How Small is Small? Non-linearities in Heterogeneous Agent Models *

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Abstract

We study the quantitative importance of nonlinearities for fiscal policy in heterogeneous-agent models. In standard calibrations that match average MPCs in the data, individual MPCs are highly nonlinear in wealth and fall sharply away from borrowing constraints. As a result, the aggregate consumption response is strongly concave in the size of the transfer: larger transfers relax constraints for many households and reduce the mass of high-MPC agents on impact. We study this mechanism first in partial equilibrium and then in a general-equilibrium model with endogenous production, labor supply, government debt, and nominal rigidities. Relative to fully nonlinear solutions, linear approximations substantially overstate the effects of empirically relevant stimulus sizes, even for modest values. Our results imply that, for this class of fiscal experiments, the set of shocks for which local methods are accurate is narrow, and quantitatively relevant policy analysis requires nonlinear methods.

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1 Introduction

There has been an explosion of work studying the effects of fiscal and monetary interventions in settings with heterogeneous agents and incomplete markets. These frameworks are useful because they do a good job of capturing relevant features of household-level spending and savings behavior. In particular, suitably calibrated versions can match both the level and distribution of marginal propensities to consume.

These aspects of consumption behavior are especially relevant for studying fiscal interventions, because the nature of failures of Ricardian equivalence lies at the heart of the aggregate and distributional effects of such policies. The size and pattern of MPCs underscore these departures from Ricardian equivalence and drives much of the difference between heterogeneous-agent and representative-agent models. Indeed, the effects of fiscal stimulus programs funded by future taxes are driven entirely by such departures.

A large part of the recent literature has analyzed these settings using various forms of first-order methods.[1] The most common approach, labeled SSJ by Auclert, Bardóczy, Rognlie and Straub (2021), computes an aggregate consumption function by aggregating consumption policy functions across households, and computes equilibria via a linear approximation of this function around its steady state in a suitably chosen vector of aggregate prices and policy variables. It is well understood that such methods approximate true equilibria well when the policy innovations or exogenous disturbances being studied are small. But how small is small?

We argue that for many of the most commonly studied types of fiscal interventions in this literature, small is indeed very small – much smaller than the aggregate shocks and interventions that macroeconomists are motivated to explore based on real-world experience.

Our starting point is the observation that for a funded fiscal stimulus program, the bulk of the aggregate effects are driven by the strength of departures from Ricardian equivalence, which in turn are driven by the extent to which households' marginal propensities to consume exceed those implied by the permanent income hypothesis. Although HA models can be calibrated to match quarterly MPCs observed in the data, the MPC functions in these models are highly nonlinear in wealth: they decline sharply away from borrowing constraints or kinks. It follows that MPCs are highly nonlinear in the size of a transfer, as large transfers move households away from constraints and substantially lower their MPCs. This observation leads

[1] Examples include Aggarwal, Auclert, Rognlie and Straub (2023), Bardoczy, Sim and Tischbirek (2024), Summers and Rachel (2019), Hänsel (2024), Campos, Fernández-Villaverde, Nuño and Paz (2024), Eichenbaum, Guerreiro and Obradovic (2025); Angeletos, Lian and Wolf (2024b,a).

us to conjecture that inferring the aggregate effects of a fiscal intervention on the basis of the aggregate consumption response to very small disturbances may be misleading. In the remainder of the paper, we investigate when this is and is not the case.

Overall, our findings do not bode well for using first-order methods, such as SSJ, to study the effects of fiscal interventions.

2 Partial Equilibrium

In this section, we present the analysis in partial equilibrium. The partial equilibrium exercise is particularly clear because it allows to highlight the key mechanism behind the non-linearity and assess its quantitative significance. In Section 3, we analyze the general equilibrium model under various specifications.

2.1 Household decision problem

Time is discrete and infinite $t = 0, 1, ...$ The economy is populated by a continuum of ex-ante identical households of measure one that face uninsurable idiosyncratic shocks.

At each date t, households are endowed with a stochastic flow of income y_t, and can trade a one-period real asset subject to a borrowing constraint $a_{i,t+1} \geq \underline{a}$. Households have a utility over consumption $u(c_t)$, which is a strictly increasing and concave, and discount the future at a rate β_{it}, which is stochastic.

The household problem is

$$\max_{\{c_{i,t}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{s \leq t-1} \beta_{is} \right) u(c_t) \tag{1}$$

subject to

$$c_{i,t} + a_{i,t+1} \leq (1 + r_{t-1}) a_{i,t} + y_{i,t} + T_{i,t}. \quad \text{and} \quad a_{i,t+1} \geq \underline{a} \tag{2}$$

The solution to the household problem yields decision rules for consumption $c(a, y)$ and next period's wealth $a'(a, y)$. These decision rules induce a stationary distribution that we denote by $\Gamma(a, y)$, with associated marginal distribution $\Gamma(a)$ over wealth.

2.2 Quantitative Results

Calibration. A period represents a quarter. We assume $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ with $\sigma = 2$. We set the interest rate to 2% annual and the borrowing limit to $\underline{a} = 0$. The income process follows Kaplan, Moll and Violante (2018), which features leptokurtic annual income growth as Guvenen, Karahan, Ozkan and Song (2015).

We assume the discount factor is *iid* and takes seven values equally spaced. We calibrate the mean and standard deviation to match: (i) and average MPC of 0.25—computed as the consumption response out of an infinitesimal increase in income; and (ii) wealth of 100% of GDP.

Results. Starting from the ergodic distribution, we consider an increase in income at period 0 for all households $T_{i,0} > 0$. Figure 1 (panel a) shows the initial stationary distribution. Figure 1 (panel b) shows the MPC as a function of initial assets. Figure 2 presents the main results of the partial equilibrium exercise. In the x-axis, the figure shows the increase in income, with a maximum of 10% of GDP. In the y-axis, the figure compares the response in the linear vs. non-linear simulations. One can see that the non-linear response is highly concave.

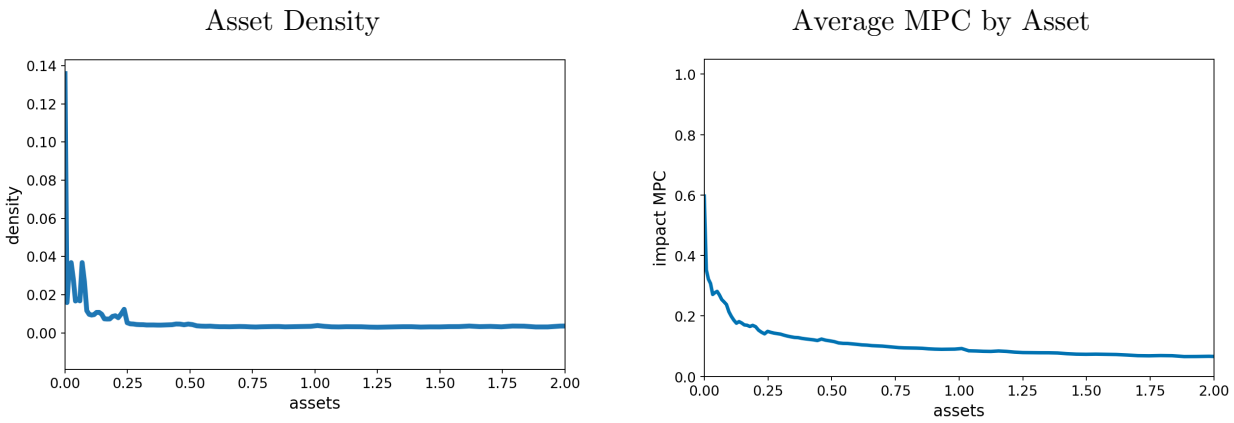


Figure 1: Partial equilibrium: steady-state asset density and MPC

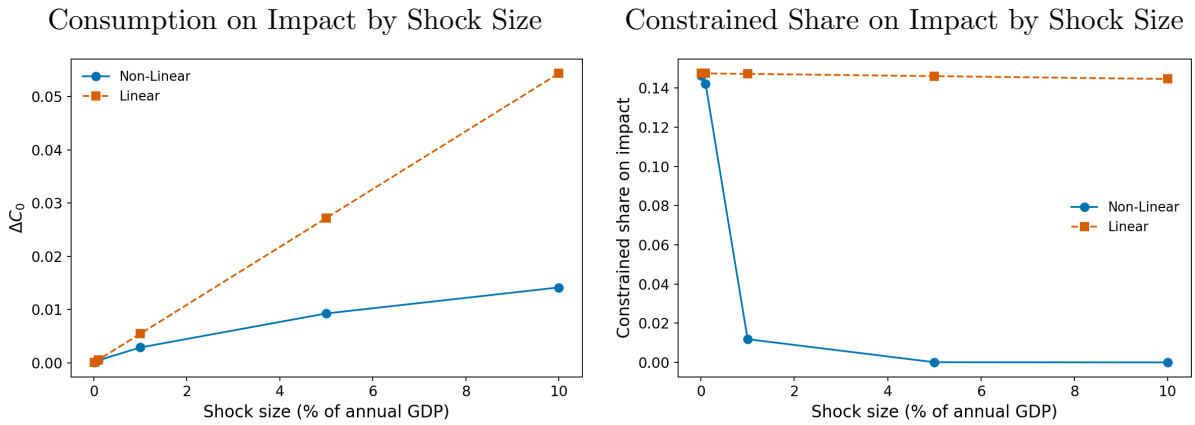


Figure 2: Partial equilibrium Responses

3 General Equilibrium Model

In this section, we study a general equilibrium model. The setup features endogenous production, labor supply, a market clearing for assets, as in Aiyagari-Huggett-Imrohoroglu incomplete market models, and nominal rigidities as in heterogenoeus agent New Keynesian models (e.g., Kaplan and Violante, 2014; Auclert, Rognlie and Straub, 2023). This will allow us to assess the macroeconomic effects of fiscal shocks, and how they are shaped by the non-linearities.

Households. Households' preferences are given by the following utility function

$$\mathbb{E}_0 \sum_{t \geq 0} \left(\prod_{s \leq t-1} \beta_{is} \right) [u(c_t) - v(n_{it})] \tag{3}$$

$v(\cdot)$ is a strictly increasing convex function in hours worked

Each period, a household i receives labor income, $e_{it} \frac{W_t}{P_t} n_{it}$, τ is a fixed tax rate and e_{it} is an idiosyncratic productivity shock. We assume that e_{it} is independent across agents and follows a Markov process with transition function π with unconditional mean normalized to one. Households also receive dividends $d_{i,t}$.

Households can trade a one-period real asset. They enter the period with a_{it} bonds that pays an interest rate r_{t-1}. Their budget constraint is given by

$$c_{i,t} + a_{i,t+1} \leq (1 + r_{t-1}) a_{i,t} + (1 - \tau) \left(d_{i,t} + \frac{W_t}{P_t} e_{i,t} n_{i,t} \right) + T_{i,t}. \tag{4}$$

where τ is a tax rate on household income.[2]

As in the partial equilibrium model, households are subject to a borrowing constraint $a_{i,t+1} \geq 0$. Hours are chosen by a labor union to be described below.

Firms. The economy can produce the final consumption good out of intermediate inputs according to a CES production function with elasticity of substitution $\mu/(\mu-1)$.

$$y_t = \left(\int_0^1 y_{jt}^{\frac{1}{\mu}} \, dj \right)^{\mu}. \tag{5}$$

Intermediate goods are produced out of labor according to $y_{jt} = n_{j,t}$. The maximization problem of the intermediate firm yields the standard monopolistic-competition pricing condition:

$$P_{jt} = \mu W_t. \tag{6}$$

In a symmetric equilibrium $P_{j,t} = P_t$.[3] Given constant markup μ over marginal cost, wage inflation equals price inflation, the real wage is $w_t = W_t/P_t = 1/\mu$, and real dividends are

$$d_t = \left(1 - \frac{1}{\mu}\right) Y_t.$$

Unions allocate hours uniformly across households in the baseline implementation, so labor disutility enters through aggregate hours.

Wage Phillips curve. We assume that wages are sticky and that all households work the same number of hours. In particular, we adopt a standard NK Phillips curve

$$\pi_t = \kappa \left(v'(N_t) - \frac{1}{\mu C_t} \right) + \bar{\beta} \, \pi_{t+1}, \tag{7}$$

where π_t denotes wage (and price) inflation, κ is the slope and $\bar{\beta}$ is the average discount factor. In a representative agent economy, (7) can be derived assuming that workers belong to monopolistic labor unions that face nominal wage adjustment costs (e.g., Erceg, Henderson and Levin, 2000). In a heterogeneous agent economy, (7) can be derived assuming that the union maximizes the welfare of a household with aggregate consumption C_t and that all households work the same amount of hours, $n_{i,t} = N_t$ for all i (Auclert, Rognlie and Straub,

[2] In our baseline experiment, we keep τ_t fixed because with endogenous labor supply, changes in tax rates generate distortionary effects even under Ricardian equivalence.

[3] Our baseline model has flexible prices and sticky wages. We consider sticky prices in Section 4.

2024).[4]

Fiscal and monetary policies. The government issues real bonds B_t. Its budget constraint is

$$B_{t+1} = G + \tau Y_t + T_t + (1 + r_{t-1})B_t, \tag{8}$$

Fiscal policy follows the rule

$$T_t = T_{ss} - \rho(r_t B_t - r_{ss}\bar{B}) + \epsilon_t \tag{9}$$

where $\{\epsilon_t\}$ represents a shock to the fiscal rule, realized at $t = 0$. The fiscal rule implies that whenever debt exceeds steady state, the amount of lump-sum transfers should be below the steady-state level.

Monetary policy follows Taylor rule for the nominal rate,

$$i_t = \bar{i} + \phi\,(\pi_t - \pi^\star). \tag{10}$$

where $\bar{i}$ is the steady-state nominal rate and $\bar{\pi}$ is the steady-state inflation.

Competitive equilibrium. We denote by $\Gamma(a, e)$ the distribution over asset holdings and productivity and by $a'_{t+1}(a_t, e_t)$ and $c_t(a_t, e_t)$ the recursive households policies. In addition, we define aggregates

$$A_{t+1} = \int a'_{t+1}(a_t, e_t)\,\Gamma_t(a, e)\,da, de, \tag{11}$$

$$C_t \equiv \int c_t(a_t, e_t)\,\Gamma_t(a, e)\,da\,de. \tag{12}$$

Market-clearing conditions are

$$A_{t+1} = B_{t+1} \tag{13}$$

for assets, and

$$C_t + G = Y_t. \tag{14}$$

for goods. We also have that arbitrage between nominal and real bonds imply

$$1 + i_t = (1 + r_t)(1 + \pi_{t+1}) \tag{15}$$

[4]An alternative is to assume that households supply a different level of labor, as in Guerrieri and Lorenzoni (2017).

Definition 1. Given a monetary policy rule (10) and a fiscal policy rule (9) an initial distribution of households over productivity and asset states Γ_0, an equilibrium is a sequence of allocations $\{Y_t, C_t, B_t, N_t, d_t\}$ and prices $\{\pi_t, w_t, i_t, r_t\}$ such that

- Households and firms optimize;
- Aggregate consumption and savings are given by (11) and (12)
- The wage equation (7) and the government budget constraint (8) are satisfied;
- The market for the final good and the bond market clear. That is, (13) and (14) hold.

3.1 Calibration

The calibration follows closely the one in Section 2. We now set the shock to the discount factor to match an annualized real interest rate of 2%, which is now endogenous in the model. Moreover, we set B_{ss} to 100% of annual GDP, the debt level of the U.S. government.

We calibrate the additional parameters that emerge in general equilibrium as follows. We assume the following functional form for the disutility of labor

$$v(n) = \chi \frac{n^{1+\nu}}{1+\nu}$$

where ν is the inverse Frisch elasticity, which we set equal to one. We normalize χ so that output equals one in steady state. We focus on zero steady-state inflation, $\bar{\pi} = 0$. We set G to 20% of GDP, $T_{ss} = 0$, and hence $\tau Y_{ss} = G + rB_{ss}$. We set $\kappa = 0.01$, consistent with standard estimates of the Phillips curve. For now, we set $\mu = 1.1$.

Table 1: Calibration

Parameter	Value	Description
B_{ss}	4	Steady-state government debt
r_{ss}	0.02	Steady-state annual real interest rate
κ	0.01	Phillips curve slope
μ	1.1	Steady-state markup
σ^{-1}	0.5	Intertemporal elasticity of substitution
ν	1	Inverse Frisch elasticity of labor supply
ϕ	1.5	Taylor coefficient
G	0.2	Government spending

Main fiscal experiment. We assume $\epsilon_0 > 0$ and $\epsilon_t = 0$ for all $t > 0$ and set $\rho = 0.78$. We consider a range of values for ϵ_0 to illustrate the role of non-linearities.

3.2 Main Results

Figure 3 presents our main result. As the size of the stimulus increases, the marginal increase in output gets smaller and smaller. Even for relatively modest shocks, the linear solution overstates significantly the aggregate response.

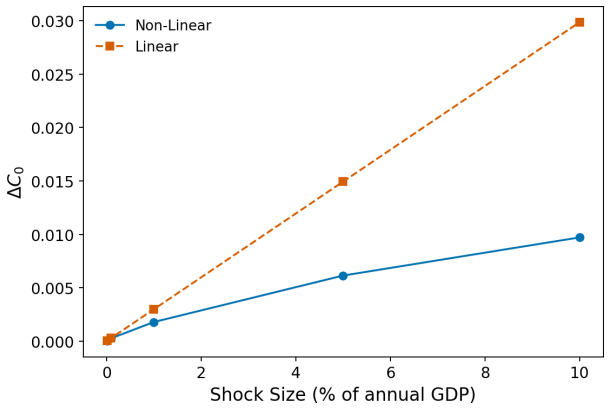


Figure 3: General equilibrium Output Response: non-linear vs SSJ

4 Extensions

In the next version of the paper, we compare results across different scenarios, including persistent ϵ_t shocks, alternative monetary policy and fiscal rules, nominal debt with unfunded shocks, flexible wages where the union chooses labor, flexible wages where each household chooses its own labor, and sticky prices with Rotemberg price adjustment costs.

5 Conclusions

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