# Appendix: For Online Publication

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# A Notes on the market clearing conditions

In the model, there are two centralized markets: the capital market and the labor market. Thus, there are two prices to be determined endogenously.

## A.1 Interest rate and capital market

Define $p := U'(c(\mathcal{S}))$. Then, from the Euler equation of the representative household,

$$\beta \mathbb{E} \frac{U'(c(\mathcal{S}'))}{U(c(\mathcal{S}))} = \frac{1}{1 + r^B(\mathcal{S})} \iff \beta \frac{p(\mathcal{S}')}{p(\mathcal{S})} = \frac{1}{1 + r^B(\mathcal{S})}$$

As there is no aggregate uncertainty, the expectation operator can be ignored.

Then, define a modified value function $\tilde{J}(z, k, j; \mathcal{S}) = p(\mathcal{S}) J(z, k, j; \mathcal{S})$.
In the following original recursive formulation,

$$\begin{aligned} J(z,k,j;\mathcal{S}) = & \max_{I, I^c} \ \pi(z,k,j;\mathcal{S})(1-\tau^c)(1-\tau^h) \\ & + \int_0^{\overline{\xi}} \max\{-I - \xi w(\mathcal{S}) - C(I,k) \\ & + \frac{1}{1+r(\mathcal{S})} \mathbb{E} J(z', k', j'; \mathcal{S}'), \\ & - I^c - C(I^c, k) + \frac{1}{1+r(\mathcal{S})} \mathbb{E} J(z', k^c; \mathcal{S}')\} dG(\xi) \end{aligned}$$

replace $\frac{1}{1+r(\mathcal{S})}$ with $\beta\frac{p(\mathcal{S}')}{p(\mathcal{S})}$. So we have,

$$
\begin{aligned}
J(z,k,j;\mathcal{S}) = \max_{I,I^c}\ & \pi(z,k,j;\mathcal{S})(1-\tau^c)(1-\tau^h) \\
& + \int_0^{\overline{\xi}} \max\{-I - \xi w(\mathcal{S}) - C(I,k) \\
& + \beta\frac{p(S')}{p(\mathcal{S})}\mathbb{E}J(z',k',j';\mathcal{S}'), \\
& - I^c - C(I^c,k) + \beta\frac{p(S')}{p(\mathcal{S})}\mathbb{E}J(z',k^c;\mathcal{S}')\}dG(\xi)
\end{aligned}
$$

Then, multiply $p(\mathcal{S})$ to both sides. It leads to

$$
\begin{aligned}
p(\mathcal{S})J(z,k,j;\mathcal{S}) = \max_{I,I^c}\ & p(\mathcal{S})\pi(z,k,j;\mathcal{S})(1-\tau^c)(1-\tau^h) \\
& + \int_0^{\overline{\xi}} \max\{ - p(\mathcal{S})I - p(\mathcal{S})w(\mathcal{S})\xi \\
& \qquad - p(\mathcal{S})C(I,k) \\
& \qquad + \beta p(\mathcal{S}')J(z',k',j';\mathcal{S}'), \\
& \qquad - p(\mathcal{S})I^c - p(\mathcal{S})C(I^c,k) \\
& \qquad + \beta p(\mathcal{S}')J(z',k^c;\mathcal{S}')\}dG(\xi)
\end{aligned}
$$

Thus, we have

$$
\begin{aligned}
\tilde{J}(z,k,j;\mathcal{S}) = \max_{I,I^c}\ & p(\mathcal{S})\pi(z,k,j;\mathcal{S})(1-\tau^c)(1-\tau^h) \\
+ \int_0^{\bar{\xi}} \max\{ & -p(\mathcal{S})I - p(\mathcal{S})w(\mathcal{S})\xi \\
& - p(\mathcal{S})C(I,k) \\
& + \beta\tilde{J}(z',k',j';\mathcal{S}'), \\
& - p(\mathcal{S})I^c - p(\mathcal{S})C(I^c,k) \\
& + \beta\tilde{J}(z',k^c;\mathcal{S}')\}dG(\xi)
\end{aligned}
$$

Therefore, a firm's problem is perfectly characterized by the price

$$p(\mathcal{S}) = U'(c(\mathcal{S})) = 1/c(\mathcal{S}).$$

## A.2 Wage and labor market

From the representative household's intra-temporal optimality condition (with respect to the labor supply),

$$\eta L^{\frac{1}{\chi}} = U'(c(\mathcal{S}))w(\mathcal{S})(1-\tau^h)$$

Therefore,

$$\eta L^{\frac{1}{\chi}} = p(\mathcal{S})w(\mathcal{S})(1-\tau^h) \implies w(\mathcal{S}) = \frac{\eta}{p(\mathcal{S})(1-\tau^h)} L^{\frac{1}{\chi}}$$

The optimal labor supply $L$ depends upon $w$, and $w$ can be determined only when the labor supply $L$ is known, leading to a fixed-point problem. Therefore, $w$ needs to be tracked together with $p$ for the computation.[1]

[1] If $\chi \to \infty$, $p$ is the only price to be tracked as in Khan and Thomas (2008).

# B State-level data on infrastructure

| State | Avg. Rank (Infra.) | # Good Group | Portion (Infra.) | Portion (GDP) | Avg. Rank (Estab.) | Portion (Estab.) |
|---|---|---|---|---|---|---|
| New York | 1.708 | 24.000 | 0.072 | 0.081 | 2.439 | 0.072 |
| California | 1.833 | 24.000 | 0.071 | 0.133 | 1.000 | 0.114 |
| Texas | 2.458 | 24.000 | 0.071 | 0.079 | 2.659 | 0.069 |
| Florida | 4.000 | 24.000 | 0.064 | 0.050 | 4.000 | 0.060 |
| Illinois | 5.000 | 24.000 | 0.049 | 0.046 | 5.341 | 0.044 |
| Ohio | 6.542 | 24.000 | 0.035 | 0.036 | 7.000 | 0.039 |
| New Jersey | 7.125 | 24.000 | 0.034 | 0.034 | 8.415 | 0.033 |
| Georgia | 8.458 | 24.000 | 0.032 | 0.029 | 11.171 | 0.027 |
| Pennsylvania | 8.708 | 24.000 | 0.032 | 0.040 | 5.561 | 0.044 |
| Massachusetts | 9.708 | 24.000 | 0.030 | 0.027 | 12.341 | 0.024 |
| Minnesota | 10.458 | 24.000 | 0.029 | 0.018 | 18.561 | 0.019 |
| North Carolina | 12.208 | 24.000 | 0.025 | 0.027 | 9.976 | 0.028 |
| Wisconsin | 13.083 | 24.000 | 0.025 | 0.017 | 17.439 | 0.020 |
| Washington | 14.250 | 24.000 | 0.024 | 0.024 | 14.561 | 0.022 |
| Virginia | 14.458 | 24.000 | 0.024 | 0.027 | 12.585 | 0.025 |
| Michigan | 16.083 | 24.000 | 0.022 | 0.030 | 9.024 | 0.032 |
| Tennessee | 16.917 | 24.000 | 0.021 | 0.018 | 19.195 | 0.019 |
| Missouri | 18.167 | 24.000 | 0.019 | 0.018 | 15.171 | 0.021 |
| Indiana | 18.833 | 24.000 | 0.018 | 0.019 | 15.171 | 0.021 |
| Kentucky | 20.292 | 24.000 | 0.018 | 0.011 | 27.415 | 0.013 |
| Louisiana | 21.333 | 24.000 | 0.017 | 0.014 | 22.805 | 0.015 |
| Iowa | 21.625 | 24.000 | 0.017 | 0.010 | 28.951 | 0.012 |
| Arizona | 22.875 | 24.000 | 0.016 | 0.017 | 23.756 | 0.016 |
| Colorado | 25.625 | 15.000 | 0.015 | 0.017 | 19.439 | 0.018 |
| Kansas | 25.833 | 13.000 | 0.014 | 0.009 | 30.829 | 0.011 |
| Alabama | 26.000 | 23.000 | 0.015 | 0.012 | 24.951 | 0.014 |
| Maryland | 26.042 | 11.000 | 0.015 | 0.020 | 20.415 | 0.018 |
| Connecticut | 26.542 | 10.000 | 0.014 | 0.016 | 25.951 | 0.014 |
| Oklahoma | 29.458 | 0.000 | 0.012 | 0.010 | 27.634 | 0.013 |
| Mississippi | 30.208 | 0.000 | 0.011 | 0.006 | 33.317 | 0.009 |
| Oregon | 30.500 | 0.000 | 0.011 | 0.011 | 25.659 | 0.014 |
| South Carolina | 31.917 | 0.000 | 0.011 | 0.011 | 26.634 | 0.013 |
| Nevada | 33.083 | 0.000 | 0.010 | 0.008 | 38.000 | 0.006 |
| Nebraska | 34.417 | 0.000 | 0.010 | 0.006 | 34.927 | 0.007 |
| Arkansas | 34.708 | 0.000 | 0.010 | 0.007 | 32.439 | 0.009 |
| New Mexico | 35.542 | 0.000 | 0.010 | 0.006 | 37.000 | 0.006 |
| West Virginia | 37.000 | 0.000 | 0.009 | 0.004 | 37.244 | 0.006 |
| Utah | 38.375 | 0.000 | 0.008 | 0.007 | 34.122 | 0.008 |
| Alaska | 39.167 | 0.000 | 0.007 | 0.003 | 51.000 | 0.002 |
| Hawaii | 39.458 | 0.000 | 0.007 | 0.005 | 41.854 | 0.005 |
| Idaho | 41.667 | 0.000 | 0.006 | 0.004 | 40.512 | 0.005 |
| Montana | 41.958 | 0.000 | 0.006 | 0.002 | 42.512 | 0.004 |
| Delaware | 42.375 | 0.000 | 0.006 | 0.004 | 47.317 | 0.003 |
| Wyoming | 44.167 | 0.000 | 0.005 | 0.002 | 49.707 | 0.003 |
| South Dakota | 45.042 | 0.000 | 0.005 | 0.002 | 45.073 | 0.003 |
| Rhode Island | 46.083 | 0.000 | 0.004 | 0.003 | 42.963 | 0.004 |
| Maine | 47.208 | 0.000 | 0.004 | 0.004 | 39.098 | 0.005 |
| North Dakota | 47.500 | 0.000 | 0.004 | 0.002 | 47.146 | 0.003 |
| New Hampshire | 49.000 | 0.000 | 0.003 | 0.004 | 39.963 | 0.005 |
| District of Columbia | 50.000 | 0.000 | 0.002 | 0.007 | 47.927 | 0.003 |
| Vermont | 51.000 | 0.000 | 0.002 | 0.002 | 47.829 | 0.003 |

Table B.1: State-level summary

*Notes*: Avg. Rank (Infra.) is the average time-series ranking of infrastructure (this variable is the sorting variable). # Good Group is how many times the state belonged to the good infrastructure group (Max:24). Portion (Infra.) is the portion of infrastructure on average. Avg. Rank (Estab.) is the average time-series ranking of the number of establishments. Portion (Estab.) is the portion of establishments on average.

## C Description of multiple-block Metropolis-Hastings

We use the multiple-block Metropolis Hastings algorithm to estimate the model parameters as well as finding market clearing prices. Let's denote the moments to match (including the market clearing conditions) as $y \equiv [\hat{\mathbf{m}}, \mathbf{0}]$. $\hat{\mathbf{m}}$ is for the moments constructed from the data and $\mathbf{0}$ is associated with solving for general equilibrium. We break the parameter space into two blocks as follows: $\Theta = (\Theta^1, \Theta^2)$ where $\Theta^1$ is for the price block and $\Theta^2$ is for the other model parameter block. Starting from an initial value $\Theta_0 = (\Theta_0^1, \Theta_0^2)$, the algorithm works as follows:
For iteration $j = 1, \ldots, M$, and for block $k = 1, 2$.

- Propose a value $\tilde{\Theta}^k$ for the $k$th block, conditional on $\Theta_{j-1}^k$ for the $k$th block and the current value of the other block ($\Theta^{-k}$). $\Theta^{-k}$ stands for the remaining block except for the $k$th block.[2]
- Compute the acceptance probability $\alpha^k = \min\left\{1, \frac{f(\tilde{\Theta}^k|\Theta^{-k},y)}{f(\Theta_{j-1}^k|\Theta^{-k},y)}\right\}$.
  Update the $k$th block as

$$\Theta_j^k = \begin{cases} \tilde{\Theta}^k & \text{w.p. } \alpha^k \\ \Theta_{j-1}^k & \text{w.p. } (1-\alpha^k) \end{cases}$$

Note that when updating the model parameter block, we condition on the updated value for the price block.

[2] In our application, $\Theta^{-1} = \Theta^2$ and $\Theta^{-2} = \Theta^1$.

# D Fiscal multipliers and corporate taxation

In this section, we compare the fiscal multipliers when the infrastructure spending is combined with different tax policies. Three different policies are considered. The first policy is decreasing the corporate tax rate by 33% from the baseline level (27%→18%). The second policy uses the baseline level (27%), and the last policy increases the corporate tax rate by 33% from the baseline level (27%→36%).[3] The remaining balance in the fiscal budget after the change in taxation is financed by the lump-sum tax. Thus, the third policy collects the least amount of lump-sum tax among the three policies.[4]

Table D.2: Fiscal multipliers

| Fiscal multipliers | Low Corp. Tax | Baseline | High Corp. Tax |
|---|---|---|---|
| **Output** | | | |
| Short-run | 1.1637 | 1.0416 | 0.9210 |
| Long-run | 2.0758 | 1.8439 | 1.6149 |
| **Short-run (2 years)** | | | |
| Consumption | 0.1308 | 0.1719 | 0.2123 |
| Investment | 0.0224 | -0.0942 | -0.2094 |
| Labor income | 0.8028 | 0.6590 | 0.5180 |
| **Long-run (5 years)** | | | |
| Consumption | 0.9822 | 0.9251 | 0.8684 |
| Investment | 0.0671 | -0.0617 | -0.1889 |
| Labor income | 1.5127 | 1.2904 | 1.0720 |

Table D.2 reports the fiscal multipliers across the three corporate tax policies.

[3]The third policy mimics the Biden administration's plan to increase the corporate tax rate by 33%. As our baseline tax level is 27% while the corporate tax rate of 2022 is 21%, there is a level difference in the tax rate.

[4]Our fiscal multiplier analysis is based on the impulse response to the MIT fiscal spending shock under perfect foresight. Therefore, the representative household becomes indifferent between lump-sum tax financing and debt financing as long as the lifetime income is unaffected. If the model considers household heterogeneity under the borrowing limit and frictional financial market, this indifference collapses, leading to divergent fiscal multipliers between tax financing and debt financing as in Hagedorn, Manovskii, and Mitman (2019).

In the first policy with low corporate tax, the short-run multiplier is around 1.16, which is the greatest among the three. In the last policy with high corporate tax, the short-run multiplier is around 0.9210, which is the lowest among the three. The same ranking is observed for the long-run multipliers.

One of the main channels that cause the differences in the fiscal multipliers is the firm-level investment. When the fiscal spending is combined with the low corporate tax policy, due to the increased incentive of cumulating the future capital stock, the private investment crowds in, as can be seen from the positive investment multiplier of 0.0224. However, in other cases, the greater public capital stock crowds out the private capital investment. A similar pattern is observed in the long-run fiscal multipliers of private investment.

The differences in the response of private capital investment to the fiscal policy lead to the differences in the labor income response. The greater the private investment, the greater the employment effect on the economy. In the low corporate tax policy, the labor income multiplier is 0.80; in the baseline corporate tax policy, the labor income multiplier is 0.66; in the high corporate tax policy, the labor income multiplier is 0.52. None of the labor income multipliers are greater than unity in the short run. As we show later, this low labor income multiplier is due to the general equilibrium effect. In the partial equilibrium, the three short-run labor income fiscal multipliers are all greater than the unity. In the long run, the multipliers are all greater than the unity, even in the general equilibrium.

However, the low corporate tax policy is not a free lunch. The low corporate tax policy leads to the lowest consumption multiplier of 0.13 in the short run. This is because this tax policy requires the greatest lump-sum tax to finance the spending shock. This clearly shows what is the trade-offs in corporate tax policies; the low tax policy sacrifices the short-run welfare to achieve long-run welfare. In the long run, due to the private investment and labor income channels, the fiscal multiplier is the greatest for the low corporate tax policy.

# References


HAGEDORN, M., I. MANOVSKII, AND K. MITMAN (2019): "The Fiscal Multiplier," NBER Working Paper.

KHAN, A., AND J. K. THOMAS (2008): "Idiosyncratic Shocks and the Role of Nonconvexities in Plant and Aggregate Investment Dynamics," *Econometrica*, 76, 395–436.