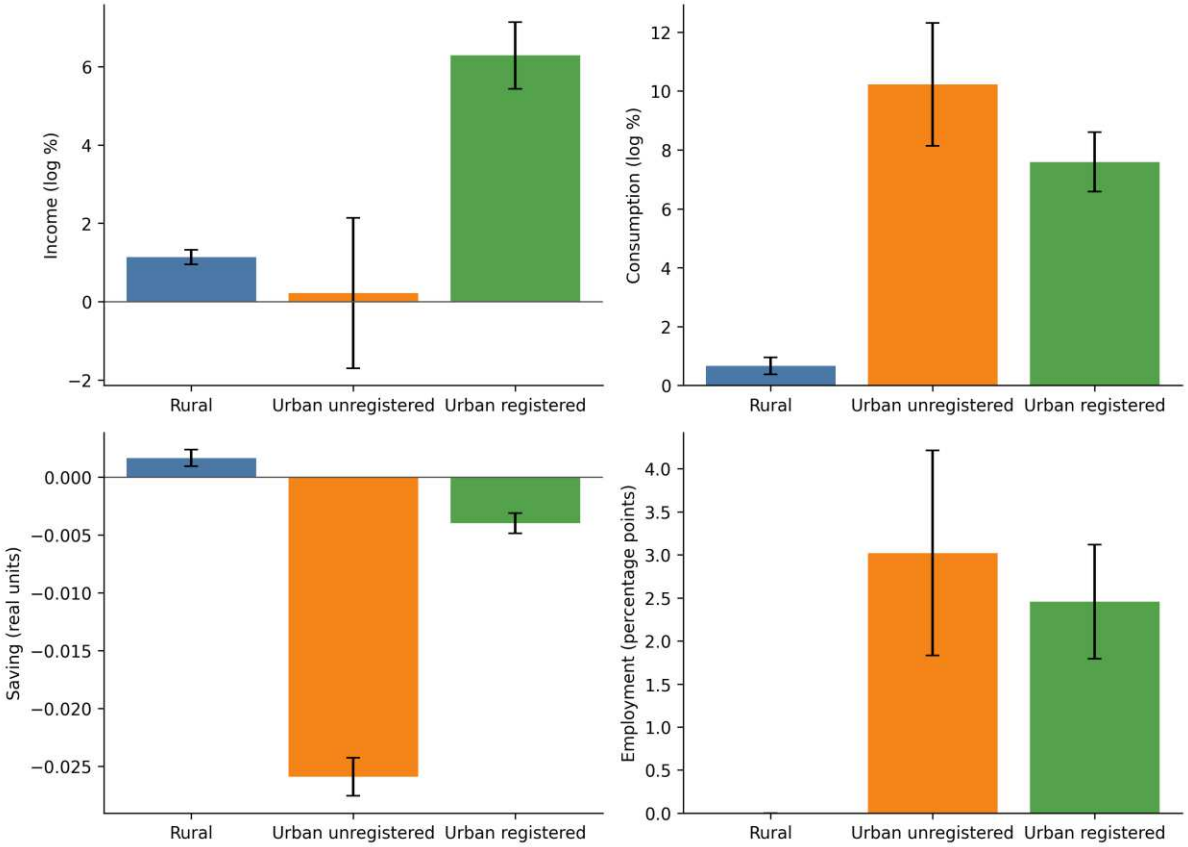


Figure 4. Distribution of comprehensive-reform effects at five years by contemporaneous household state. Error bars are 95% simulation intervals across 32 paired seeds. Income, consumption, and saving are CPI-deflated; employment is measured among active households, with rural households in own-account production.

Wage distributions respond less than household income and consumption. Productivity raises the employed-wage Gini coefficient by 0.00251, comprehensive reform lowers it by 0.00137, and the combined change is −0.00088. The larger household-level responses therefore arise from employment, migration, benefits, and demand as well as wage offers. Online Resource 1 reports within-sector wage dispersion; the replication package contains the full state-channel panels.

6. Open-economy consequences and sensitivity

6.1 Domestic traded prices and exchange-rate measures

The productivity-only experiment isolates the pricing mechanism. Five years after the shock, the traded-sector wage is 1.876 log percent higher, but the non-traded wage changes by only −0.015 log percent. The non-traded price changes by −0.033 log percent, while the traded price falls by 1.938 log percent. The CPI-based real exchange rate Q falls by 1.076 log percent, with all 32 paired seeds negative, but the relative non-traded-goods price p rises by 1.905. Export receipts rise by 0.416 log percent. The shock

therefore does not lower the relative price of non-traded goods; it lowers Q because the real traded-price decline dominates.

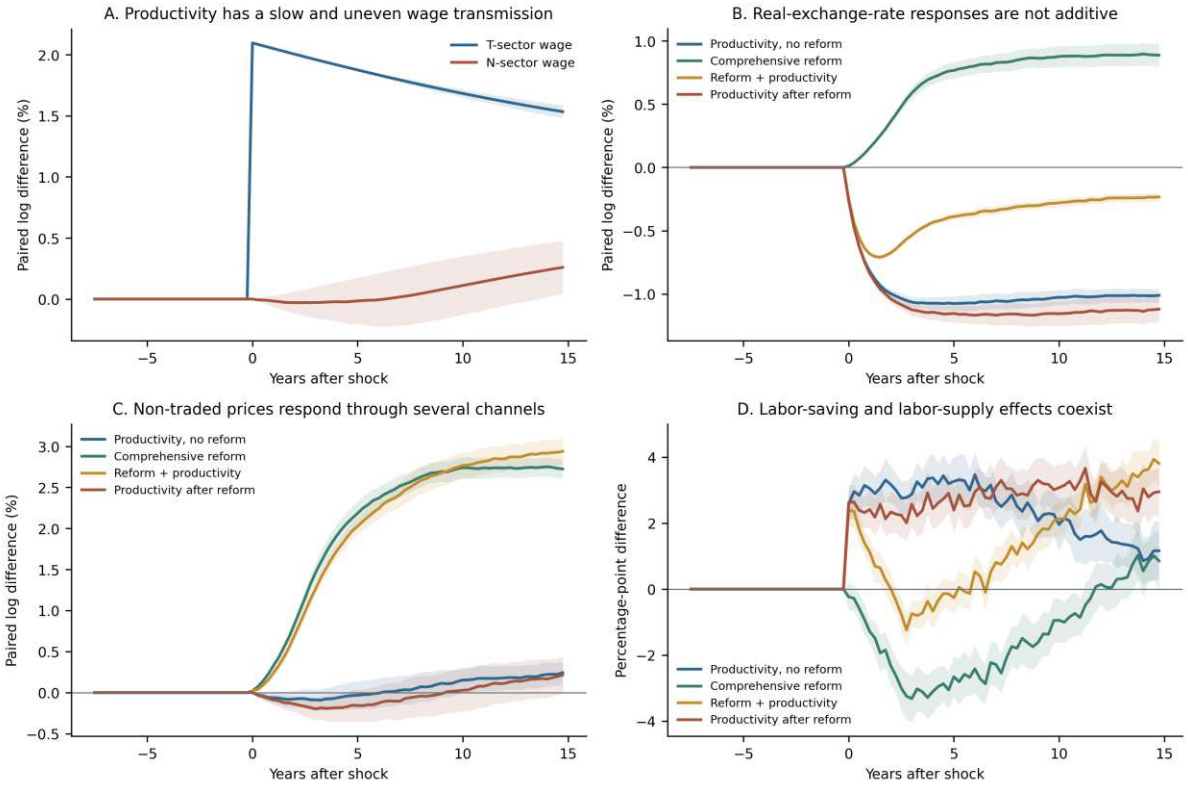


Figure 5. Paired responses of wages, the CPI-based real exchange rate, non-traded prices, and unemployment. Shaded areas are 95% simulation intervals across seeds.

Real output changes by −0.165 log percent at five years, with a simulation interval that includes zero, while urban unemployment rises by 3.265 percentage points. Desired real investment is unchanged by construction and desired real exports rise by 2.617 log percent, but desired real consumption of traded and non-traded goods falls by 0.633 and 2.529 log percent. At given desired sales, higher productivity reduces labor requirements; employment losses lower subsequent expected income and consumption. Export gains only partly offset weaker domestic demand. This employment–income feedback amplifies the initial reduction in labor requirements under the central demand rules.

6.2 Reform level effects and productivity interactions

Comprehensive reform raises both exchange-rate measures. Five years after implementation, non-traded wages and prices are 1.932 and 2.185 log percent higher. The CPI-based measure rises by 0.767 log percent and p rises by 2.063. Real output rises by 2.636 log percent and urban unemployment falls by 2.653 percentage points. Government debt declines by 0.721 log percent, while net foreign assets fall by 5.254% of reference quarterly GDP. Stronger domestic absorption is accompanied by a decline in net foreign assets.

The combined scenario separates the price responses again. The CPI-based measure is 0.388 log percent lower, whereas p is 3.911 log percent higher. Non-traded prices rise by 2.027 log percent and real output rises by 3.068 log percent. Unemployment is 0.261 percentage points lower, with substantial seed dispersion. Relative to productivity alone, reform cushions CPI-based depreciation; relative to reform alone, adding productivity reverses the sign of Q but not of p.

The post-reform productivity effect makes the non-additivity explicit. Productivity after reform lowers Q by 1.154 log percent, compared with 1.076 without reform; the interaction is −0.078 at five years. For p, the corresponding productivity effects are 1.848 and 1.905, with an interaction of −0.057. Citizenization has a positive level effect on both measures but does not, on average, strengthen subsequent productivity transmission in either measure.

Table 8. Five-year paired aggregate effects. Except for unemployment, entries are log differences multiplied by 100, with 95% simulation intervals in parentheses. Unemployment entries and intervals are percentage points. The interaction is the post-reform productivity effect minus the no-reform productivity effect.

Contrast	Q	$p = P_N/P_T$	Real GDP	Unemployment	Government debt
Productivity only	−1.076 (0.057)	1.905 (0.169)	−0.165 (0.299)	3.265 (0.726)	3.887 (0.324)
Reform only	0.767 (0.065)	2.063 (0.120)	2.636 (0.322)	−2.653 (0.613)	−0.721 (0.305)
Combined	−0.388 (0.027)	3.911 (0.140)	3.068 (0.191)	−0.261 (0.476)	3.263 (0.311)
Post-reform prod.	−1.154 (0.067)	1.848 (0.186)	0.432 (0.347)	2.392 (0.680)	3.983 (0.295)
Interaction	−0.078 (0.042)	−0.057 (0.139)	0.597 (0.377)	−0.873 (1.022)	0.096 (0.451)

At one, three, five, and ten years, productivity-only changes in Q are −0.821, −1.065, −1.076, and −1.027 log percent. Reform-only changes are 0.156, 0.589, 0.767, and 0.878. Combined changes are −0.684, −0.537, −0.388, and −0.279. The combined CPI-based depreciation narrows over time but does not change sign; the interaction reaches −0.130 at ten years.

6.3 Sensitivity to pricing, shock size, and demand

Two closures restore combined appreciation in Q. A full world-price anchor raises Q by 0.664 log percent, with all 16 seeds positive. A 5% productivity shock leaves a 0.165 log-percent combined increase, with 15 of 16 seeds positive. A 15% shock produces a 0.865 log-percent decline. The sign of Q is therefore conditional on pricing and shock size.

Other variants largely preserve combined depreciation. Full traded cost pricing produces −1.444 log percent, removing wage pass-through produces −0.679, removing the direct institutional wage spillover produces −0.468, and adding a service-productivity response produces −1.175. Eight and 16 firms per sector produce −0.360 and −0.365. Managed and floating exchange-rate closures produce −0.376 and −0.415. The interaction in Q is positive in only 2 of 17 variants, with wide or near-zero responses. Level effects, total combined effects, and interactions must be interpreted separately.

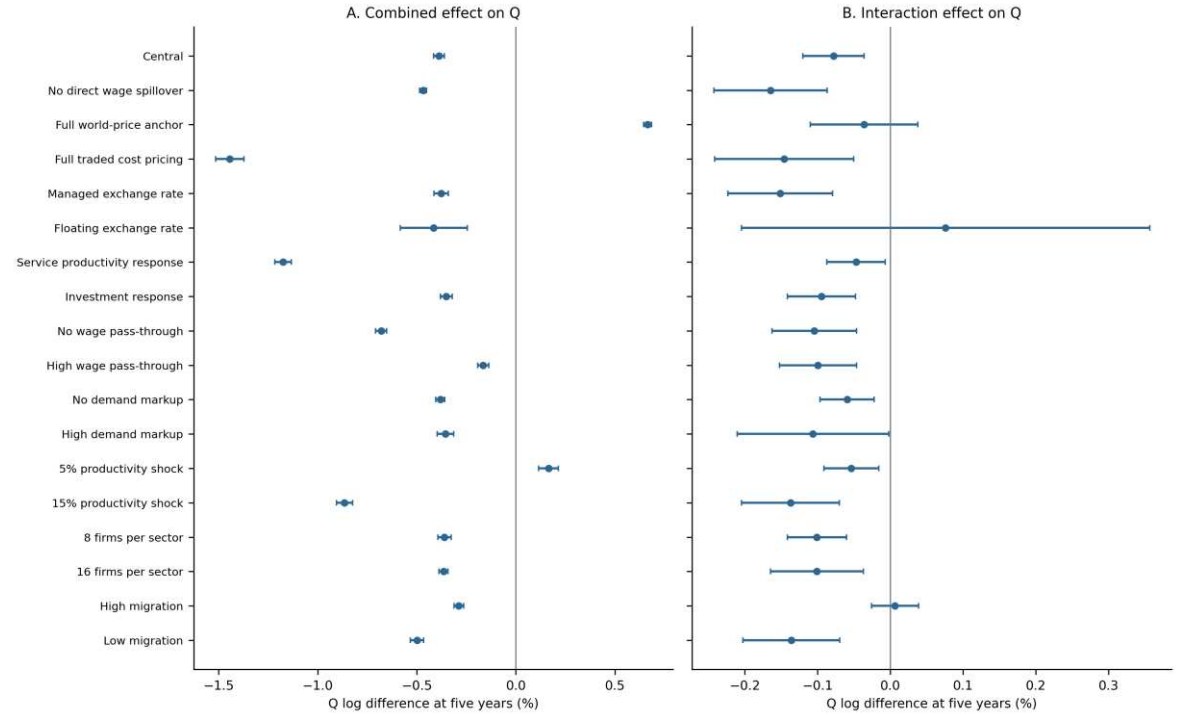


Figure 6. Structural sensitivity at five years for Q. Points are means and bars are 95% simulation intervals. Panel A reports the combined effect; panel B reports the interaction.

The joint pricing–shock grid makes the boundary explicit. The relative non-traded-goods price rises in all 18 cells and in every paired seed. At the central weight of 0.50, a 5% shock raises combined Q by 0.144, a 10% shock lowers it by 0.388, and a 15% shock lowers it by 0.888. At a weight of 0.60, the responses are 0.249, −0.169, and −0.537. At 0.75, they are 0.389, 0.138, and −0.076. A full world-price anchor gives 0.627, 0.639, and 0.676. The sign of Q emerges jointly from pricing and the productivity impulse, while the sign of p remains positive throughout the grid.

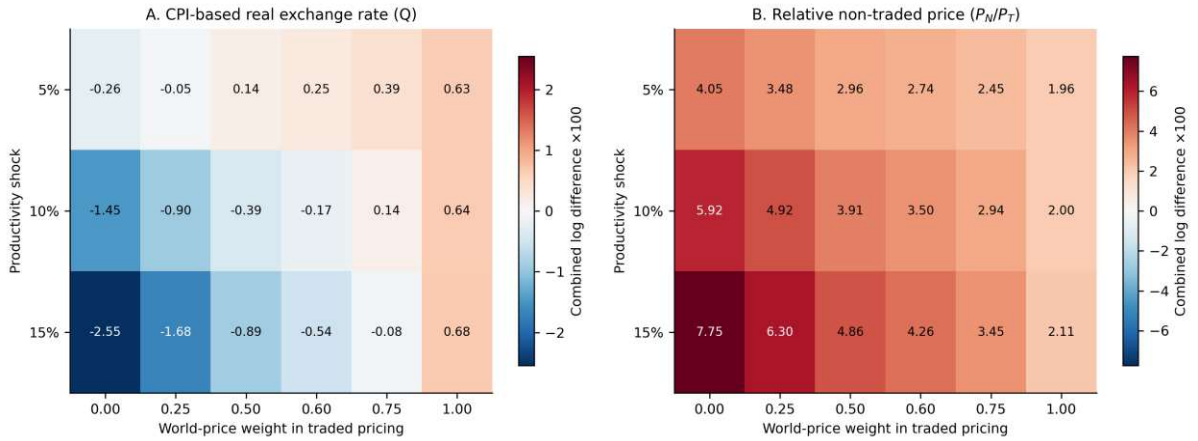


Figure 7. Joint pricing–shock boundary at five years. Each cell reports the combined reform-and-productivity effect relative to baseline, averaged over 32 paired seeds. The left panel shows Q; the right panel shows $p = P_N/P_T$.

Demand closures locate the source of the real-side contraction. An investment response raises real GDP by 0.519 log percent after productivity, a higher export-price elasticity raises it by 1.090, and productivity-linked income expectations raise it by 2.414. Their joint closure raises output by 4.083 and lowers unemployment by 1.034 percentage points, while Q still falls by 0.990. Stronger demand can

overturn the central real-side contraction without removing CPI-based depreciation. Cost timing and investment–capacity closures likewise change employment more than either price sign. Online Resource 1 reports these paths, financing comparisons, and stock diagnostics.

7. Discussion

7.1 Household states, demand, and aggregate adjustment

Household attributes matter through the rules that connect them to employment and demand. State-dependent matching allocates jobs; registration conversion changes access; repeated unemployment can induce return migration. Contributions and consumption behavior then change disposable income and expenditure. The attribute counterfactual alters output and unemployment responses within this interaction structure, even though the signs of the price responses remain unchanged. The paired comparisons quantify these changes while the price divergence persists.

The channel experiments locate a second distinction. In the central social-insurance experiment, contribution costs account for most of the price-level effect, while the precautionary-saving response has a smaller role. Financing arrangements change fiscal and employment outcomes. The direction of a price response therefore cannot summarize the effects of insurance reform on households and firms.

Demand feedback determines how productivity becomes employment and output. Higher productivity lowers labor requirements at given sales. Lower employment reduces expected income and subsequent consumption under the central rules. Investment, exports, and income-expectation responses can reverse this real-side contraction. Domestic traded-price adjustment still allows CPI-based depreciation alongside relative-non-traded-price appreciation. The model thus separates household adjustment from the conditions governing its price consequences.

7.2 Relation to Balassa–Samuelson and rural-led appreciation

The model connects the Balassa–Samuelson mechanism to domestic traded-price adjustment. Public data show positive but unstable co-movement between relative productivity and relative prices. In the central simulation, weak cross-sector wage transmission leaves non-traded prices almost unchanged after the productivity shock, while traded prices decline. This combination explains the opposing responses of the two price measures over the five-year horizon.

Menzies et al. (2016) study a historical decomposition in which rural output is largely non-traded and mobile capital complements labor leaving that sector. Our rural production enters the traded account, our non-traded sector consists of urban services, and investment does not accumulate into productive capital in the central closure. Their relative-price appreciation and our CPI-based depreciation are different objects. Menzies and Xiao (2012) also note that migration into urban non-traded services can attenuate or reverse the aggregate non-traded-price response. That result highlights the importance of distinguishing the sectors that receive migrating workers.

Assigning 25% rather than 100% of rural output to the traded account leaves combined Q at −0.406, compared with −0.388 centrally, while p rises by 4.048 rather than 3.911. Combined unemployment rises by 2.583 percentage points rather than falling by 0.261. As in the homogeneity experiment, labor-market adjustment changes more than the direction of the two price responses. The approximately one-

third rural-led contribution in Menzies et al. belongs to a 2000–2013 decomposition with a different model and price measure; its magnitude is therefore not directly comparable with these five-year responses.

7.3 Scope and empirical limitations

The public-data analysis is descriptive. WIOD ends in 2014, sectoral tradability is approximate, the employment series has a level shift, and compensation per person engaged mixes employment concepts. Migrant wage means are not composition adjusted. The absence of micro-level joint distributions prevents estimation of migration, consumption, and wage equations, and the time-series regressions provide no exogenous reform or productivity instrument.

The model deliberately limits its scope. Capital user costs and autonomous investment are fixed calibration devices in the central closure. There is no housing market, regional dispersion, detailed skill production, forward-looking expectations, portfolio capital flow, or interest-parity condition. Exchange-rate alternatives are reduced-form accounting closures. Rural household production enters the traded account but is not a detailed agricultural sector. The five-year window concerns medium-run transition dynamics; ten-year paths are not steady-state forecasts because net foreign assets and bank equity continue to evolve.

Gini coefficients summarize simulated household outcomes and can be sensitive to state composition and the treatment of inactive or zero-income households. State-panel effects compare contemporaneous groups rather than fixed cohorts. Homogenization removes skill and continuous-attribute dispersion but preserves initial states and all behavioral equations; it is not a full representative-agent model. Separately homogenizing skills and citizenship attributes, or also harmonizing state-dependent rules, would distinguish additional sources of heterogeneity.

Most household and wage parameters remain normalizations or exploratory values. The reported intervals quantify seed-related precision conditional on these values. Sensitivity experiments examine selected alternatives but do not supply a probability distribution over behavioral parameters or model structures. Future empirical work should estimate behavioral equations with linked household, employer, and administrative data. Model extensions can then examine regional labor markets, housing, and endogenous capital accumulation without losing the accounting and distribution audit developed here.

8. Conclusion

Household state transitions connect hukou reform to aggregate employment and demand. Registration-dependent matching and conversion, return migration, contributions, and consumption give the three reform margins different roles. Within this structure, homogenizing initial skills and continuous citizenship attributes raises the mean output response to productivity and reduces the unemployment increase. The comparison shows that these attribute differences affect real adjustment even when the signs of the price responses are unchanged.

The social-insurance ablations identify contribution costs as the main source of its price-level effect in the central calibration, with a smaller role for precautionary saving. State transitions and distributional measures trace how the reform changes household outcomes. The exchange-rate

divergence follows from domestic traded-price adjustment and the price-index relationship; it is one open-economy consequence of the model's pricing and demand rules.

These results are conditional mechanisms. Empirical estimates of migration, matching, return, and consumption rules would allow the model to assess how the channels operate in observed reforms. The present comparisons establish which household attributes and behavioral channels account for the simulated aggregate responses.

Use of AI-assisted tools

AI-assisted tools, including Kimi (Moonshot AI) and Codex (OpenAI), supported code editing, analysis-script preparation, and language revision. Codex was also used to check paired simulation contrasts and bibliographic metadata. The authors retain responsibility for verifying the analyses, references, and text, and for the final content of the manuscript.

Data and code availability

The World Bank, WIOD, BIS, and NBS data used in this study are publicly available from the sources listed in the references. The accompanying replication package contains the derived datasets, source URLs and access dates, model and analysis code, experiment specifications, quarterly and household-state ledgers, and validation reports. No confidential individual-level data are used. The replication files are supplied as accompanying material for review.

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