Fiscal Policy Experiments in a Macroeconomic ABM with Capital and Credit

Tiziana Assenza, Paola Colzani, Domenico Delli Gatti, Jakob Grazzini

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Motivation

- We want to perform policy experiments in a macro ABM with capital and credit (CC-MABM) (Assenza, Delli Gatti, Grazzini, 2015).
- There are other macroeconomic agent based models with a banking system and capital accumulation (EURACE@Genoa: Cincotti-Raberto et al., EURACE@Bielefeld: Dawid et al., Keynes meeting Schumpeter: Dosi-Fagiolo et al.).
- CC-MABM is much simpler (for instance, there is no technical progress) and focuses on the short run effects (i.e. at the business cycle frequency: there is no growth) of capital accumulation and financial fragility.
- It should be easier, therefore to open the black box of the ABM and understand the macroeconomic effects of agents' interactions.

Related literature

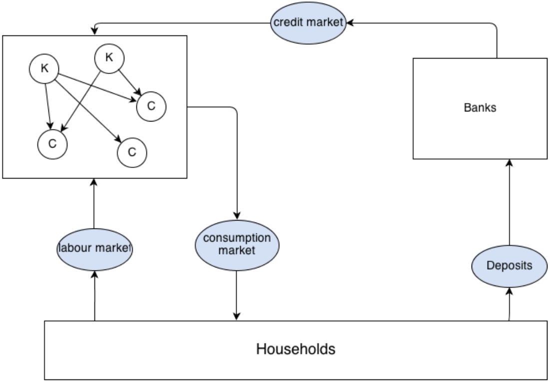
Experiments concerning the impact of fiscal, monetary and structural policies have already been performed within much more sophisticated macro ABMs (see Fagiolo-Roventini 2014 for an overview and comparison with DSGE models). To name just a few:

- Raberto-Cincotti-Teglio (2014)
- Dosi-Fagiolo-Napoletano-Roventini-Treibich (2014)
- Harting (2015)

CC-MABM

- Agents: households, firms, banks (and the public sector in the background).
- Markets: C-goods, labour, credit, deposits, K-goods
- Capital is produced by K-firms using only labor and sold to C-firms.
- C-firms use K-goods and labour to produce C-goods to be sold to households.
- Both types of firms use *credit* to finance production and *investment.*

The architecture of the model



Households

Households can be either workers or “capitalists”.

- The h-th *worker* ($h = 1, 2, ...H$) supplies inelastically one unit of labor.
  - If employed, he works and receives a (given) nominal wage w. A fraction t_w of the wage is taxed. t_w is the tax rate on wages. The employed worker's disposable income therefore is $w(1 - t_w)$.
  - If unemployed, he receives a subsidy zw where $0 < z < 1$ is the subsidy rate. He visits Z_e firms (chosen at random) and applies to firms with open vacancies.
- “Capitalists” own firms. There is one capitalist per firm.
  - If the f-th firm has made a profit, the f-th capitalist ($f = 1, 2, ...F$) receives dividends $\tau\pi_{ft-1}$. A fraction t_d of the dividends is taxed. t_d is the tax rate on dividends. The capitalist's disposable income therefore is $\tau\pi_{ft-1}(1 - t_d)$.

Consumers (1)

- As consumers – i.e. purchasers of C-goods – workers and capitalists behave exactly in the same way.
- The consumer computes *permanent income* as a weighted average of past incomes (wages or subsidies for workers, dividends for capitalists) with decaying weights.
- The budget allocated to consumption = permanent income + a fraction of wealth (deposits).
- Savings – i.e. the difference between current income and the budget allocated to consumption – are accumulated in the form of deposits at banks.
- Once the budget has been determined, the consumer goes shopping...

Consumers (2)

- The consumer visits Z_c C-firms (chosen at random) and buys C-goods starting from the firm which posts the lowest price.
- Since consumers rank the firms they visit and start buying from the firm posting the lowest price, there is an *implicit negative price elasticity* of the demand for the good produced by each C-firm.

Setting the price and the quantity

- The i-th *C-firm* ($i = 1, 2, ...F_c$) chooses the pair (P_{it}, Y_{it}) in conditions of uncertainty.
- Since households do not explore the entire space of purchasing opportunities (each household visits only few C-firms), the firm has *market power* on its own local market (i.e. there are as many local C-markets as there are C-firms).
- The firm does not know the demand Y_{it}^{d} for the goods she produces but she knows the *average price of competitors* P_t.
- *Desired production* Y_{it} is set at the level of *expected demand* Y_{it}^{e}.

Demand, inventories, queues (1)

- At the chosen price P_{it}, *given the average price* P_t, demand Y_{it}^d can be different from realized production $Y_{it} = Y_{it}^e$.
- If $\Delta_{it} := Y_{it} - Y_{it}^d = Y_{it}^e - Y_{it}^d > 0$: inventory accumulation $\Rightarrow$ *signal* of excess supply/positive forecasting error (demand has been overestimated).
  - C-goods are non-storable. If the firm ends up with a positive inventory, she gets rid of the unsold goods at zero costs.
- If $\Delta_{it} < 0$: queue of unsatisfied borrowers $\Rightarrow$ *signal* of excess demand/negative forecasting error (demand has been undererestimated).
- If $\Delta_{it} = 0$: "equilibrium"/no forecasting error

Demand, inventories, queues (2)

- The firm therefore receives *two signals*: the price charged by competitors P_t and the level of net supply Δ_{it} which reveals forecasting errors.
- On the basis of these two signals the firm decides *whether* to change the price or the expected demand and therefore the desired quantity (but not both).

Price adjustment

- The firm *changes the price* P_i wrt the status quo according to the following *rule of thumb*:

$$P_{it+1} = \begin{cases} P_{it}\left(1+\eta_{it+1}\right) & \text{if } \Delta_{it} \leq 0; \quad P_{it} < P_t \\ P_{it}\left(1-\eta_{it+1}\right) & \text{if } \Delta_{it} > 0; \quad P_{it} > P_t \end{cases} \tag{1}$$

- where η_{it+1} is a random positive parameter, $0 < \eta_{it+1} < 0.1$
- P_i cannot be smaller than average cost (including interest payments) AC.

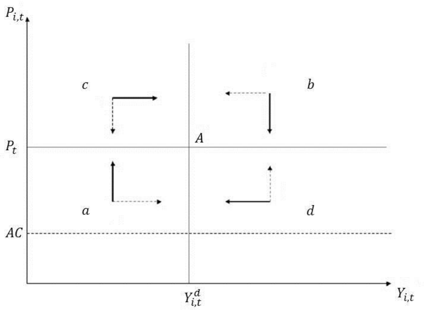
Quantity adjustment

- The firm updates *the expectation of future demand* Y_i^e and therefore the *desired scale of activity* Y_i^* according to the following *rule of thumb*:

$$\underbrace{Y_{it+1}^*}_{=Y_{it+1}^e} = \begin{cases} Y_{it} + \rho(-\Delta_{it}) & \text{if} \quad \Delta_{it} \leq 0; \quad P_{it} > P_t \\ Y_{it} - \rho\Delta_{it} & \text{if} \quad \Delta_{it} > 0; \quad P_{it} < P_t \end{cases} \tag{2}$$

- where ρ is a positive parameter, $0.5 < \rho < 1$
- *Adaptive expectations:* agents use the forecasting error they made to update expectations.

Price/quantity adjustment (1)



From price/quantity to capacity utilization

- Following the adaptive rules (1) (2) the firm tends to adjust her price toward the average price and her desired production towards demand.
- Once a decision has been taken on the desired output, the firm determines how much labor and how much capital she needs to reach that level of activity.
- Generally, only a fraction of the available capital will be utilized *(the rate of capacity utilization is generally smaller than one).*
- Labour is a variable input. Employment will be adjusted to reach the desired rate of capital utilization.

Labor and capital requirements

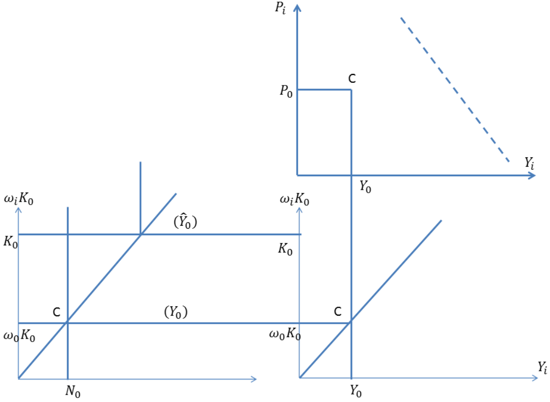
- Leontief technology: $\hat{Y}_{it} = min(\alpha N_{it}, \kappa K_{it})$ where $\hat{Y}_{it}$ is output *at full capacity utilization of capital.*
- By assumption, labor is always abundant. Output at full capacity can therefore be rewritten as $\hat{Y}_{it} = \kappa K_{it}$.
- Hence $\hat{N}_{it} = \frac{\kappa}{\alpha} K_{it}$ is employment at full capacity utilization. $\frac{\kappa}{\alpha}$ is the reciprocal of capital intensity.
- When *capacity is not fully utilized* output is $Y_{it} = \omega_{it} \hat{Y}_{it} = \omega_{it} \kappa K_{it}$ where $0 < \omega_{it} \leq 1$ is the *rate of capacity utilization.*
- In this case, labour requirements will be $N_{it} = \omega_{it} \hat{N}_{it} = \omega_{it} \frac{\kappa}{\alpha} K_{it}$.

Scaling up production (1)

- Suppose the firm wants to scale up production in t+1, i.e. $Y^*_{it+1} = Y_1 > Y_{it} = Y_0$ where $Y_0 = \omega_0 \kappa K_0$.
- The actual capital available in t+1 has been determined by investment in t I_{it} (based on adaptive expectations concerning future demand): $K_{it+1} = K_0$
- Current employment is $N_0 = \omega_0 \frac{\kappa}{\alpha} K_0$.
- Hence the maximum output attainable given the current stock of capital is $\hat{Y}_0 = \kappa K_0$.

Scaling up production (2)

- If the capital stock is "large", i.e. $kK_0 > Y_1$, then the firm could reach the desired scale of activity by setting *capacity utilization* at the required level: $\omega_1 = Y_1/K_0$.
- Therefore desired employment will be $N_1 = \frac{Y_1}{\alpha} = \frac{\omega_1 \kappa K_0}{\alpha}$
- The firm will post vacancies $\upsilon_{i,t+1} = N^*_{it+1} - N_{it}$ i.e., $\upsilon_1 = N_1 - N_0$



P_i
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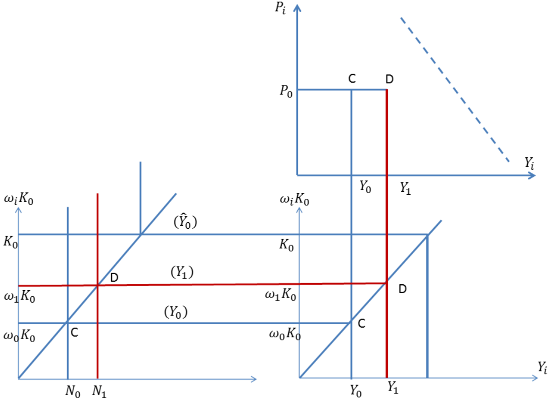
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The availability of capital as a constraint on production

- If desired output Y_1 is greater than output at full capacity $\hat{Y}_0$, the firm is constrained to produce at full capacity, given the current capital stock.
- Also employment will be set at full capacity utilization of capital: $\hat{N}_0 = \frac{\hat{Y}_0}{\alpha}$
- The scale of activity the firm can reach is constrained by the availability of capital.

The availability of labor as a constraint on production

- Vacancies are $\upsilon_{i,t+1} = \max\left(N^*_{it+1} - N_{it}, 0\right)$
- Unemployed workers visits Z_e firms (chosen at random) in order to find a job.
- Since the wage is uniform, once they have found a firm with an unfilled vacancy they stop searching.
- Actual employment $N_{it+1} \leq N^*_{it+1}$. In fact the firm may not be able to fill all the vacancies.
- By assumption, labor is always abundant but frictions on the labor market may leave some vacancies unfilled. The scale of activity the firm can reach is therefore constrained by the availability of labor.

Investment in a nutshell

- Investment is implemented in t to increase capital in t+1.
- The firm computes the average capital stock used until period t-1 $\overline{K}_{it-1}$ using an *adaptive rule*: $\overline{K}_{it-1}$ is a weighted average of past *utilized* capital with exponentially decaying weights.
- The firm plans a buffer: capital desired in t+1 is $\overline{K}_{it-1}/\bar{\omega}$ where $\bar{\omega}$ is the desired "long run" rate of capital utilization (set at 85% in the simulations).
- Hence investment will be $I_{it} = \frac{\overline{K}_{it-1}}{\bar{\omega}} - K_{it} + \delta \overline{K}_{it-1}$

C-firms: the financing gap

- Given desired production and therefore labor and capital requirements, the firm determines the financing gap, i.e. the difference between the funds necessary to carry out production and "internal liquidity":

$$F_{it} = \max\left(wN_{it}^{*} + P_t^K I_{it} - M_{it-1}, 0\right)$$

- P^K is the price index of capital goods and M_i is the firm's internal liquidity (deposits).
- The financing gap determines the demand for loans of the firm.

K-firms in a nutshell

- The j-th *K-firm* $(i = 1, 2, ...F_k)$ produces a K-good by means of a technology that uses only labor $K_{jt} = \alpha N_{jt}$
- It chooses the pair $\left(P^K_{jt}, K_{jt}\right)$ without knowing the demand K^d_{jt} for the goods she produces (coming from C-firms).
- *Desired production* is set at the level of *expected demand*. This determines therefore also desired employment.
- The firm posts *vacancies* if desired employment is greater than current employment.
- The firm experiences a *financing gap* if the wage bill is greater than internal liquidity. In this case, she will ask for a bank loan.

The interest rate

- For simplicity we assume that there is only one bank who receives deposits from households and firms and supplies funds to firms.
- The bank has to decide how much credit she should extend to each borrower and the interest rate to charge.
- She evaluates the borrower's credit risk by means of the following definition of leverage ($f = i, j$)

$$\lambda_{ft} = \frac{debt_{ft}}{assets_{ft}}$$

The interest rate (cont'd)

- The interest rate r_{ft} is increasing with the policy (risk free) rate r and with the borrower's probability of bankruptcy p_{ft}, which in turn is increasing with leverage: $p_{ft} = p(\lambda_{ft})$. In the end, therefore

$$r_{ft} = \mu(r, \lambda_{ft}) \qquad \mu_r, \mu_\lambda > 0$$

- The bank asks for an external finance premium proportional to the financial fragility of the borrowing firm.

Credit allocation and rationing

- The maximum amount of credit the bank allocates to each borrower (credit limit) is increasing with the bank's equity E_{bt} and the bank's leverage λ_b and decreasing with the borrower's leverage λ_{ft}:

$$\bar{F}_{ft} = \frac{\phi(\lambda_{ft} F_{ft})}{assets_{bt}} \lambda_b E_{bt}$$

- The loan actually extended is

$$l_{ft} = \min\left(F_{ft}, \bar{F}_{ft}\right)$$

- Higher leverage implies a higher interest rate and a smaller loan
- The firm can be rationed if the demand for new loans (financing gap) is greater than the credit limit. The scale of activity the firm can reach is therefore constrained by the availability of credit.

Summing up

- The C-firm enjoys full flexibility in adjusting production when production must be scaled down and when output should be increased but "not too much"
- When the desired increase in output is sizable the C-firm hits a capacity constraint.
- Actual production may be *smaller* than desired if the C-firm does not succeed in achieving
  - the"appropriate" level of capital (because of insufficient investment in the past) and/or
  - the "appropriate" level of employment (because of unfilled vacancies) and/or
  - the "appropriate" level of funding (because of credit rationing).
- For K-firms, actual production may be smaller than desired if the firm does not succeed in achieving the "appropriate" level of employment and/or credit.

Taxes, subsidies, bonds

- The Government raises taxes on wages and on dividends, carries on Government expenditure and implements transfers in the form of unemployment subsidies and interest payments on Government bonds.
- For the moment, for simplicity we assume that there is not Government expenditure, no taxes on dividends and no interest payments on Government bonds. Therefore taxes are $TA = t_w wN = t_w \frac{w}{\alpha} Y$ where N is total employment and Y is real GDP and transfers are $TR = zw(H - N) = z\frac{w}{\alpha}(\bar{Y} - Y)$ where $\bar{Y}$ is potential output
- A public sector deficit occurs if if $zw\,(H - N) > w\,(1 - t)\,N$ i.e. if $u > \frac{t}{t+z}$ where u is the unemployment rate. Equivalently, a deficit occurs if $Y < \frac{z}{t+z}\bar{Y}$.
- If a deficit occurs, bonds are issued and sold to the bank. The bank has a portfolio constraint and cannot refuse to purchase Government bonds.

Updating the firm's net worth

- Profits of the i-th firm after interest payments are

$$\pi_{it} = P_{it} s_{it} - (wN_{it} + \omega_{it}\delta K_{it}) - r_{it} L_{it}$$

- s_{it} are actual sales, i.e. $s_{it} = Y_{it} - \Delta_{it}$ if $\Delta_{it} > 0$; $s_{it+1} = Y_{it}$ if $\Delta_{it} \leq 0$.
- Retained profits are used to accumulate net worth (and therefore liquidity available for investment).
- The same procedure applies to K-firms (but K-firms do not incur the cost of capital).

Updating the bank's net worth

- The profits of the bank coincide with interest payments received (deposits are not remunerated):

$$\pi_{Bt} = \sum_{f \in \Theta^+} r_{ft} L_{ft}$$

where Θ^+ is the set of solvent borrowers.

- Profits are used to accumulate the bank's net worth

$$E_{bt+1} = E_{bt} + \pi_{Bt} - BD_t$$

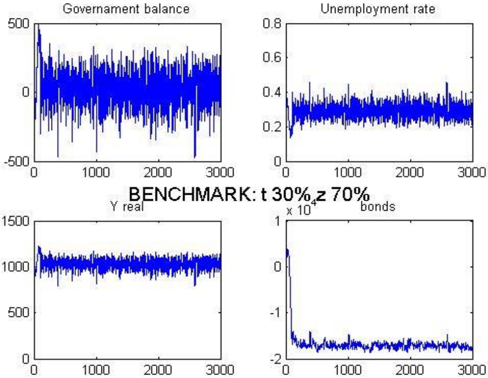
- BD_t is "bad debt" i.e. the total value of non performing loans $\sum_{f \in \Theta^-} \Delta L_{ft}$ where Θ^- is the set of insolvent borrowers.
- Each bankrupt firm is replaced by a new entrant. This *one-to-one replacement* of bankrupt firms with entrant firms allows us to keep the total firms' population constant.

Calibration

- 3000 periods
- Workers: $H = 3000$
- C-firms: $F_c = 200$
- K-firms: $F_k = 50$
- Applications $Z_e = 5; Z_c = Z_k = 2$
- 12 private sector parameters + 2 fiscal policy parameters (z and t_w)
- 6 initial conditions

We start with a benchmark parameter configuration: $z = 0.70$ and $t_w = 0.30$

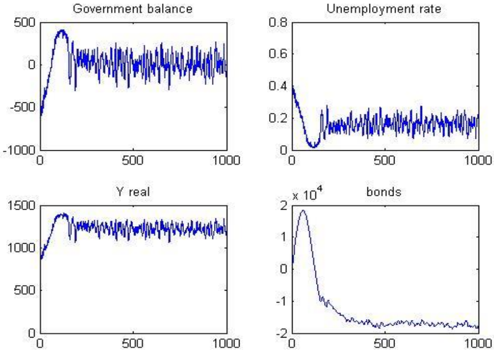
Unemployment, GDP, bonds with $z = 0.70$ and $t_w = 0.30$



Unemployment, GDP, bonds with $z = 0.70$ and $t_w = 0.30$ (cont'd)

- Irregular fluctuations of the unemployment rate around long run mean of ≈30% and of GDP around a long run mean slightly greater than 1000.
- The public sector balance oscillates around a long run mean slightly greater than... zero! On average, surpluses (more than) offset deficits so that the public sector accumulates (liquid) assets.

Unemployment, GDP, bonds with $z = 0.75$ and $t_w = 0.15$



Unemployment, GDP, bonds with $z = 0.75$ and $t_w = 0.15$ (cont'd)

- With higher z and lower t_w the long run mean of u falls to ≈15% and that of GDP increases to 1250.
- The public sector balance oscillates around a long run mean slightly greater than... zero! On average, surpluses (more than) offset deficits so that the public sector accumulates (liquid) assets.

The macroeconomic effects of fiscal policy

- With a reduction in taxes and an increase in unemployment subsidies the economy is better off: the unemployment rate decreases.
- But there is more than that. Over the long run the macroeconomy self-organizes around an unemployment rate (and a level of output) such that the public sector is balanced.

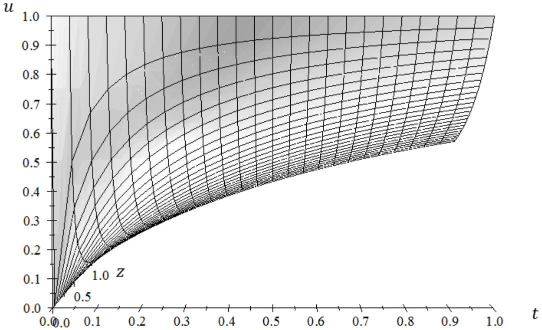
$$u \approx \frac{t}{t+z} \tag{3}$$

- Therefore on average the public sector does not accumulate debt.

The macroeconomic effects of fiscal policy (cont'd)

- Why is it so? Unemployment is decreasing with z. By introducing subsidies, consumption increases, hence employment and income. Given t_w, tax revenues also go up, filling the gap between public transfers and taxes.
- The social planner can choose any point on the *policy surface* represented by (3)

Policy frontier



Blinder-Solow resurrected

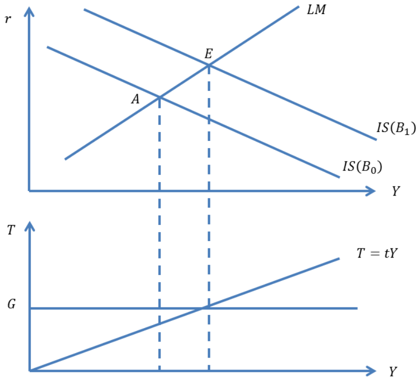
To get the flavour of what's happening to the macroeconomy, let's go back to Blinder-Solow ("Does Fiscal Policy Matter",1974)

$$Y = \alpha G + \beta B + \gamma M \tag{4}$$

$$\dot{B} = G - tY \tag{5}$$

A budget deficit makes bonds increase ⇒ household's wealth increases (this is a non-Barrian world) ⇒ consumption increases (this is a non-Ricardian world) and so does output and tax revenues.

Blinder-Solow resurrected (cont'd)



Translating Blinder-Solow into CC-MABM

- Deficit financed unemployment subsidies $\Rightarrow$ households' consumption increases (and so do does their wealth).
- Also C-firms are better off: leverage goes down and so does the interest rates they are charged.
- Also K- firms are better off: higher consumption $\Rightarrow$ higher investment
- The increase in GDP feeds into tax revenues and helps filling the public sector financing gap.

Translating Blinder-Solow into CC_MABM (cont'd)