Online Supplement to
"A Spatiotemporal Equilibrium Model of Migration and Housing Interlinkages"

by

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S1 Supplementary simulation results

S1.1 Migration flows between U.S. states during 2000-2014

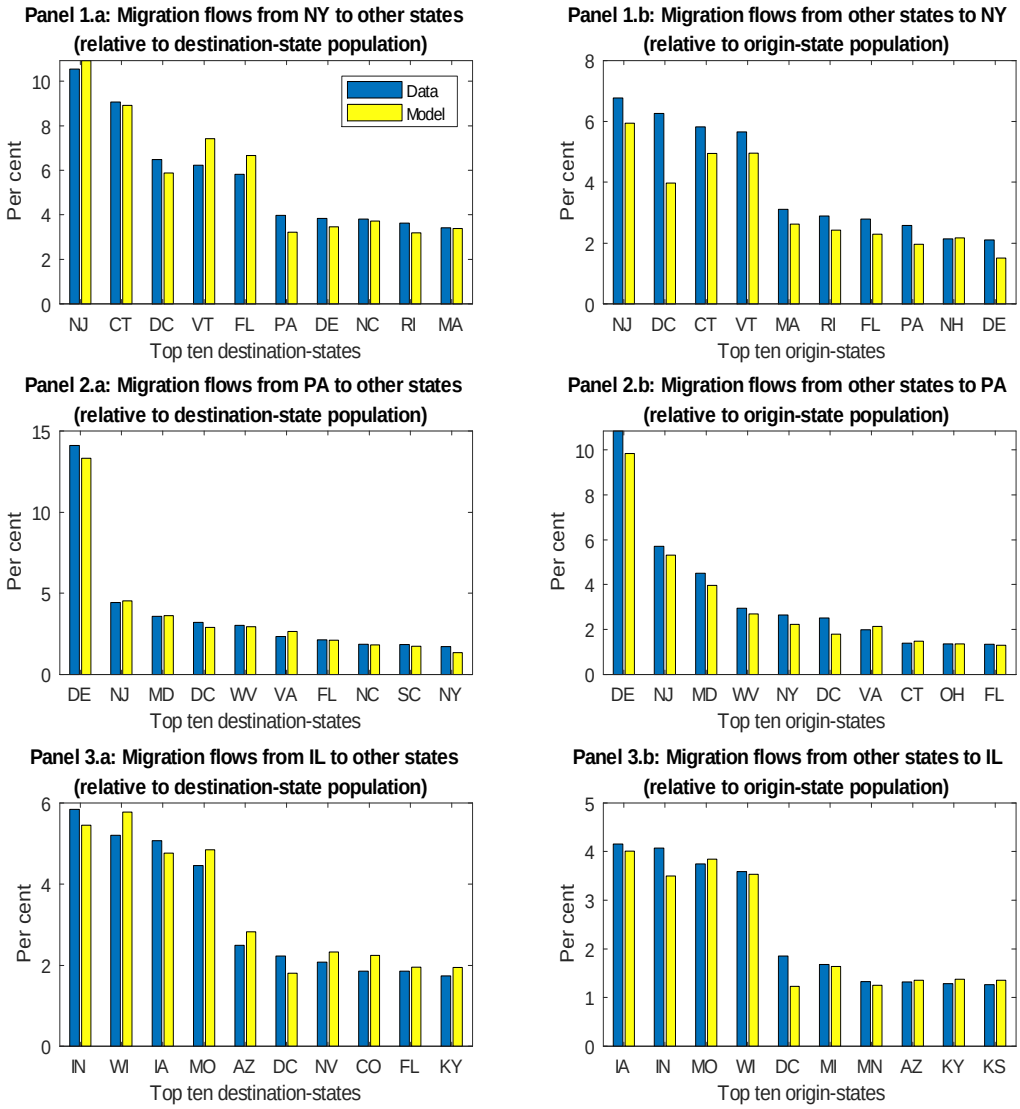


Figure S1: Bilateral migration flows between U.S. states during the evaluation sample (2000-2014)

Notes: Panel 1.a shows the realized and simulated accumulated migration flows from New York to other states during the period 2000-2014 relative to destination-state population in 2014. Only the ten destination-states with the largest migration flows from New York (relative to their own population) are displayed. Panel 1.b shows the realized and simulated accumulated migration flows from other states to New York relative to origin-state population. Similarly, Panels 2.a and 2.b show the bilateral migration flows between Pennsylvania and other U.S. states, and Panels 3.a and 3.b show the bilateral migration flows between Illinois and other U.S. states.

S1.2 Increasing land supply in California: a counterfactual exercise

In this sub-section, we consider the application of the model to study the effects of local land-use regulations on regional house prices and spatial population allocation. This exercise is complementary to the California land-use deregulation experiment carried out by Herkenhoff et al. (2018). These authors emphasize the positive impact of land-use deregulation in California on the national output through population reallocation, whilst our analysis focusses on the spatiotemporal patterns of the population reallocation resulting from the land-use deregulation. It is shown that the population reallocation towards California is mainly from nearby states, while the population reallocation from distant states to California are both smaller in magnitude and slower in speed.

We consider exogenous increases in the annual supply of new land in California by 10 per cent in each year from 2000 to 2014. Increasing the annual new land supply in California by a different rate will not qualitatively change our main findings. We simulate the model using the counterfactual baseline state-level land supply values.

Table S1 gives the impact of increasing land supplies on house prices, population and output in California in 2014. Increasing land supply in California leads to a decline in house prices and housing rents by 3.8 and 1.5 per cent respectively in 2014, and the net outward migration from California decreases by 0.7 per cent, which in turn raises California's population and output in 2014 by 0.06 and 0.04 per cent, respectively.

Table S1: Effects of increasing land supply in California

	California				
	House price in 2014	Housing rent in 2014	Net outward migration during 2000-2014	Population in 2014	Output in 2014
Baseline	273.6 (Thousands $)	11.64 (Thousands $)	2.6099 (Millions)	29.65 (Millions)	0.8772 (Trillions $)
Counterfactually increase the new land supply in CA (per cent change from the baseline values)	-3.8229	-1.4618	-0.6559	0.0621	0.0443

Notes: This table shows the impact of a 10 per cent exogenous increase in the annual flows of new land released in California in each year from 2000 to 2014. The first row reports the results from the baseline simulation in Section 7 of the main paper. The second row reports the results from the counterfactual simulation expressed as per cent change from the counterpart values in the baseline simulation.

Figure S2 shows the counterfactual changes in U.S. population by states in 2004, 2009 and 2014, in response to the counterfactual increases in California land supplies. In each panel, the first bar corresponds to California, and the rest of the bars correspond to other U.S. states, arranged in order of their distance from California. As can be seen, first the percentage change of population tends to be larger for states that are geographically close to California, and smaller for the distant states. Second, since land-use deregulation increases stock of housing only very gradually, it takes a long time for the effects of deregulation to show up in

population reallocation. As shown in Panel 1, in 2004, only the population changes in the nearby states are non-negligible. Third, as shown in Figure S3, the counterfactual changes of the output of U.S. states have a similar spatiotemporal pattern. Finally, population reallocation towards California leads to an increase in California output, and at the same time a decrease in the output of the rest of the U.S. states. Since California has higher labor productivity than other U.S. states, the reallocation of population towards California leads to a net increase in the national output. See Figure S5.

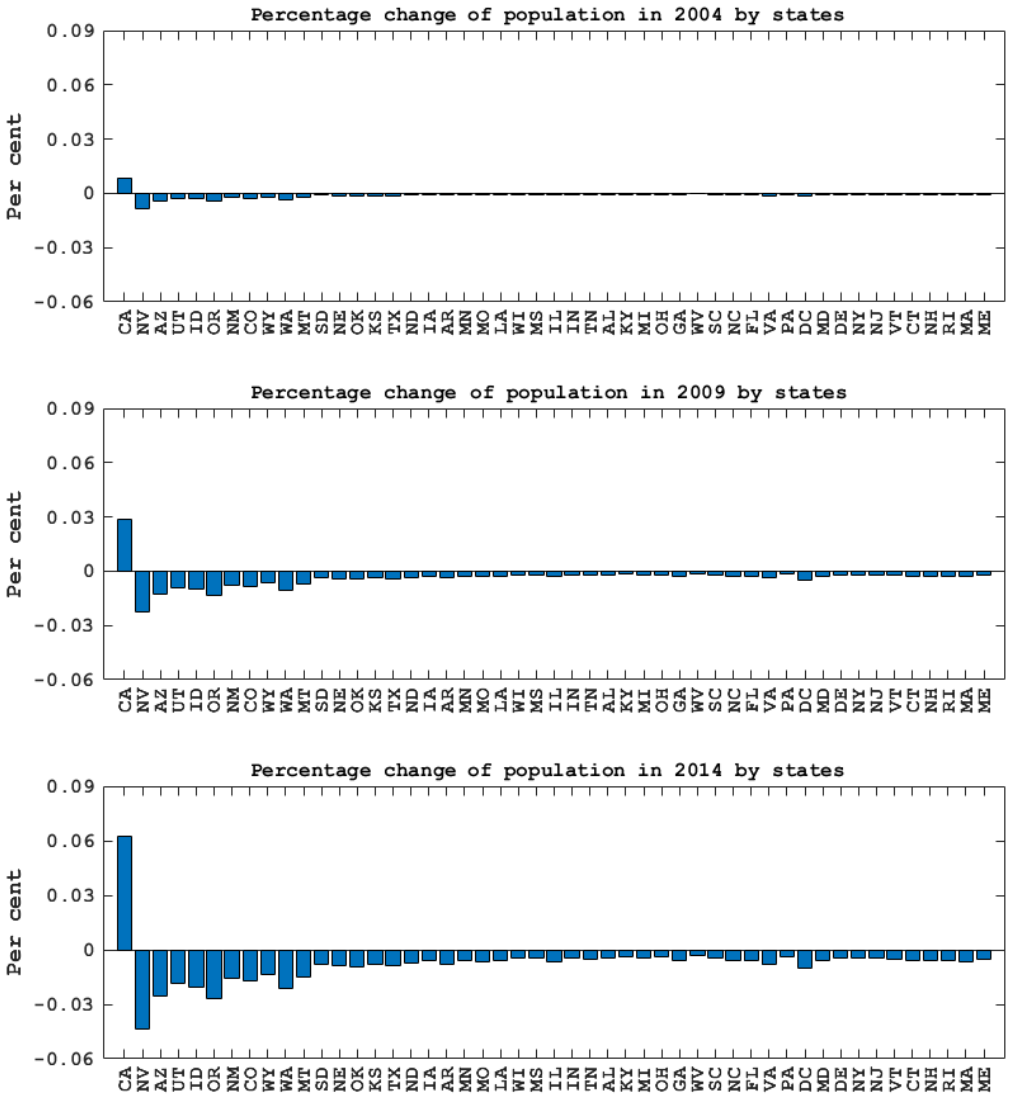


Figure S2: Effects of increasing land supplies in California on population by states

Notes: Each panel shows the percentage changes of population by states for the year noted above in response to a 10 per cent exogenous increase in the annual flows of new land released in California in each year from 2000 to 2014. States are ordered ascendingly by their distance from California.

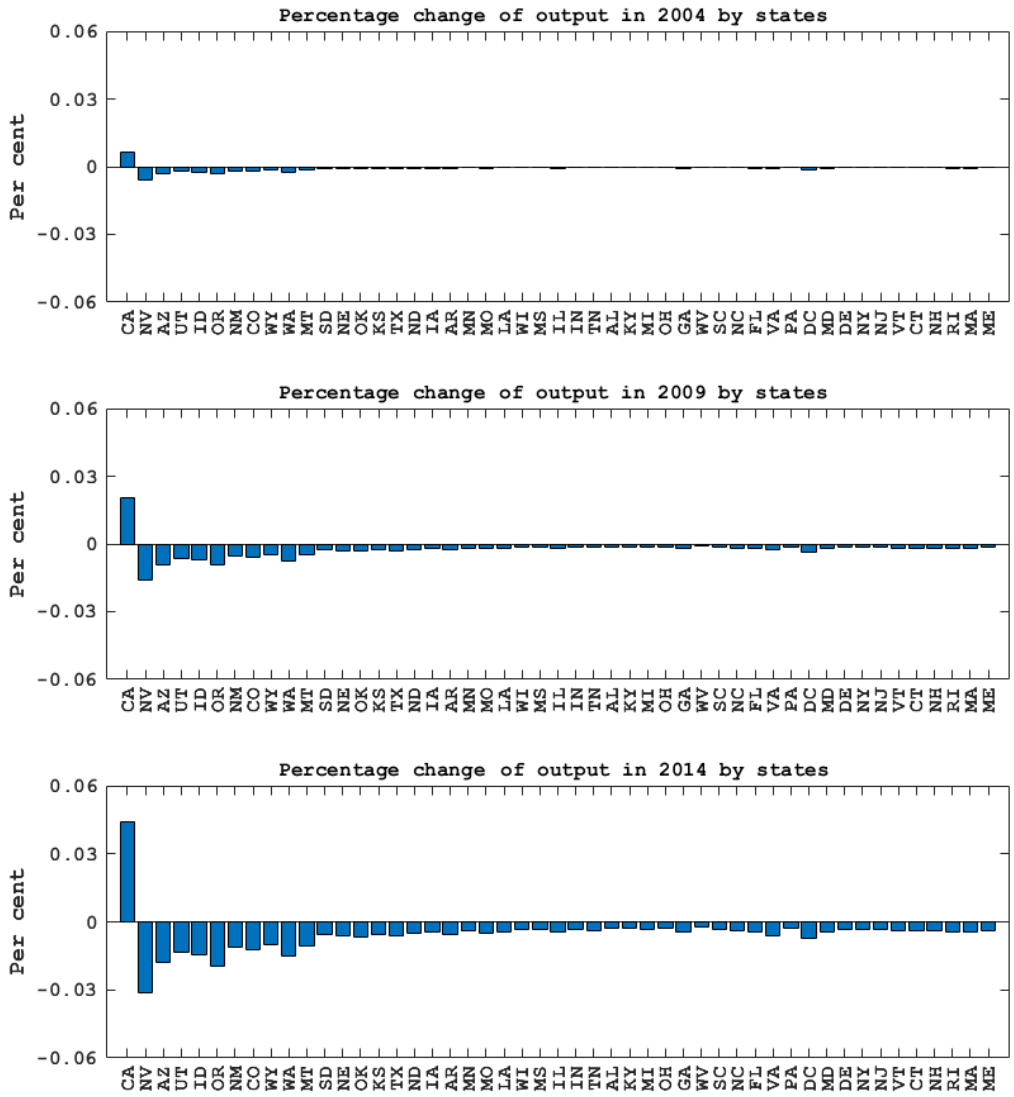


Figure S3: Effects of increasing land supplies in California on output by states

Notes: Each panel shows the percentage changes of output by states for the year noted above in response to a 10 per cent exogenous increase in the annual flows of new land released in California in each year from 2000 to 2014. States are ordered ascendingly by their distance from California.

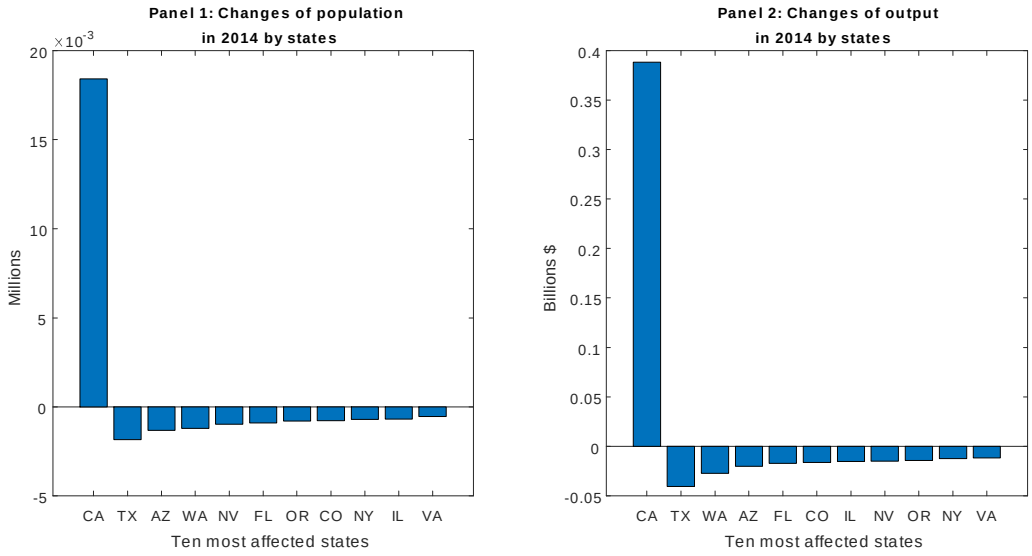


Figure S4: Effects of increasing land supplies in California on population and output by states

Notes: Panels 1 and 2 show respectively the absolute changes of population and output in 2014 by states in response to a 10 per cent exogenous increase in the annual flows of new land released in California in each year from 2000 to 2014. In each panel, only California and the ten most affected states (in terms of the magnitudes of the counterfactual changes) are displayed.

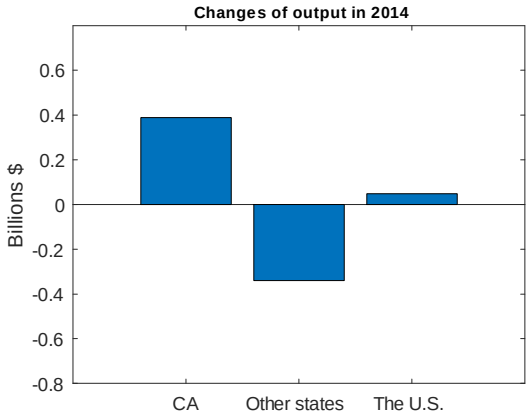
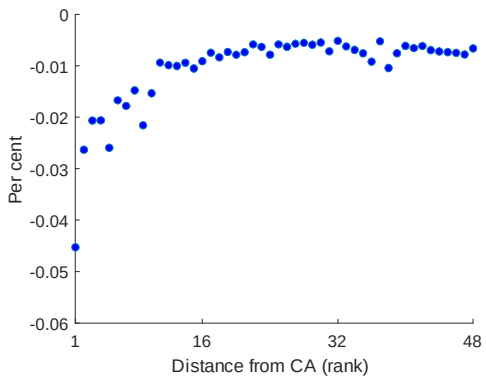


Figure S5: Effects of increasing land supplies in California on U.S. output

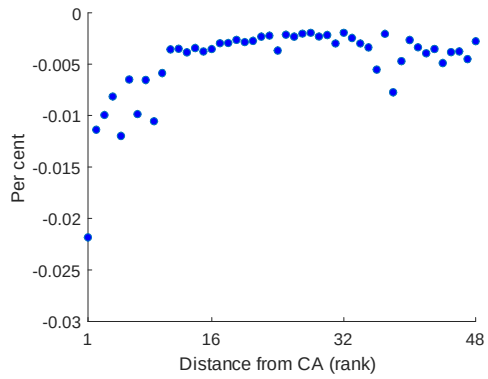
Notes: This figure shows the absolute changes of output in 2014 for California, all U.S. states except for California, and the U.S. in response to a 10 per cent exogenous increase in the annual flows of new land released in California in each year from 2000 to 2014.

S1.3 Spatiotemporal impulse responses

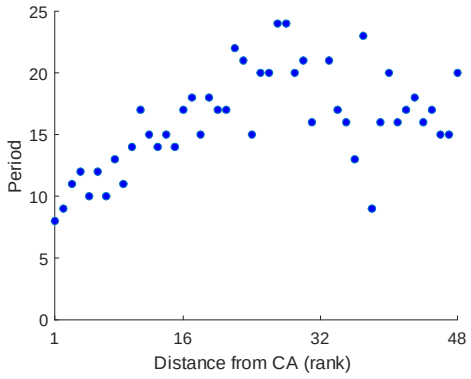
S1.3.1 Responses to regional shocks in California



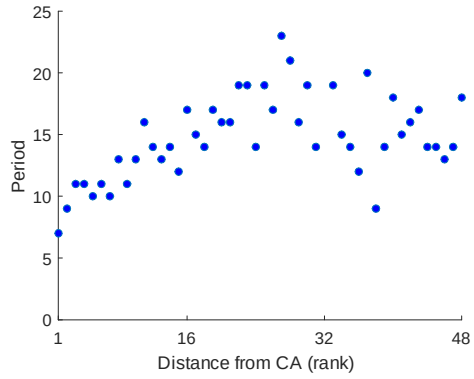
Panel 1.a: Extreme values of the responses of log population (by states)



Panel 1.b: Extreme values of the responses of log house price-to-income ratios (by states)



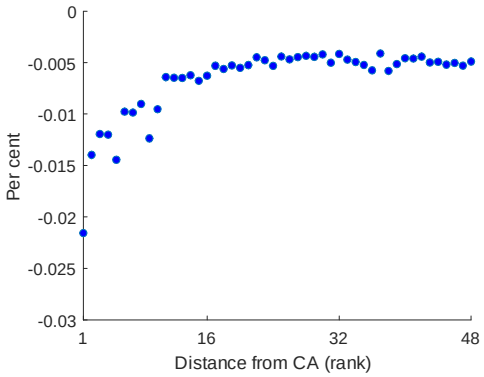
Panel 2.a: Periods in which the responses of log population reach their extreme values (by states)



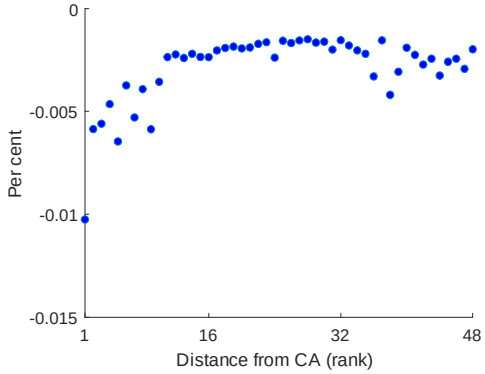
Panel 2.b: Periods in which the responses of log house price-to-income ratios reach their extreme values (by states)

Figure S6: Size and speed of responses of U.S. states (except for California) to a positive productivity shock in California

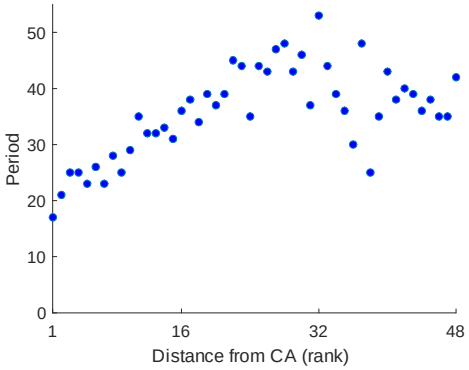
Notes: In each panel, a dot represents a state. In Panels 1.a and 1.b, the vertical axis corresponds to the extreme value of a state's response after a one per cent positive productivity shock in California, and in Panels 2.a and 2.b, the vertical axis corresponds to period in which a state's response reaches its extreme value. States are ordered ascendingly by their distance from California, and the horizontal axis corresponds to a state's rank in terms of distance from California.



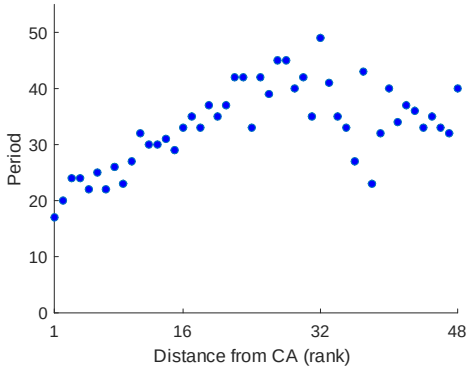
Panel 1.a: Extreme values of the responses of log population (by states)



Panel 1.b: Extreme values of the responses of log house price-to-income ratios (by states)



Panel 2.a: Periods in which the responses of log population reach their extreme values (by states)



Panel 2.b: Periods in which the responses of log house price-to-income ratios reach their extreme values (by states)

Figure S7: Sizes and speed of responses of U.S. states (except for California) to a positive land-supply shock in California

Notes: In each panel, a dot represents a state. In Panels 1.a and 1.b, the vertical axis corresponds to the extreme value of a state's response after a ten per cent positive land-supply shock in California, and in Panels 2.a and 2.b, the vertical axis corresponds to period in which a state's response reaches its extreme value. States are ordered ascendingly by their distance from California, and the horizontal axis corresponds to a state's rank in terms of distance from California.

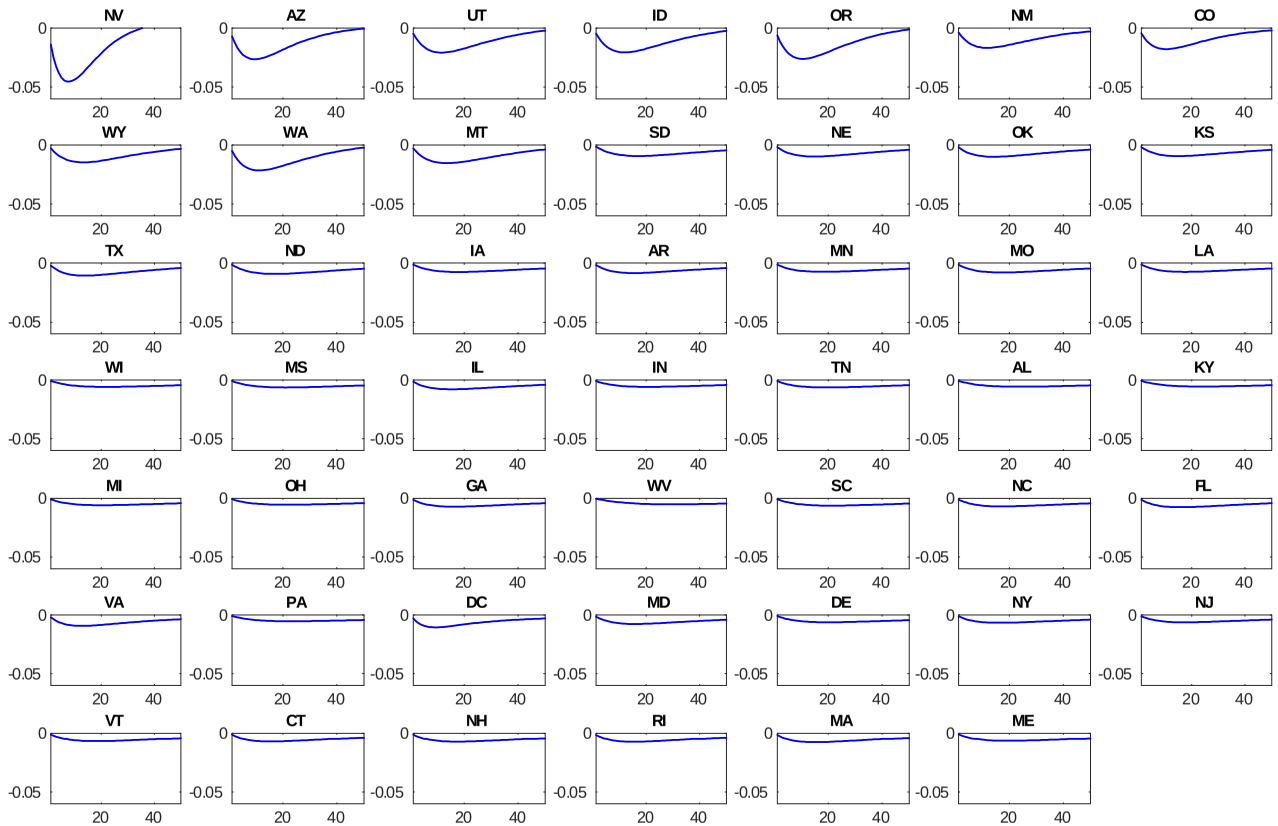


Figure S8: Spatiotemporal responses of log population of U.S. states to a positive productivity shock in California

Notes: This figure shows responses of log population of U.S. states (except for California) to a one per cent positive shock to labor productivity in California. States are ordered by their distance from California. The unit on the horizontal axis is year. The unit on the vertical axis is per cent.

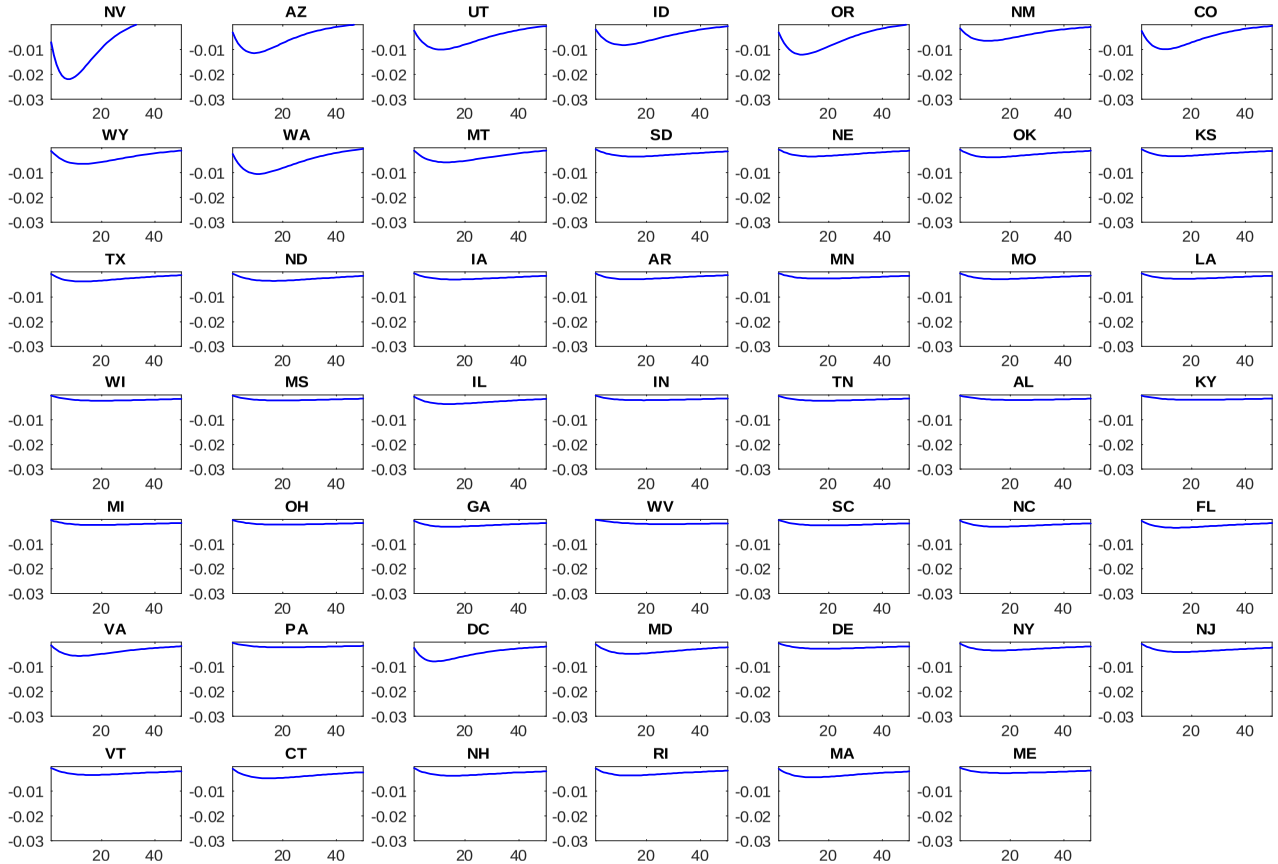


Figure S9: Spatiotemporal responses of log house price-to-income ratios of U.S. states to a positive productivity shock in California

Notes: This figure shows responses of log house price-to-income ratios of U.S. states (except for California) to a one per cent positive shock to labor productivity in California. States are ordered by their distance from California. The unit on the horizontal axis is year. The unit on the vertical axis is per cent.

S1.3.2 Responses to regional shocks in Texas

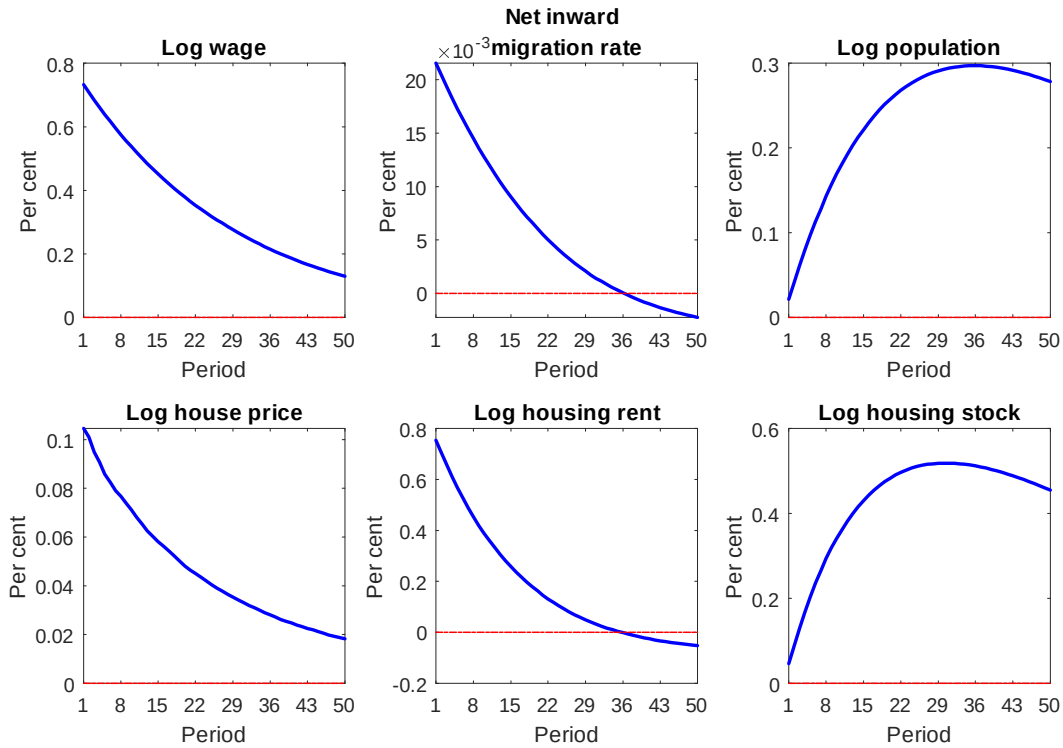


Figure S10: Reponses of variables in Texas to a positive productivity shock in Texas

Notes: This figure shows responses of log wage rate, net inward migration rate (i.e., the ratio of net inward migration to local population), log population, log house price, log housing rent and log housing stock in Texas to a one per cent positive shock to labor productivity in Texas.

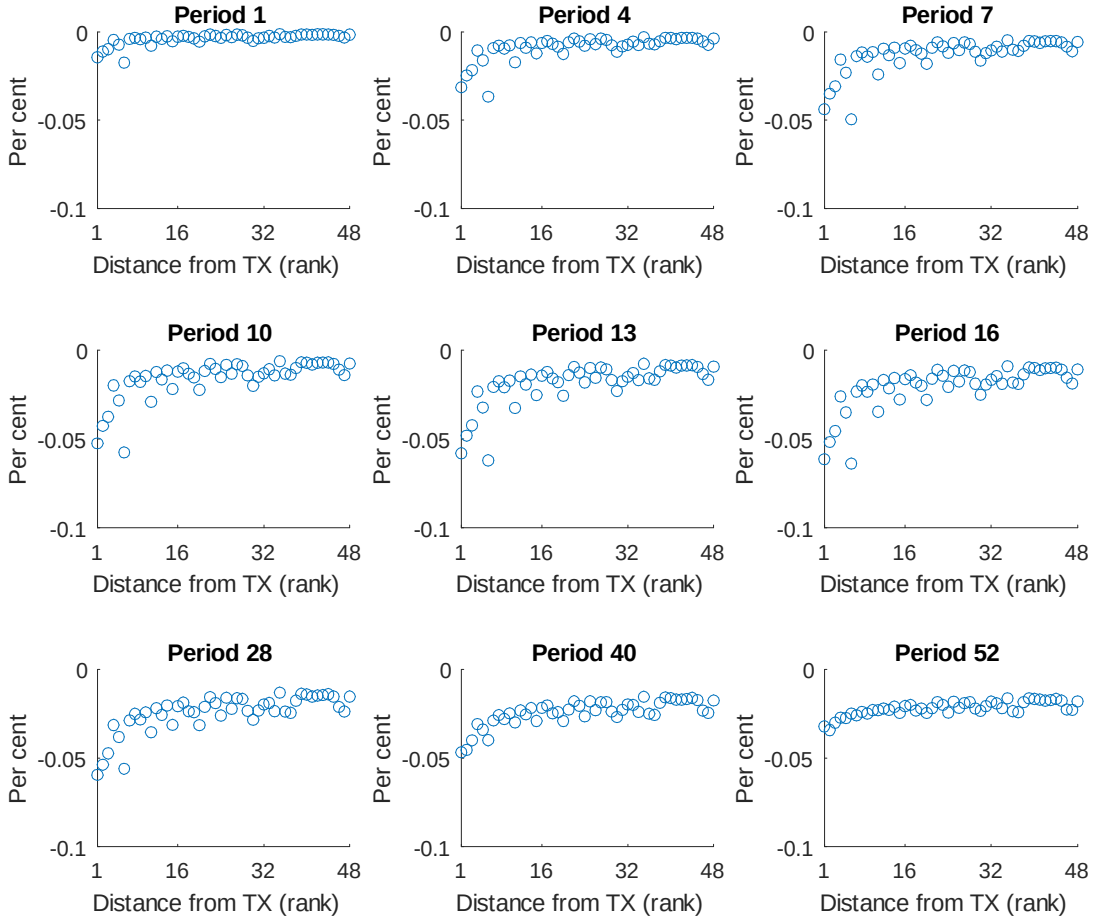


Figure S11: Spatiotemporal responses of log population of U.S. states to a positive productivity shock in Texas

Notes: Each panel shows responses of log population of U.S. states (except for Texas) to a one per cent positive shock to labor productivity in Texas, for the period noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from Texas, and the horizontal axis corresponds to a state's rank in terms of distance from Texas.

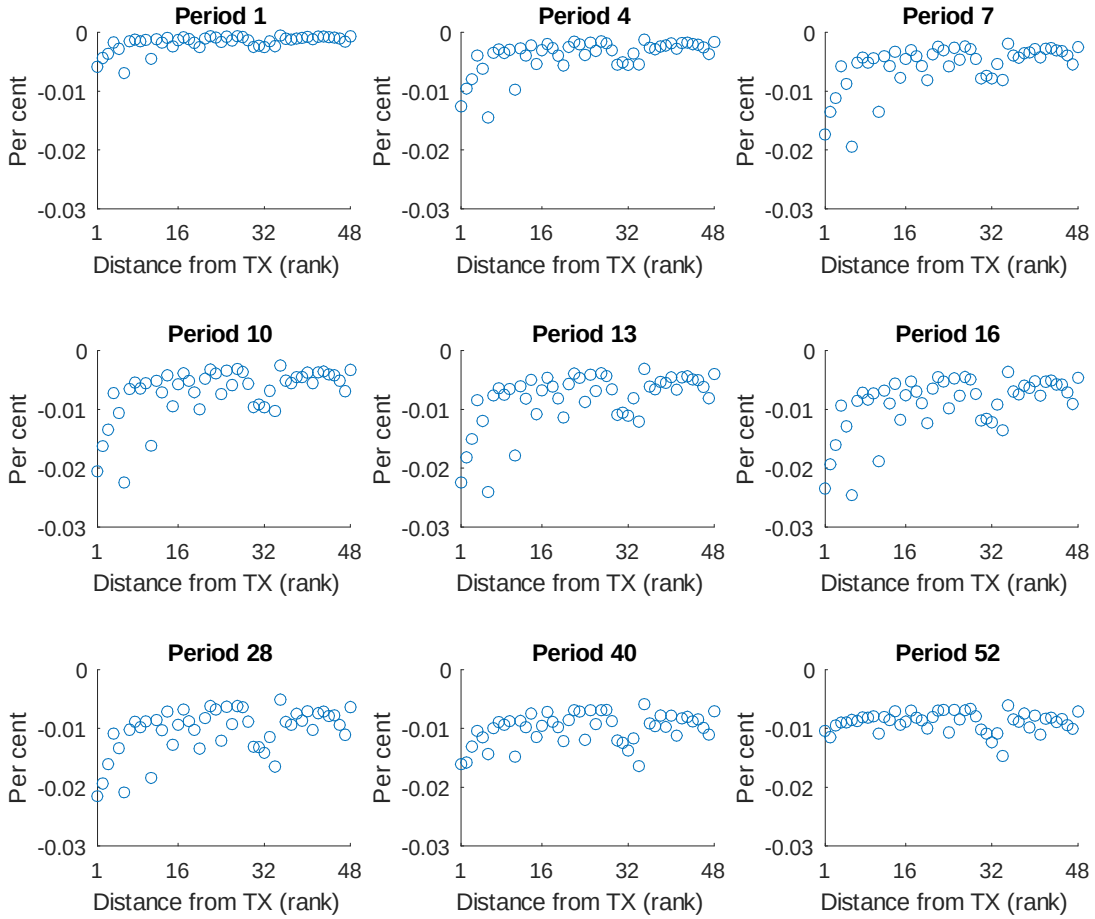


Figure S12: Spatiotemporal responses of log house price-to-income ratios of U.S. states to a positive productivity shock in Texas

Notes: Each panel shows responses of log house price-to-income ratios of U.S. states (except for Texas) to a one per cent positive shock to labor productivity in Texas, for the period noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from Texas, and the horizontal axis corresponds to a state's rank in terms of distance from Texas.

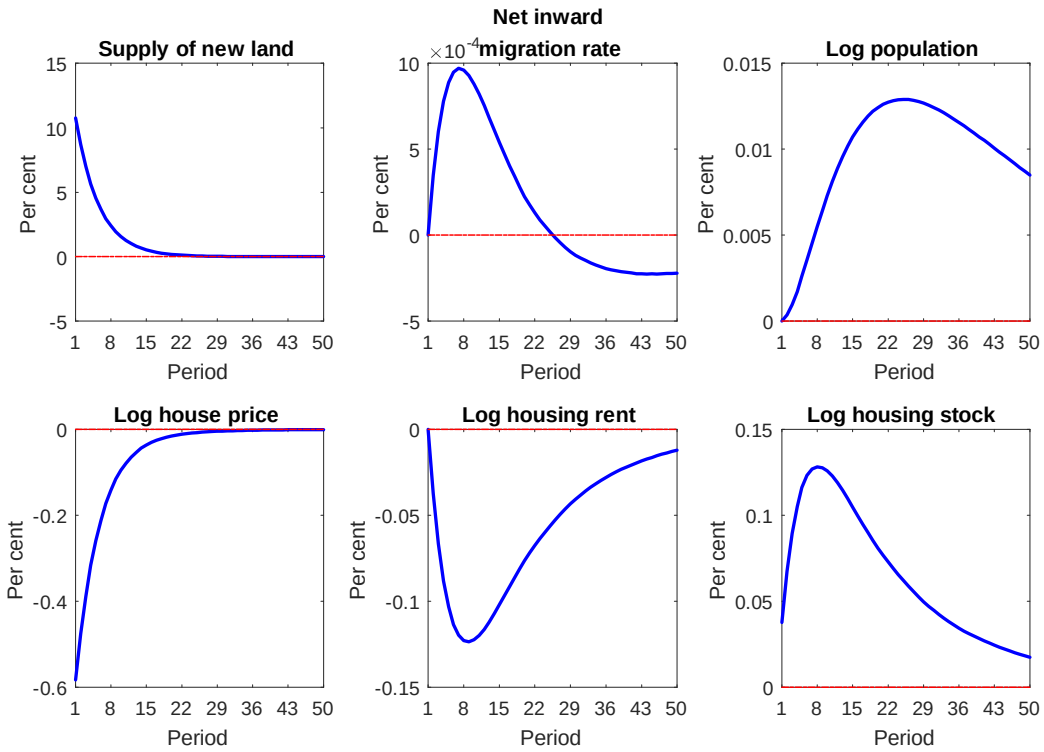


Figure S13: Reponses of variables in Texas to a positive land-supply shock in Texas

Notes: This figure shows responses of log wage rate, net inward migration rate (i.e., the ratio of net inward migration to local population), log population, log house price, log housing rent and log housing stock in Texas to a ten per cent positive shock to the annual supply of new land in Texas.

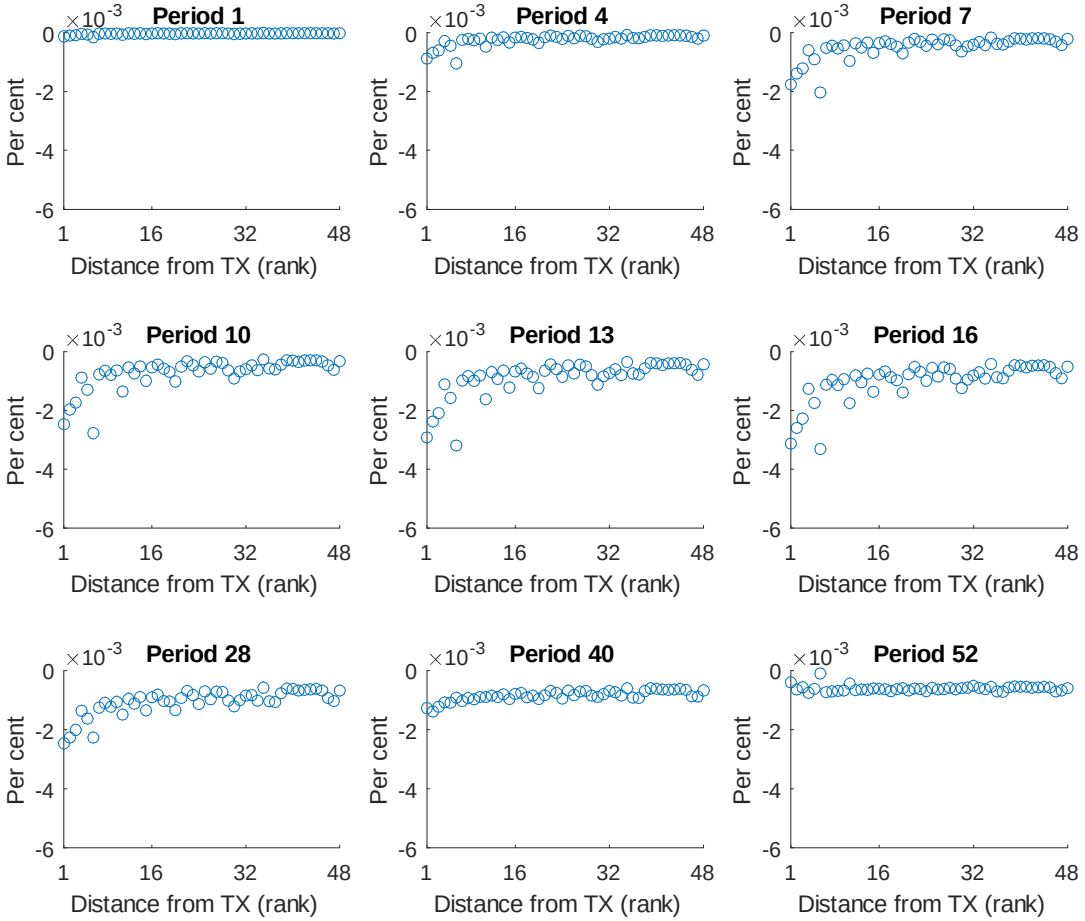


Figure S14: Spatiotemporal responses of log population of U.S. states to a positive land-supply shock in Texas

Notes: Each panel shows responses of log population of U.S. states (except for Texas) to a ten per cent positive shock to the annul supply of new land in Texas, for the period noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from Texas, and the horizontal axis corresponds to a state's rank in terms of distance from Texas.

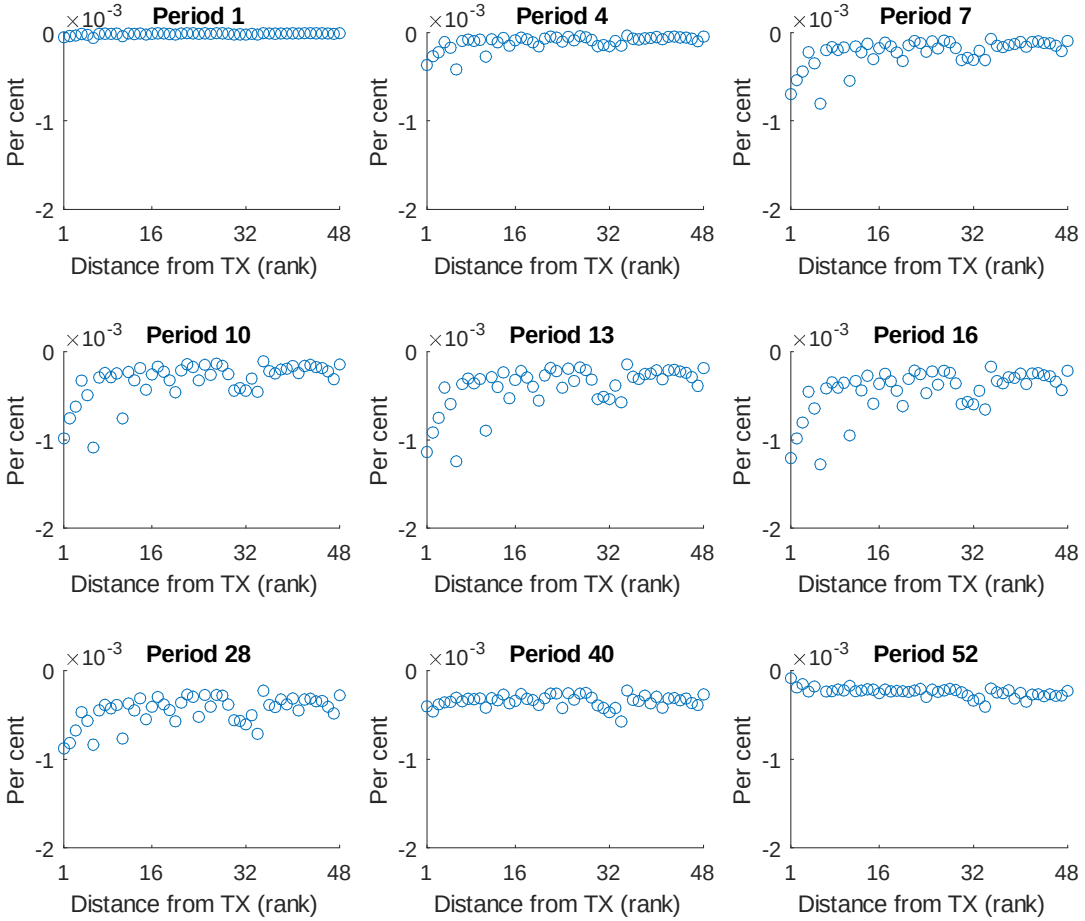


Figure S15: Spatiotemporal responses of log house price-to-income ratios of U.S. states to a positive land-supply shock in Texas

Notes: Each panel shows responses of log house price-to-income ratios of U.S. states (except for Texas) to a ten per cent positive shock to the annul supply of new land in Texas, for the period noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from Texas, and the horizontal axis corresponds to a state's rank in terms of distance from Texas.

S1.3.3 Responses to regional shocks in Florida

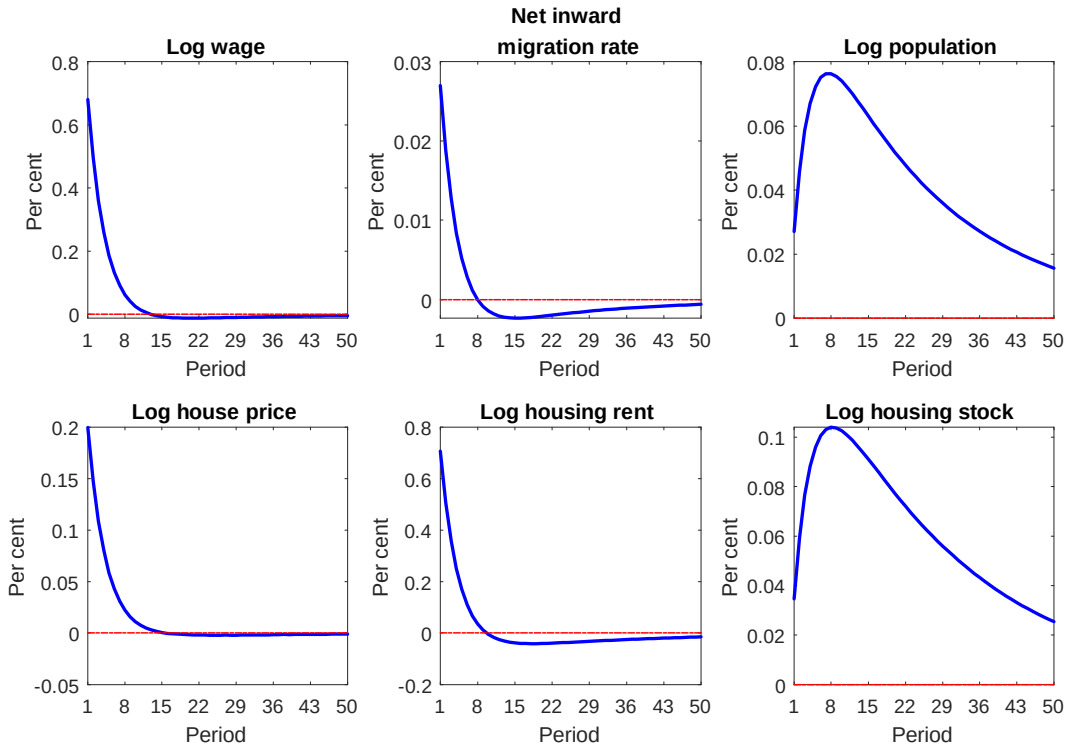


Figure S16: Reponses of variables in Florida to a positive productivity shock in Florida

Notes: This figure shows responses of log wage rate, net inward migration rate (i.e., the ratio of net inward migration to local population), log population, log house price, log housing rent and log housing stock in Florida to a one per cent positive shock to labor productivity in Florida.

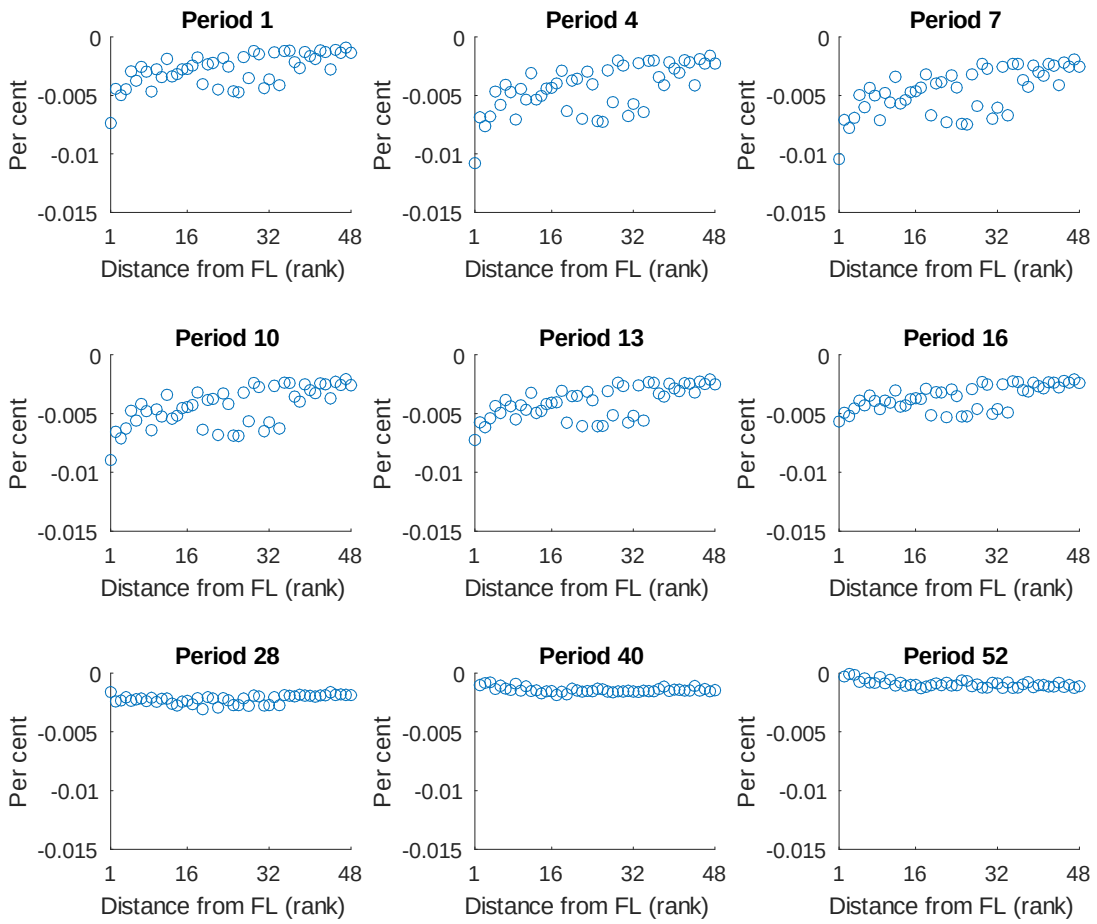


Figure S17: Spatiotemporal responses of log population of U.S. states to a positive productivity shock in Florida

Notes: Each panel shows responses of log population of U.S. states (except for Florida) to a one per cent positive shock to labor productivity in Florida, for the period noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from Florida, and the horizontal axis corresponds to a state's rank in terms of distance from Florida.

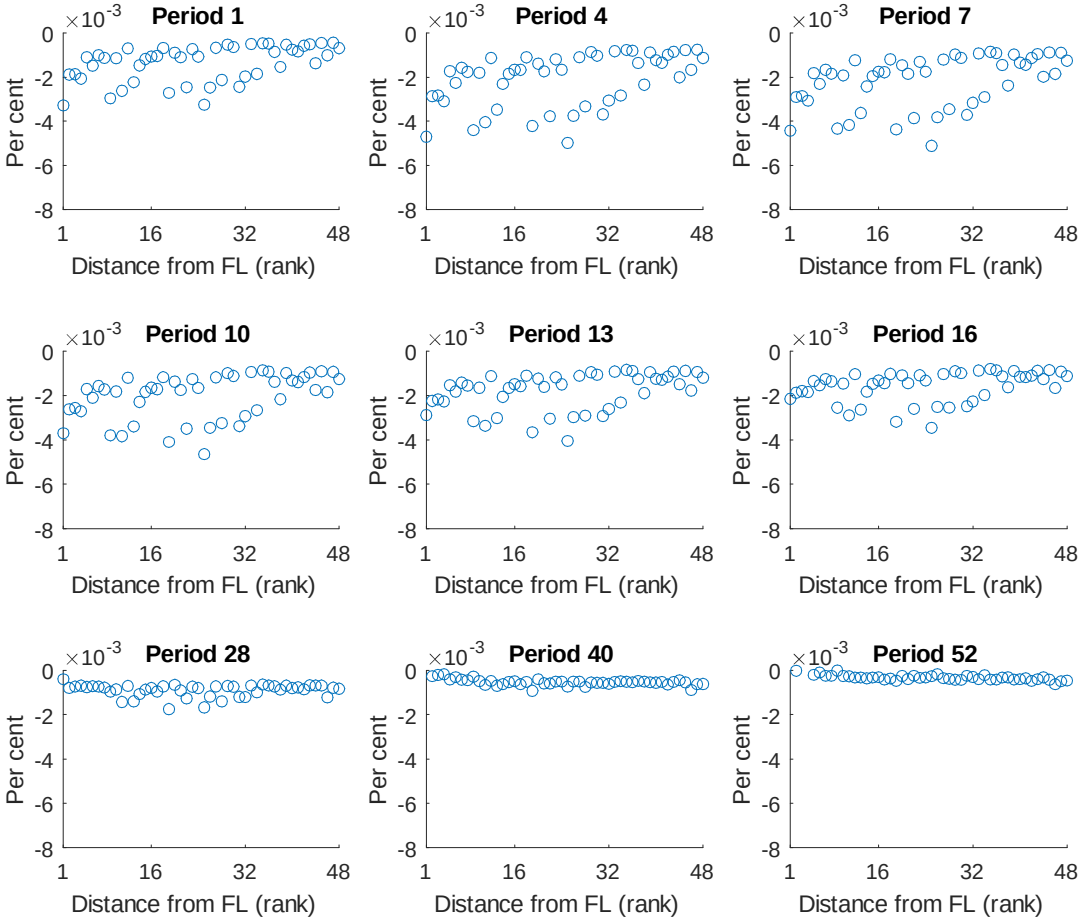


Figure S18: Spatiotemporal responses of log house price-to-income ratios of U.S. states to a positive productivity shock in Florida

Notes: Each panel shows responses of log house price-to-income ratios of U.S. states (except for Florida) to a one per cent positive shock to labor productivity in Florida, for the period noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from Florida, and the horizontal axis corresponds to a state's rank in terms of distance from Florida.

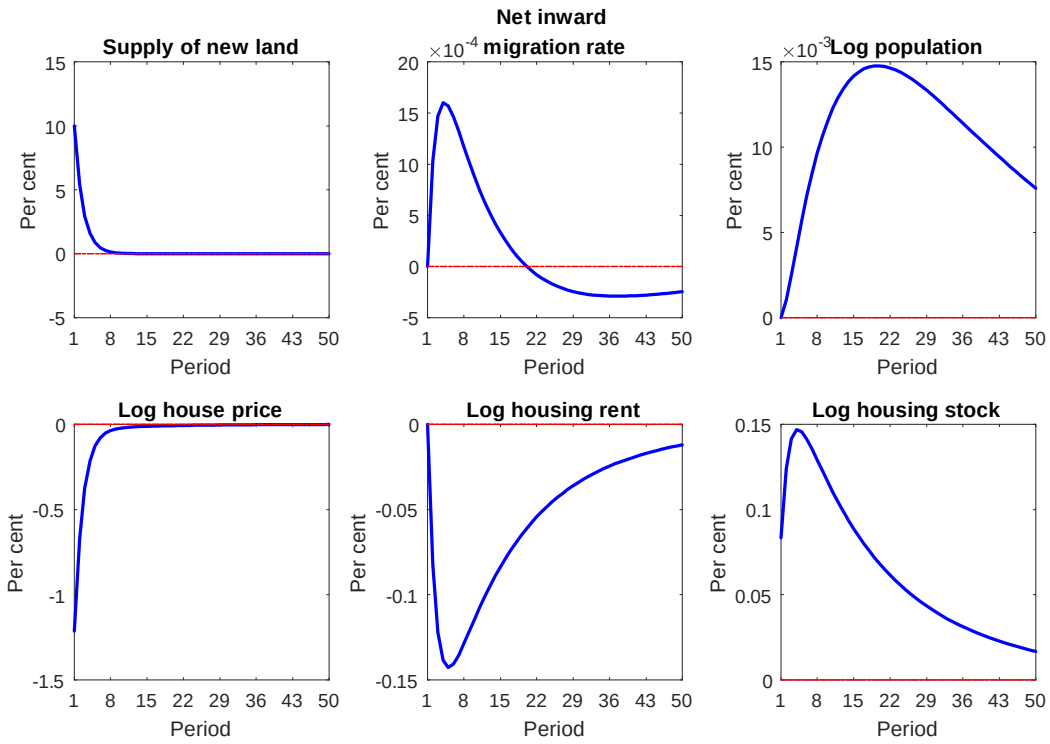


Figure S19: Reponses of variables in Florida to a positive land-supply shock in Florida

Notes: This figure shows responses of log wage rate, net inward migration rate (i.e., the ratio of net inward migration to local population), log population, log house price, log housing rent and log housing stock in Florida to a ten per cent positive shock to the annual supply of new land in Florida.

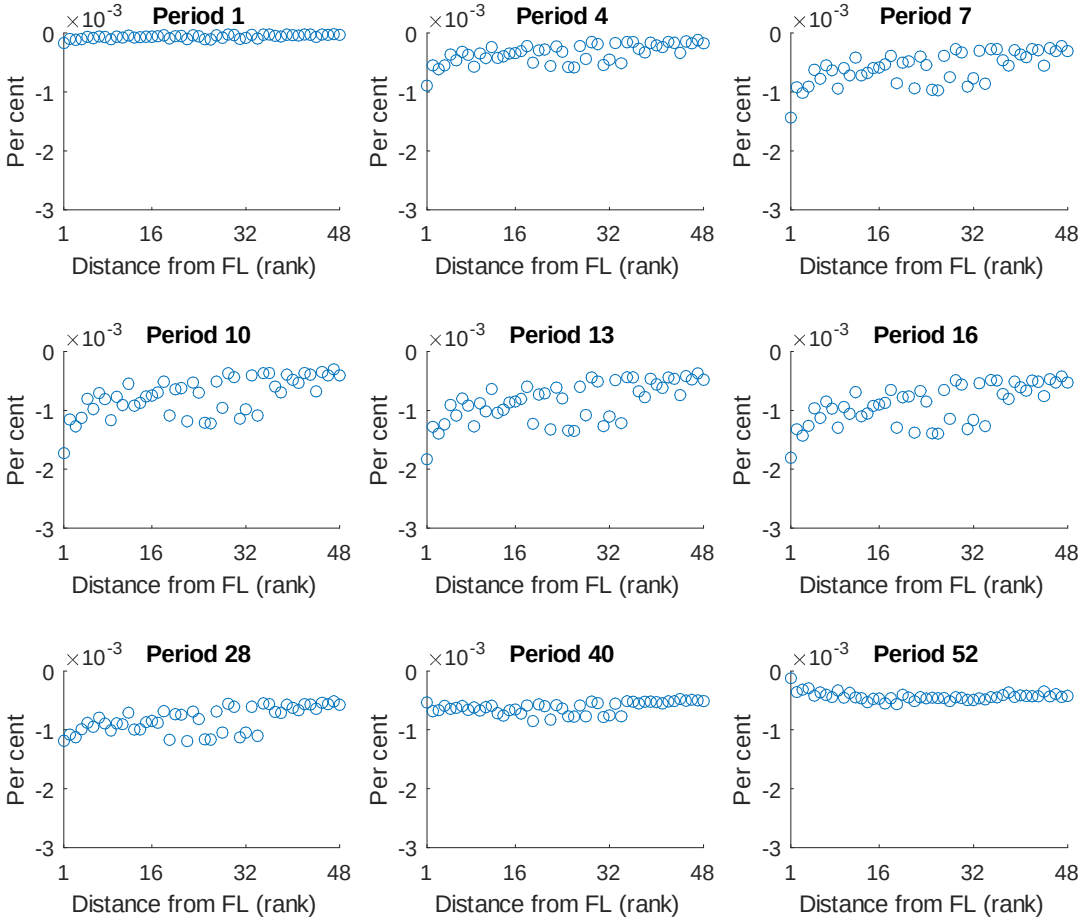


Figure S20: Spatiotemporal responses of log population of U.S. states to a positive land-supply shock in Florida

Notes: Each panel shows responses of log population of U.S. states (except for Florida) to a ten per cent positive shock to the annul supply of new land in Florida, for the period noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from Florida, and the horizontal axis corresponds to a state's rank in terms of distance from Florida.

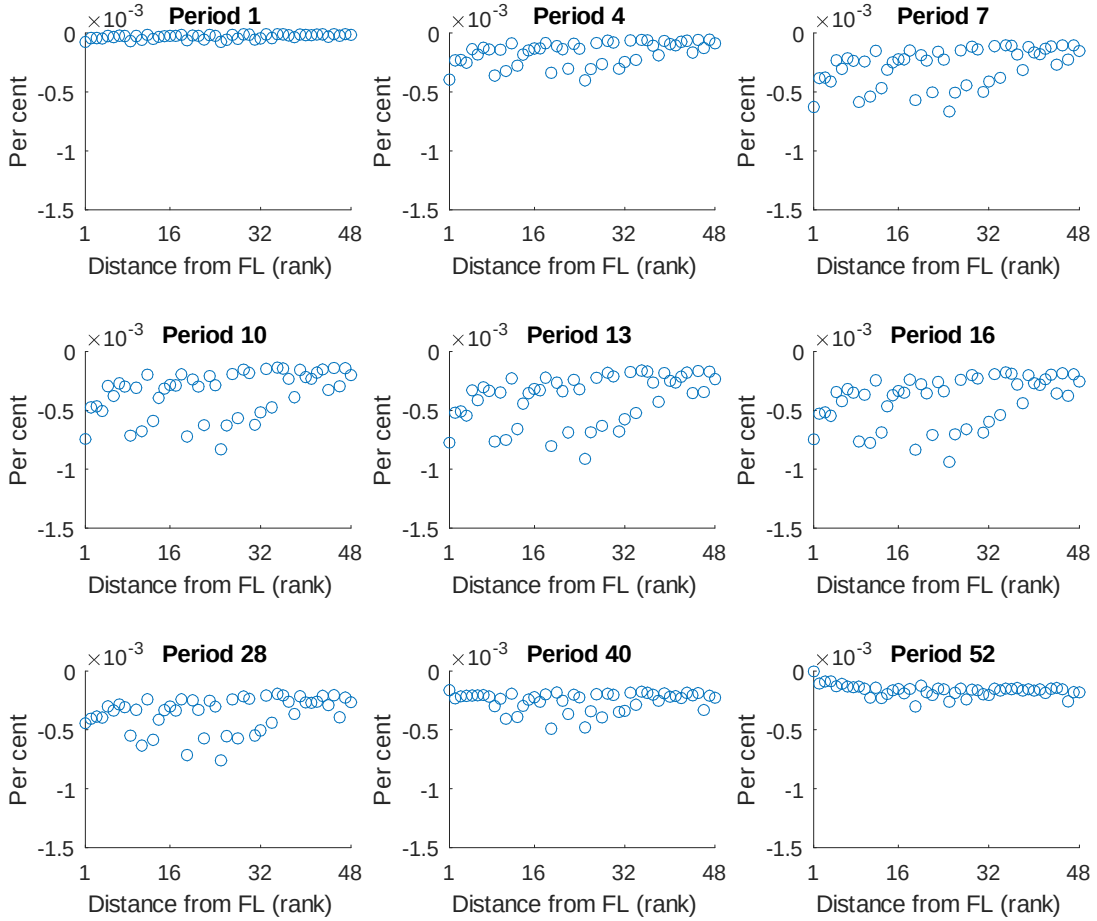
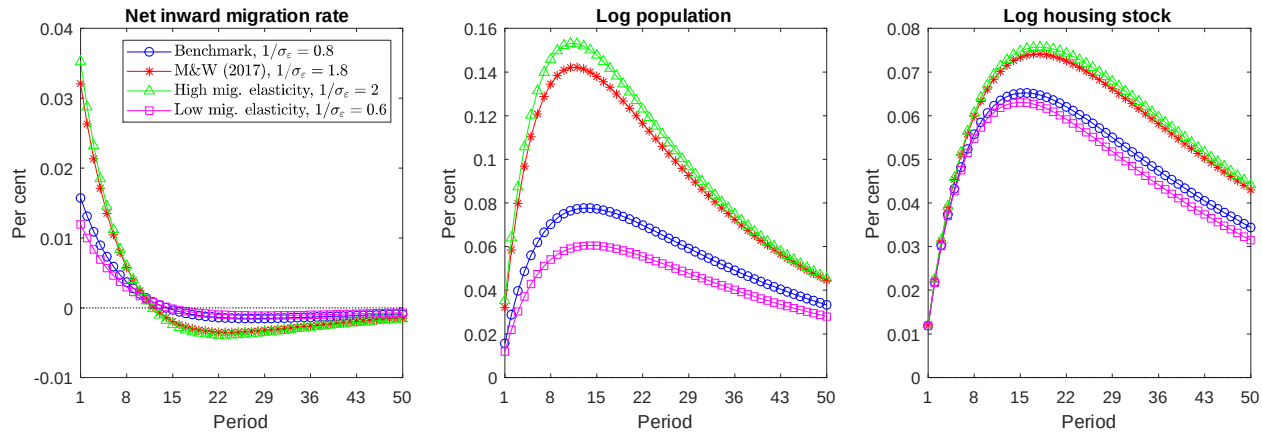


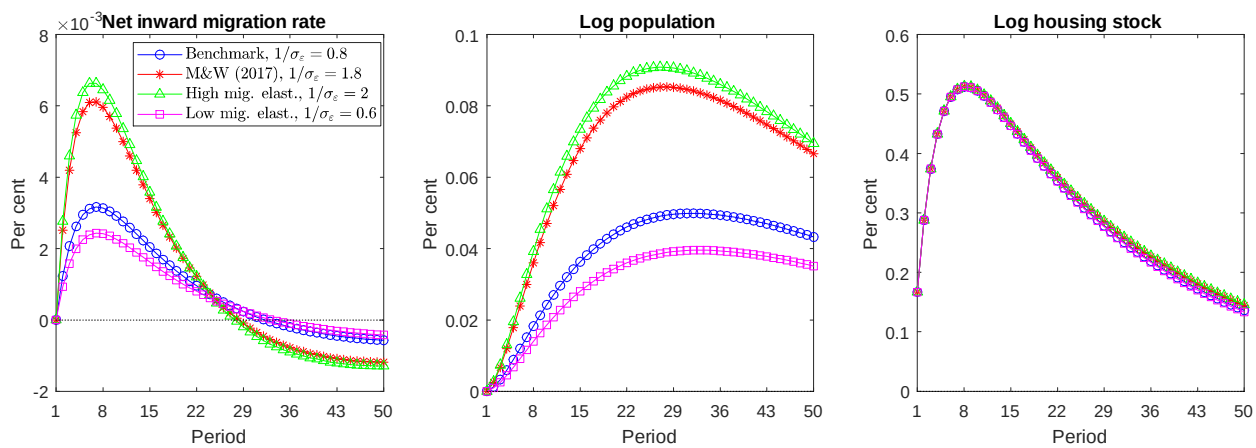
Figure S21: Spatiotemporal responses of log house price-to-income ratios of U.S. states to a positive land-supply shock in Florida

Notes: Each panel shows responses of log house price-to-income ratios of U.S. states (except for Florida) to a ten per cent positive shock to the annul supply of new land in Florida, for the period noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from Florida, and the horizontal axis corresponds to a state's rank in terms of distance from Florida.

S1.3.4 Calibration sensitivity



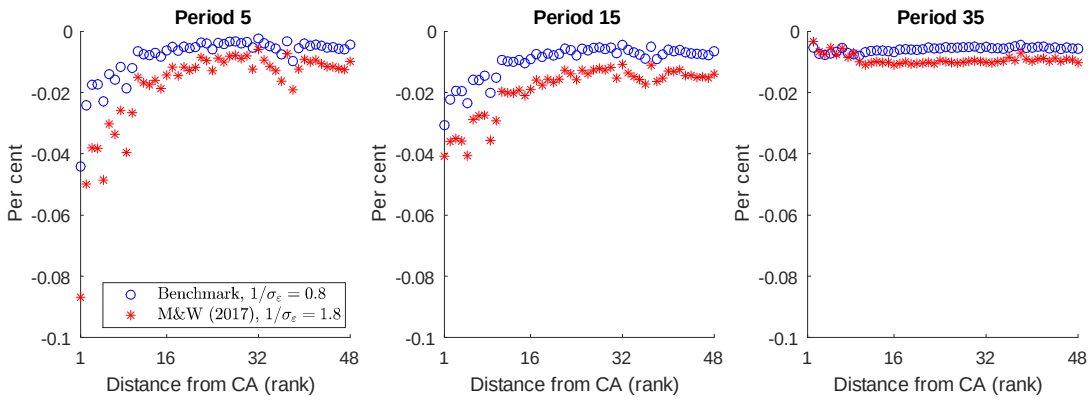
Panel 1: Reponses of variables in California to a positive labor productivity shock in California



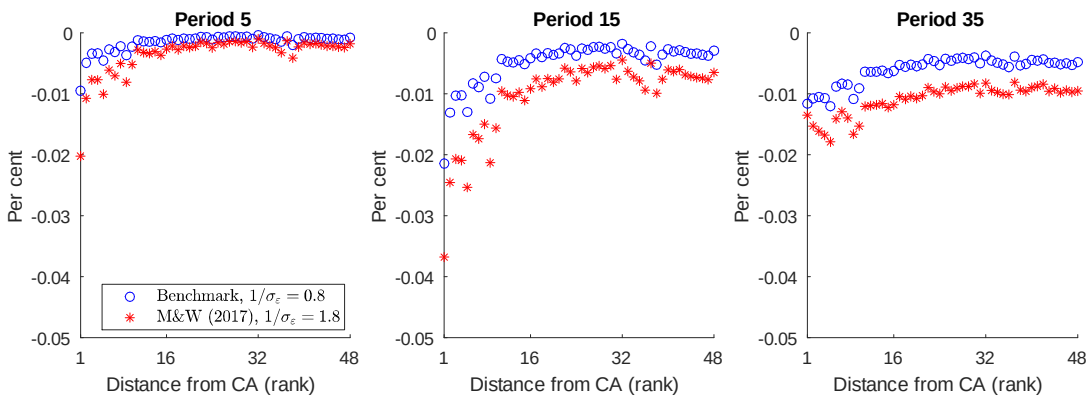
Panel 2: Reponses of variables in California to a positive land-supply shock in California

Figure S22: Reponses of variables in California to local shocks for different estimates of the migration elasticity, $1/\sigma_\varepsilon$

Notes: Panel 1 shows responses of net inward migration rate (i.e., the ratio of net inward migration to local population), log population and log housing stock in California to a one per cent positive shock to labor productivity in California. The blue lines designated with 'o' correspond to the benchmark model calibrated in Section 6 of the main paper (with $1/\sigma_\varepsilon = 0.8$). The red lines designated with '$\star$' correspond to the re-calibrated model when the migration elasticity, $1/\sigma_\varepsilon$, is set to 1.8, which is the benchmark estimate for the migration elasticity of "star scientists" in Moretti and Wilson (2017). The green lines designated with 'Δ' correspond to the re-calibrated model when $1/\sigma_\varepsilon$ is set to 2, and the purple lines designated with '$\square$' correspond to the re-calibrated model when $1/\sigma_\varepsilon$ is set to 0.6. Similarly, Panel 2 shows responses of the variables in California to a ten per cent positive shock to the annual supply of new land in California, when $1/\sigma_\varepsilon$ is set to different values.



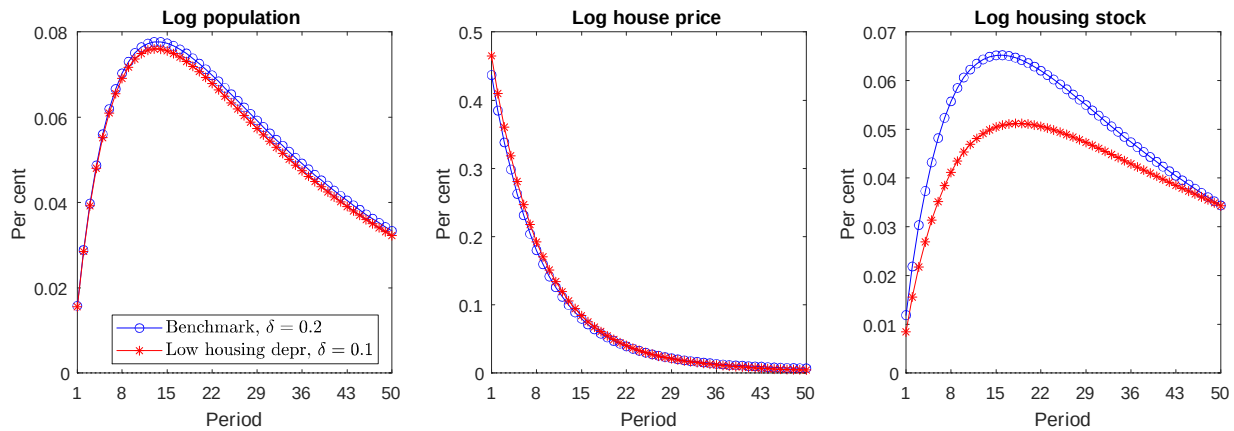
Panel 1: Spatiotemporal responses of log population of U.S. states to a positive labor productivity shock in California



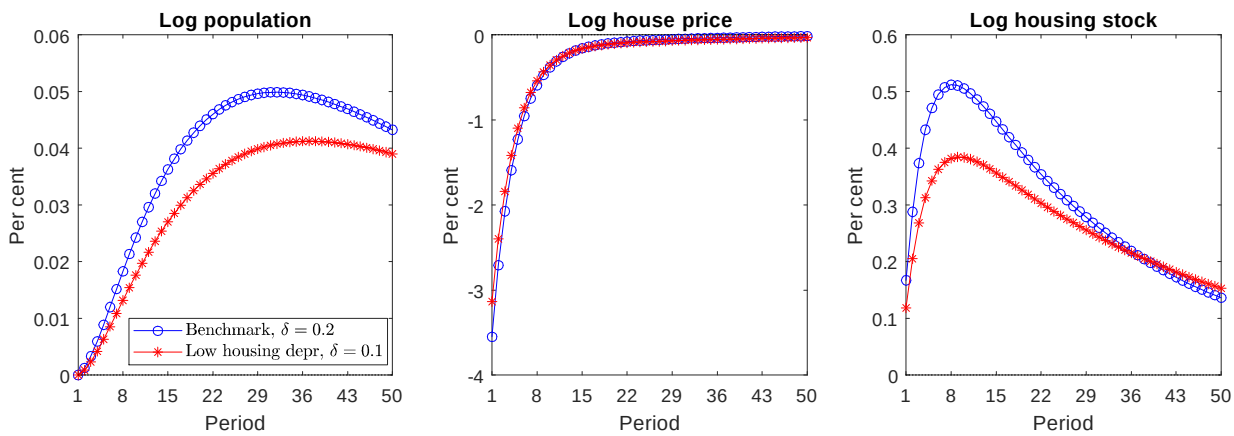
Panel 2: Spatiotemporal responses of log population of U.S. states to a positive land-supply shock in California

Figure S23: Spatiotemporal responses of log population of U.S. states to shocks in California for different estimates of the migration elasticity, $1/\sigma_\varepsilon$

Notes: Panel 1 shows responses of log population of U.S. states (except for California) to a one per cent positive shock to labor productivity in California, for the periods noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from California, and the horizontal axis corresponds to a state's rank in terms of distance from California. The blue circles correspond to the benchmark model calibrated in Section 6 of the main paper (with $1/\sigma_\varepsilon = 0.8$). The red stars correspond to the re-calibrated model when the migration elasticity, $1/\sigma_\varepsilon$, is set to 1.8, which is the benchmark estimate for the migration elasticity of "star scientists" in Moretti and Wilson (2017). Similarly, Panel 2 shows responses of log population of U.S. states (except for California) to a ten per cent positive shock to the annual supply of new land in California, when $1/\sigma_\varepsilon$ is set to different values.



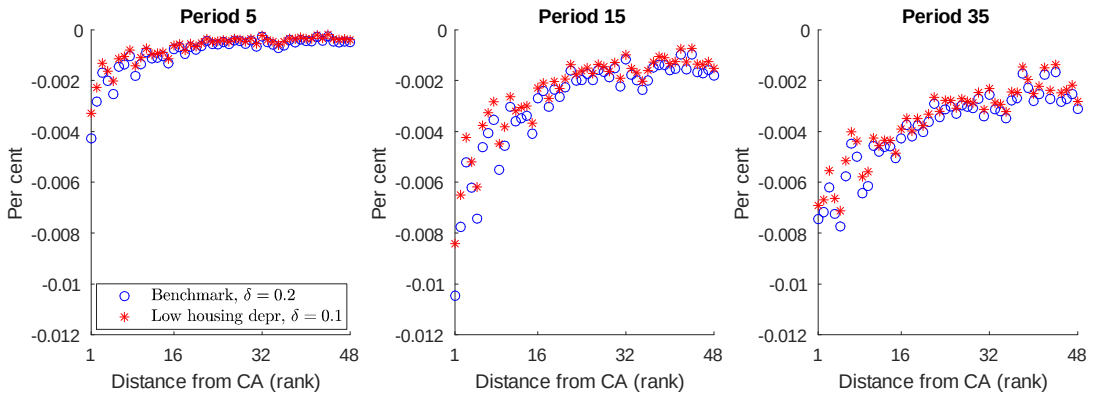
Panel 1: Reponses of variables in California to a positive labor productivity shock in California



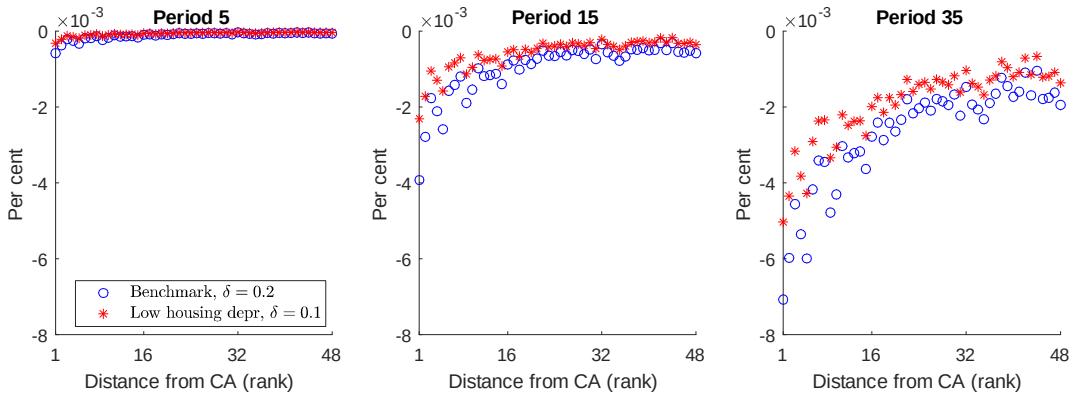
Panel 2: Reponses of variables in California to a positive land-supply shock in California

Figure S24: Reponses of variables in California to local shocks for different choices of the housing depreciation rate, δ

Notes: Panel 1 shows responses of log population, log house price and log housing stock in California to a one per cent positive shock to labor productivity in California. The blue lines designated with 'o' correspond to the benchmark model calibrated in Section 6 of the main paper (with $\delta = 0.2$). The red lines designated with '$\star$' correspond to the model in which the housing depreciation rate, δ, is set to 0.1. Similarly, Panel 2 shows responses of the variables in California to a ten per cent positive shock to the annual supply of new land in California, when the housing depreciation rate, δ, is set to different values.



Panel 1: Spatiotemporal responses of log housing stocks of U.S. states to a positive labor productivity shock in California



Panel 2: Spatiotemporal responses of log housing stocks of U.S. states to a positive land-supply shock in California

Figure S25: Spatiotemporal responses of log housing stocks of U.S. states to shocks in California for different choices of the housing depreciation rate, δ

Notes: Panel 1 shows responses of log housing stocks of U.S. states (except for California) to a one per cent positive shock to labor productivity in California, for the periods noted at the top. Each dot represents a state. States are ordered ascendingly by their distance from California, and the horizontal axis corresponds to a state's rank in terms of distance from California. The blue circles correspond to the benchmark model calibrated in Section 6 of the main paper (with $\delta = 0.2$). The red stars correspond to the model in which the housing depreciation rate, δ, is set to 0.1. Similarly, Panel 2 shows responses of log housing stocks of U.S. states (except for California) to a ten per cent positive shock to the annual supply of new land in California, when the housing depreciation rate, δ, is set to different values.

S2 Computation of the impulse responses

The impulse responses reported in the paper are computed using the Monte Carlo techniques developed by Koop et al. (1996). As discussed in Section 4, the model economy set out in Sections 2 and 3 of the main paper can be written in a compact form as

$$\boldsymbol{\zeta}_t = \boldsymbol{f}\left(\boldsymbol{\zeta}_{t-1}, \boldsymbol{a}_t, \boldsymbol{a}_{t-1}, \boldsymbol{\kappa}_{t-1}, \boldsymbol{g}_{l,t}; \Theta\right), \tag{S.1}$$

where Θ is a row vector that contains all the parameters, $\boldsymbol{\zeta}_t = [\boldsymbol{l}(t), \boldsymbol{q}_t]$ is a $1 \times 2n$ vector, and

$$\boldsymbol{\chi}_t = \boldsymbol{g}\left(\boldsymbol{\zeta}_t, \boldsymbol{a}_t, \boldsymbol{\kappa}_t; \Theta\right), \tag{S.2}$$

where $\boldsymbol{\chi}_t = [\boldsymbol{p}_t, \boldsymbol{h}_t]$ is a $1 \times 2n$ vector.

Set $\boldsymbol{\xi}_t = [\boldsymbol{\zeta}_t, \boldsymbol{\chi}_t]$, which is a $1 \times 4n$ vector. Then equations (S.1) and (S.2) can be combined and written as

$$\boldsymbol{\xi}_t = \boldsymbol{\psi}\left(\boldsymbol{\xi}_{t-1}, \boldsymbol{a}_t, \boldsymbol{a}_{t-1}, \boldsymbol{\kappa}_t, \boldsymbol{\kappa}_{t-1}, \boldsymbol{g}_{l,t}; \Theta\right). \tag{S.3}$$

The stochastic processes of $\boldsymbol{a}_t$ and $\boldsymbol{\kappa}_t$, are given by

$$\begin{aligned}
\ln \boldsymbol{a}_t &= \ln \boldsymbol{a} + \boldsymbol{g}_a t + \boldsymbol{\lambda} f_t + \boldsymbol{z}_{a,t}, && \text{(S.4)}\\
f_t &= \rho_f f_{t-1} + \sigma_f \varepsilon_{f,t}, && \text{(S.5)}\\
\boldsymbol{z}_{a,t} &= \boldsymbol{z}_{a,t-1}\mathbf{diag}(\rho_{a,1}, \rho_{a,2}, ...\rho_{a,n}) + \boldsymbol{\varepsilon}_{a,t}\mathbf{diag}(\sigma_{a,1}, \sigma_{a,2}, ...\sigma_{a,n}), && \text{(S.6)}
\end{aligned}$$

and

$$\begin{aligned}
\ln \boldsymbol{\kappa}_t &= \ln \boldsymbol{\kappa} + \boldsymbol{g}_\kappa t + \boldsymbol{z}_{\kappa,t}, && \text{(S.7)}\\
\boldsymbol{z}_{\kappa,t} &= \boldsymbol{z}_{\kappa,t-1}\mathbf{diag}(\rho_{\kappa,1}, \rho_{\kappa,2}, ...\rho_{\kappa,n}) + \boldsymbol{\varepsilon}_{\kappa,t}\mathbf{diag}(\sigma_{\kappa,1}, \sigma_{\kappa,2}, ...\sigma_{\kappa,n}), && \text{(S.8)}
\end{aligned}$$

and the values of state level intrinsic population growth rates, $\boldsymbol{g}_{l,t}$, for $t = 0, 1, 2, ...$, are exogenously given.

Impulse response function: To illustrate the computation algorithm used, we consider impulse responses to one standard error negative productivity shock to state i^*, as an example. Recall that the model is Markovian so that the relevant history is only the period before the start of simulations. Let the shock hits the economy in period 1. Then, the impulse response function is given by

$$\begin{aligned}
GI_\xi(t, \varepsilon_{a,i^*1}, \boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0) &= E(\boldsymbol{\xi}_t | \varepsilon_{a,i^*1}, \boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0) - E(\boldsymbol{\xi}_t | \boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0)\\
\text{for } t &= 1, 2, ..., T,
\end{aligned}$$

where T is the horizon of the impulse responses, $E(\boldsymbol{\xi}_t | \boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0)$ is the expectations of $\boldsymbol{\xi}_t$ conditional on $\boldsymbol{\xi}_0$, $\boldsymbol{a}_0$ and $\boldsymbol{\kappa}_0$, and $E(\boldsymbol{\xi}_t | \varepsilon_{a,i^*1}, \boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0)$ is the expectations of $\boldsymbol{\xi}_t$ conditional on $\boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0$ as well as ε_{a,i^*1}. Recall that ε_{a,i^*1} is the innovation to the local productivity shock in state i^* in period 1.

Initial values: In simulating impulse responses, we assume that the economy is on a balanced growth path at time $t = 0$. Recall that in Section 5 of the main paper we established

the uniqueness of the balanced growth path by showing that for given values of $L_0, \boldsymbol{\kappa}$ and $\boldsymbol{a}$, the steady states of the detrended variables are uniquely determined by the equation system (47)-(54) in the main paper. Note that detrended and non-detrended variables coincide when $t = 0$. Thus we use the steady state values of the detrended variables as the initial values for the corresponding non-detrended variables in the impulse response simulations, which implies that the economy is on a balanced growth path at $t = 0$.

Deterministic variables: The intrinsic population growth rates of all states are set equal to the balanced growth path level given by equation (42) in the main paper

$$\boldsymbol{g}_{l,t} = [\hat{g}_l, \hat{g}_l, ..., \hat{g}_l], \text{ for } t = 1, 2, ..., T,$$

where g_l is the balanced growth path intrinsic population growth rate, which is assumed to be common to all states, and set to the average growth rate of U.S. population during 1976-2014.

Stochastic processes: The state level productivities and land supplies, $\boldsymbol{a}_t$ and $\boldsymbol{\kappa}_t$, are simulated using equations (S.4) - (S.8), with f_0, $\boldsymbol{z}_{a0}$ and $\boldsymbol{z}_{\kappa 0}$ set to 0.

We set the number of replications and horizons to R and T, and independently draw innovations from the standard normal distribution. Let $\varepsilon_{f,t}^{(r)}$, $\boldsymbol{\varepsilon}_{a,t}^{(r)}$ and $\boldsymbol{\varepsilon}_{\kappa,t}^{(r)}$ denote the simulated values of $\varepsilon_{f,t}$, $\boldsymbol{\varepsilon}_{a,t}$ and $\boldsymbol{\varepsilon}_{\kappa,t}$, for replication r, where $\boldsymbol{\varepsilon}_{a,t}^{(r)} = \left[\varepsilon_{a,1t}^{(r)}, \varepsilon_{a,2t}^{(r)}, ..., \varepsilon_{a,nt}^{(r)}\right]$ and $\boldsymbol{\varepsilon}_{\kappa,t}^{(r)} = \left[\varepsilon_{\kappa,1t}^{(r)}, \varepsilon_{\kappa,2t}^{(r)}, ..., \varepsilon_{\kappa,nt}^{(r)}\right]$. The innovations, $\varepsilon_{f,t}^{(r)}$, $\varepsilon_{a,it}^{(r)}$ and $\varepsilon_{\kappa,it}^{(r)}$, for $i = 1, 2, ..., n$, $t = 1, 2., ..., T$ and $r = 1, 2., ..., R$, are also independently drawn from the standard normal distribution.

Productivity processes without shocks: In the absence of shocks, for each replication r, we plug the simulated innovations, $\varepsilon_{f,t}^{(r)}$ and $\boldsymbol{\varepsilon}_{a,t}^{(r)}$, into (S.4) - (S.6), and obtain a series of simulated productivities, $\boldsymbol{a}_t^{(r)}$, for $t = 1, 2., ..., T$.

Productivity processes subject to shocks: In the presence of shocks, for each replication r, we plug the simulated innovations, $\varepsilon_{f,t}^{(r)}$ and $\boldsymbol{\varepsilon}_{a,t}^{(r)}$, with the i^*th element of $\boldsymbol{\varepsilon}_{a,1}^{(r)}$, i.e., $\varepsilon_{a,i^*1}^{(r)}$, being replaced by -1 (a negative one standard error shock), into (S.4) - (S.6), and obtain another series of simulated productivities, $\check{\boldsymbol{a}}_t^{(r)}$, for $t = 1, 2., ..., T$.

Land supply processes: For both cases, with and without shocks, and for each replication, r, we plug the simulated innovations, $\boldsymbol{\varepsilon}_{\kappa,t}^{(r)}$, into (S.7) - (S.8), and obtain a series of simulated productivities, $\boldsymbol{\kappa}_t^{(r)}$, for $t = 1, 2., ..., T$.

To compute $E(\boldsymbol{\xi}_t|\boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0)$ and $E(\boldsymbol{\xi}_t|\varepsilon_{a,i^*1}, \boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0)$ numerically, we conduct the following simulations:

- *Simulation 1 (without shocks):* For each replication r, given the initial values, $\boldsymbol{\xi}_0, \boldsymbol{a}_0$ and $\boldsymbol{\kappa}_0$, and the deterministic processes of $\boldsymbol{g}_{l,t}$, we simulate model (S.3) using the simulated productivity processes, $\boldsymbol{a}_t^{(r)}$ and $\boldsymbol{\kappa}_t^{(r)}$, for $t = 1, 2, ..., T$, and obtain $\boldsymbol{\xi}_t^{(r)}$, for $t = 1, 2, ..., T$:
$$\boldsymbol{\xi}_t^{(r)} = \boldsymbol{\psi}\left(\boldsymbol{\xi}_{t-1}^{(r)}, \boldsymbol{a}_t^{(r)}, \boldsymbol{a}_{t-1}^{(r)}, \boldsymbol{\kappa}_t^{(r)}, \boldsymbol{\kappa}_{t-1}^{(r)}, \boldsymbol{g}_{l,t}; \Theta\right).$$

- *Simulation 2 (with shocks):* For each replication r, given the initial values, $\boldsymbol{\xi}_0, \boldsymbol{a}_0$ and $\boldsymbol{\kappa}_0$, and the deterministic processes of $\boldsymbol{g}_{l,t}$, we simulate model (S.3) using the

simulated productivity processes, $\check{\boldsymbol{a}}_t^{(r)}$ and $\boldsymbol{\kappa}_t^{(r)}$, for $t = 1, 2, ..., T$, and obtain $\check{\boldsymbol{\xi}}_t^{(r)}$, for $t = 1, 2, ..., T$:

$$\check{\boldsymbol{\xi}}_t^{(r)} = \boldsymbol{\psi}\left(\check{\boldsymbol{\xi}}_{t-1}^{(r)}, \check{\boldsymbol{a}}_t^{(r)}, \check{\boldsymbol{a}}_{t-1}^{(r)}, \boldsymbol{\kappa}_t^{(r)}, \boldsymbol{\kappa}_{t-1}^{(r)}, \boldsymbol{g}_{l,t}; \Theta\right).$$

Then the two expectations, $E(\boldsymbol{\xi}_t|\boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0)$ and $E(\boldsymbol{\xi}_t|\varepsilon_{a,i^*1}, \boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0)$, are approximated as the averages across replications:

$$\hat{E}_R(\boldsymbol{\xi}_t|\boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0) = \frac{1}{R}\sum_{r=1}^{R} \boldsymbol{\xi}_t^{(r)} \quad \text{and} \quad \hat{E}_R(\boldsymbol{\xi}_t|\varepsilon_{a,i^*1}, \boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0) = \frac{1}{R}\sum_{r=1}^{R} \check{\boldsymbol{\xi}}_t^{(r)}.$$

Thus the approximated impulse response in period t is given by

$$GI_{\boldsymbol{\xi}}(t, \varepsilon_{a,i^*1}, \boldsymbol{\xi}_0, \boldsymbol{a}_0, \boldsymbol{\kappa}_0) = \frac{1}{R}\sum_{r=1}^{R} \check{\boldsymbol{\xi}}_t^{(r)} - \frac{1}{R}\sum_{r=1}^{R} \boldsymbol{\xi}_t^{(r)}.$$

S3 Parameter values

Table S2: Location-specific parameters related to housing supplies and investment

State		$\hat{\vartheta}_{\kappa,i}$	$\hat{\theta}_i$			$\hat{\vartheta}_{\kappa,i}$	$\hat{\theta}_i$
AL	Alabama	0.0707	0.0175	NE	Nebraska	0.0598	0.0278
AZ	Arizona	0.1362	0.0155	NV	Nevada	0.2070	0.0071
AR	Arkansas	0.0571	0.0279	NH	New Hampshire	0.2394	0.0183
CA	California	0.5176	0.0092	NJ	New Jersey	0.4045	0.0130
CO	Colorado	0.2785	0.0138	NM	New Mexico	0.1067	0.0066
CT	Connecticut	0.4770	0.0056	NY	New York	0.2328	0.0160
DE	Delaware	0.1508	0.0178	NC	North Carolina	0.1390	0.0228
DC	District of Columbia	0.5312	0.0130	ND	North Dakota	0.0971	0.0184
FL	Florida	0.1442	0.0304	OH	Ohio	0.1109	0.0191
GA	Georgia	0.1210	0.0249	OK	Oklahoma	0.0857	0.0264
ID	Idaho	0.1058	0.0126	OR	Oregon	0.1665	0.0167
IL	Illinois	0.1854	0.0137	PA	Pennsylvania	0.1034	0.0233
IN	Indiana	0.0780	0.0200	RI	Rhode Island	0.2331	0.0097
IA	Iowa	0.1037	0.0283	SC	South Carolina	0.1062	0.0225
KS	Kansas	0.0687	0.0286	SD	South Dakota	0.0857	0.0248
KY	Kentucky	0.0654	0.0242	TN	Tennessee	0.0792	0.0247
LA	Louisiana	0.0826	0.0186	TX	Texas	0.0602	0.0343
ME	Maine	0.1330	0.0188	UT	Utah	0.2039	0.0102
MD	Maryland	0.3666	0.0179	VT	Vermont	0.2351	0.0158
MA	Massachusetts	0.3138	0.0137	VA	Virginia	0.3216	0.0218
MI	Michigan	0.0955	0.0286	WA	Washington	0.2029	0.0129
MN	Minnesota	0.0712	0.0217	WV	West Virginia	0.0975	0.0190
MS	Mississippi	0.0628	0.0258	WI	Wisconsin	0.1116	0.0206
MO	Missouri	0.0704	0.0258	WY	Wyoming	0.1678	0.0062
MT	Montana	0.0947	0.0121				
Average across the U.S. states		0.1682	0.0189				

Table S3: Location-specific parameters of labor productivity processes

State		$\hat{\lambda}_i$	SE	p-value	$\hat{\rho}_{a,i}$	SE	p-value	$\hat{\sigma}_{a,i}$
AL	Alabama	1.3500	0.0830	0.0000	0.8589	0.1086	0.0000	0.0133
AZ	Arizona	0.9067	0.1355	0.0000	0.8089	0.1153	0.0000	0.0228
AR	Arkansas	0.9156	0.0932	0.0000	0.7286	0.1414	0.0000	0.0194
CA	California	0.3449	0.1533	0.0343	0.8694	0.1057	0.0000	0.0239
CO	Colorado	1.1385	0.1041	0.0000	0.8507	0.1390	0.0000	0.0191
CT	Connecticut	1.6242	0.1737	0.0000	0.8270	0.1132	0.0000	0.0280
DE	Delaware	1.3316	0.1136	0.0000	0.7059	0.1565	0.0002	0.0252
DC	District of Columbia	0.5195	0.1849	0.0099	0.7746	0.0992	0.0000	0.0269
FL	Florida	1.5818	0.1475	0.0000	0.7405	0.1315	0.0000	0.0276
GA	Georgia	2.1065	0.1119	0.0000	0.7394	0.1463	0.0000	0.0240
ID	Idaho	0.6251	0.1496	0.0004	0.7247	0.1147	0.0000	0.0252
IL	Illinois	0.9811	0.0533	0.0000	0.3842	0.1758	0.0398	0.0138
IN	Indiana	1.1175	0.0826	0.0000	0.8134	0.1025	0.0000	0.0123
IA	Iowa	0.2285	0.1354	0.1051	0.4526	0.1889	0.0255	0.0378
KS	Kansas	0.6216	0.0567	0.0000	0.3714	0.1929	0.0672	0.0159
KY	Kentucky	0.9512	0.0836	0.0000	0.7206	0.1464	0.0001	0.0178
LA	Louisiana	0.2497	0.1011	0.0214	0.6956	0.1178	0.0000	0.0173
ME	Maine	1.1732	0.1084	0.0000	0.8417	0.1267	0.0000	0.0196
MD	Maryland	1.3749	0.0959	0.0000	0.7012	0.1505	0.0001	0.0211
MA	Massachusetts	1.6583	0.1668	0.0000	0.8216	0.1227	0.0000	0.0294
MI	Michigan	1.0009	0.0898	0.0000	0.7040	0.1369	0.0000	0.0180
MN	Minnesota	1.2649	0.0570	0.0000	0.0955	0.2094	0.6527	0.0176
MS	Mississippi	1.0084	0.1246	0.0000	0.8873	0.1014	0.0000	0.0185
MO	Missouri	1.2509	0.0597	0.0000	0.5434	0.1879	0.0085	0.0159
MT	Montana	-0.3493	0.1437	0.0233	0.3939	0.1899	0.0500	0.0403
NE	Nebraska	0.8859	0.0708	0.0000	-0.1827	0.1980	0.3663	0.0206
NV	Nevada	1.4794	0.1905	0.0000	0.9022	0.0993	0.0000	0.0275
NH	New Hampshire	1.9806	0.2323	0.0000	0.7920	0.1068	0.0000	0.0358
NJ	New Jersey	1.4646	0.1077	0.0000	0.7568	0.1439	0.0000	0.0219
NM	New Mexico	0.5373	0.0585	0.0000	0.7661	0.1673	0.0001	0.0130
NY	New York	1.2613	0.1260	0.0000	0.8292	0.1375	0.0000	0.0243
NC	North Carolina	1.9992	0.1169	0.0000	0.6985	0.1519	0.0001	0.0263
ND	North Dakota	-0.1182	0.2531	0.6448	0.0022	0.2127	0.9917	0.0796
OH	Ohio	0.8190	0.0685	0.0000	0.6346	0.1530	0.0004	0.0155
OK	Oklahoma	-0.3802	0.1414	0.0131	0.6517	0.1587	0.0005	0.0325
OR	Oregon	0.7045	0.1365	0.0000	0.7930	0.1063	0.0000	0.0213
PA	Pennsylvania	1.0008	0.0845	0.0000	0.7710	0.1288	0.0000	0.0157
RI	Rhode Island	0.9745	0.1682	0.0000	0.8807	0.1042	0.0000	0.0252
SC	South Carolina	1.5644	0.0742	0.0000	0.6996	0.1511	0.0001	0.0164
SD	South Dakota	0.8927	0.1288	0.0000	0.2804	0.2052	0.1857	0.0388
TN	Tennessee	2.1752	0.1451	0.0000	0.7874	0.1265	0.0000	0.0271
TX	Texas	1.1899	0.1242	0.0000	0.9746	0.1236	0.0000	0.0195
UT	Utah	1.0823	0.1101	0.0000	0.9438	0.0994	0.0000	0.0149
VT	Vermont	1.4196	0.1048	0.0000	0.7451	0.1277	0.0000	0.0195
VA	Virginia	1.3727	0.1008	0.0000	0.7820	0.1264	0.0000	0.0186
WA	Washington	1.0695	0.0763	0.0000	0.7613	0.1380	0.0000	0.0154
WV	West Virginia	0.1421	0.0726	0.0624	0.4836	0.1887	0.0178	0.0201
WI	Wisconsin	1.2697	0.0689	0.0000	0.6330	0.1633	0.0008	0.0166
WY	Wyoming	-0.7628	0.1712	0.0002	0.5032	0.1872	0.0134	0.0446
Average across the U.S. states		1.0000			0.6723			0.0237

Table S4: Location-specific parameters of land supply processes

State		WRI	$\hat{g}_{K,i}$	SE	p-value	$\hat{\rho}_{K,i}$	SE	p-value	$\hat{\sigma}_{K,i}$
AL	Alabama	-1.1401	0.0879	0.0273	0.0040	0.9017	0.1206	0.0000	0.4879
AZ	Arizona	0.9917	0.1009	0.0171	0.0000	0.8163	0.1307	0.0000	0.3275
AR	Arkansas	-1.0279	0.2017	0.0334	0.0000	0.8833	0.1299	0.0000	0.6364
CA	California	1.0057	-0.0081	0.0077	0.3003	0.7490	0.1143	0.0000	0.1377
CO	Colorado	0.8514	0.0225	0.0114	0.0614	0.9233	0.1082	0.0000	0.1785
CT	Connecticut	0.7112	-0.0067	0.0127	0.6033	0.8830	0.0994	0.0000	0.1981
DE	Delaware	0.8514	-0.0566	0.0198	0.0092	0.8576	0.1024	0.0000	0.3137
DC	District of Columbia		-0.0161	0.0070	0.0321	0.7467	0.1231	0.0000	0.1366
FL	Florida	0.6972	0.0782	0.0052	0.0000	0.5419	0.2119	0.0180	0.1508
GA	Georgia	-0.1163	0.0375	0.0109	0.0023	0.8757	0.1464	0.0000	0.2193
ID	Idaho	-0.7053	0.0724	0.0264	0.0120	0.9174	0.0965	0.0000	0.3950
IL	Illinois	-0.0882	-0.0141	0.0170	0.4156	0.8445	0.1159	0.0000	0.3115
IN	Indiana	-1.2383	0.0132	0.0266	0.6242	0.8812	0.1208	0.0000	0.4837
IA	Iowa	-1.2102	0.1207	0.0392	0.0055	0.9313	0.0960	0.0000	0.5719
KS	Kansas	-1.4066	0.1999	0.0341	0.0000	0.9754	0.1184	0.0000	0.5596
KY	Kentucky	-0.6212	-0.0064	0.0301	0.8329	0.9128	0.1144	0.0000	0.5116
LA	Louisiana	-1.3084	0.2236	0.0422	0.0000	0.8887	0.1041	0.0000	0.6419
ME	Maine	1.1319	-0.0676	0.0293	0.0312	0.8537	0.1052	0.0000	0.4875
MD	Maryland	1.2862	-0.0060	0.0066	0.3766	0.8722	0.1118	0.0000	0.1155
MA	Massachusetts	2.3661	-0.0731	0.0213	0.0024	0.9124	0.0852	0.0000	0.2864
MI	Michigan	0.2063	-0.0969	0.0340	0.0093	0.9010	0.1105	0.0000	0.5697
MN	Minnesota	0.2904	0.0285	0.0250	0.2671	0.8120	0.1543	0.0000	0.5412
MS	Mississippi	-0.9718	0.2309	0.0341	0.0000	0.9083	0.1348	0.0000	0.6544
MO	Missouri	-1.2663	0.0443	0.0269	0.1140	0.8103	0.1424	0.0000	0.5783
MT	Montana	-0.3267	0.0411	0.0346	0.2477	0.8736	0.1145	0.0000	0.6103
NE	Nebraska	-0.7755	0.0995	0.0418	0.0265	0.9879	0.0989	0.0000	0.5934
NV	Nevada	-0.4529	0.0711	0.0091	0.0000	0.6113	0.1325	0.0001	0.1877
NH	New Hampshire	2.0856	0.0053	0.0244	0.8313	0.8596	0.1003	0.0000	0.3874
NJ	New Jersey	1.4124	-0.0286	0.0137	0.0491	0.8934	0.0976	0.0000	0.2096
NM	New Mexico	0.0240	0.0382	0.0159	0.0249	0.7506	0.1249	0.0000	0.3071
NY	New York	0.1642	-0.0855	0.0225	0.0010	0.9254	0.0870	0.0000	0.3060
NC	North Carolina	-0.3126	0.0033	0.0100	0.7425	0.8698	0.1344	0.0000	0.1983
ND	North Dakota	-0.5791	0.1953	0.0321	0.0000	0.6902	0.1663	0.0004	0.8126
OH	Ohio	-0.3267	0.0090	0.0262	0.7357	0.9157	0.0980	0.0000	0.3951
OK	Oklahoma	-0.8035	0.2954	0.0414	0.0000	0.8535	0.1097	0.0000	0.6672
OR	Oregon	0.2904	-0.0435	0.0298	0.1583	0.9397	0.0863	0.0000	0.3977
PA	Pennsylvania	0.6972	-0.0828	0.0297	0.0107	0.8690	0.0988	0.0000	0.4594
RI	Rhode Island	2.3942	-0.0643	0.0230	0.0107	0.8991	0.1019	0.0000	0.3656
SC	South Carolina	-0.8877	0.0277	0.0113	0.0227	1.0186	0.1315	0.0000	0.1939
SD	South Dakota	-1.2804	0.0545	0.0292	0.0759	0.8546	0.1260	0.0000	0.5606
TN	Tennessee	-0.7755	0.0051	0.0220	0.8190	0.8618	0.1263	0.0000	0.4200
TX	Texas	-0.4529	0.2911	0.0401	0.0000	0.8064	0.1141	0.0000	0.6618
UT	Utah	0.0801	0.0169	0.0212	0.4323	0.9599	0.0847	0.0000	0.2717
VT	Vermont	0.6691	-0.0108	0.0134	0.4264	0.7502	0.1447	0.0000	0.3043
VA	Virginia	-0.0882	0.0135	0.0059	0.0327	0.8146	0.1240	0.0000	0.1171
WA	Washington	1.2161	-0.0574	0.0148	0.0008	0.8107	0.1222	0.0000	0.2866
WV	West Virginia	-1.0840	0.1989	0.0341	0.0000	0.9383	0.1046	0.0000	0.5298
WI	Wisconsin	0.2764	-0.0002	0.0313	0.9955	0.8987	0.1082	0.0000	0.5181
WY	Wyoming	-0.4529	0.1273	0.0266	0.0001	0.9425	0.0920	0.0000	0.3673
Average across the U.S. states		0.0000	0.0455			0.8611			0.4005

Notes: The average WRI is computed across the 48 states on the U.S. mainland, since Alaska and Hawaii are excluded from our analyses, and WRI values of the included states are re-scaled accordingly, such that the mean and the standard deviation of WRI over the 48 states are zero and one, respectively.

Reference

Herkenhoff K.F., Ohanian, L.E., and Prescott, E.C. (2018). Tarnishing the golden and empire states: Land-use restrictions and the U.S. economic slowdown. *Journal of Monetary Economics*, 93, 89–109.

Koop, G., Pesaran, M.H., and Potter, S.M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics*, 74, 119–147.

Moretti, E. and Wilson, D.J. (2017). The effect of state taxes on the geographical location of top earners: Evidence from star scientists. *American Economic Review*, 107, 1858–1903.