Pseudo Code of the Simulation Program for:

"Unemployment Benefits and Financial Leverage in an Agent Based Macroeconomic Model"

by

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We provide a "pseudo code" of the simulation program which describes the algorithmic structure of our agent based macroeconomic model. In what follows the symbol % is used to introduce some comments about variables, parameters, etc. In particular, the pseudo code is organized in different "modules" which describe the various markets of the economy and other characteristics. We hope that the pseudo code can be of help, together with the description of the model proposed in the paper, in reproducing simulation results, independently of the particular programming software.

% SET TIME SPAN AND NUMBER OF AGENTS

$T = 150$;   % number of simulation periods
$H = 500$;   % number of households/workers
$F = 80$;   % number of firms
$B = 10$;   % number of banks

% PARAMETER SETTING

$phi = 3$;   % (fixed) labour productivity
$c1 = 0.8$; $c2 = 0.3$;   % propensity to consume income/wealth
$chi = 0.2$;   % matching imperfect information
$pw = \text{round}(0.33*H)$;   % fraction of public workers
$wagemin = 0.5$;   % setting of a lower bound for wages
$tau = 0.3$;   % tax rate on income
$taupatr = 0.05$;   % tax rate on wealth
$parpatr = 3$;   % setting of tax wealth
$parsc = 0.1$;   % setting of firms' inventories
$beta = 0.1$;   % maximum banks' exposure on a single firm
$reg1 = 10$;   % regulatory parameter for credit supply
$reg2 = 0.5$;   % regulatory parameter for credit supply
$alpha = 0.05$;   % adjustment parameter
$rho = 2$;   % setting of firm-specific component of interest rate on bank loans
$rCB = 0.01$;   % policy rate set by the central bank
$levatmin = 0.01$;   % setting of a lower bound for firm leverage

%%
%%% INITIAL CONDITIONS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%

%%% FIRMS

FOR each firm
      set random values for firm's net worth;
      set random values for prices;
      set initial values for firm leverage;
      set initial dividend share = ½;
      set initial firm-component of the interest rate = rCB % equal to policy rate
      (set zero for other variables)
ENDFOR

%%% BANKS

FOR each bank
      set random values for bank's net worth;
      set random values for deposits;
      set initial dividend share = ½;
      set random values for the bank-specific component of the interest rate
      set random values for offered interest rate on deposits
      (set zero for other variables)
ENDFOR

%%% HOUSEHOLDS

FOR each household
      set random values for household's wealth;
      set random values for wage;
      set random values for required interest rate on deposits
      (set zero for other variables)
ENDFOR

%%% CENTRAL BANK

SET initial CB's money supply (= 0);

%%% GOVERNMENT

SET all variables equal to zero

%%%
%%% MAIN PROGRAM %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%

FOR each period of time (t)

%%% ONE-TO-ONE REPLACEMENT OF DEFAULTED AGENTS %%%%%%%%%%%%

FOR each firm/bank

    IF an agent went bankruptcy
        replace with a new agent with initial conditions
        new entrants are financed from dividends
        (if dividends are not enough, then the public sector intervenes)
    ENDIF

ENDFOR

%%% CREDIT MARKET %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%% firms' credit demand %%%

FOR each firm

    IF (profit rate(t-1) > average interest rate on banks' loan(t-1)) AND (inventories(t-1) < (*parsc* .* production (t-1))
        firm leverage = firm leverage (t-1) * (1 + *alpha* * U(0,1))
    ELSE IF (profit rate(t-1) = average interest rate on banks' loan(t-1)) AND (inventories(t-1) < (*parsc* .* production(t-1))
        firm leverage = firm leverage (t-1)
    ELSE IF (profit rate(t-1) < average interest rate on banks' loan(t-1)) OR (inventories(t-1) ≥ (*parsc* .* production(t-1))
        firm leverage = firm leverage (t-1) * (1 – *alpha* * U(0,1))
    ENDIF

    firm's leverage = max(firm leverage, *levatmin*);

    firm's credit demand = firm's leverage * firm's net worth

    firm-specific component of the interest rate = (*rho* .^ levat) / 100;

ENDFOR

%%% interest rate setting: banks %%%

FOR each bank

        IF the bank did not manage to lend all credit supply
                bank-specific component of the interest rate (t) = bank-specific component of the interest rate (t-1) * (1 – *alpha**U(0,1));
        ELSE
                bank-specific component of the interest rate (t) = bank-specific component of the interest rate (t-1) * (1 + *alpha**U(0,1));
        ENDIF
ENDFOR

%%% banks' credit supply %%%

banks' money from the CB = CB's total money supply .* (banks' net worth / banking sector's net worth capital);

interests paid to the CB = *rCB* * banks' money from the CB

bank capital "k1" = *reg1* * banks' net worth;

bank capital "k2" = *reg2* * banks' net worth + banks' deposits + banks' money from the CB;

banks' credit supply = min(bank capital "k1", bank capital "k2");

banks' max credit supply to single firm = *beta* * banks' credit supply

%%% Credit market matching %%%

residual bank credit supply = bank credit supply

residual firm credit demand = credit demand

WHILE (total residual firms' credit demand > 0 AND total residual banks' credit supply > 0)

        SET a random list of "active" firms (that is, with positive residual credit demand)

        FOR each firm (according to the random order)

                observe a random subset (*chi* * B) of "active" banks (that is, with positive credit supply)
                choose the bank with lowest interest rate
                effective bank loan to firm = min(residual firm credit demand, residual bank credit supply, banks' max credit supply to single firm)
                residual firm credit supply = residual firm credit supply – effective bank loan to firm

        ENDFOR

ENDWHILE

firms' capital = firms' net worth + firms' bank loans

%%% central bank %%%

CB's total money supply(t+1) = max(0 , ½ * CB's total money supply(t) + ½ * (residual firms' credit demand – residual banks' credit supply))

%%%%%%%%% LABOUR MARKET MATCHING %%%%%%%%%%%%%%

%%% Public workers %%%

SET a random set of "public" workers (to be employed by the government)

%%% Labor market matching %%%

WHILE (there are unemployed workers AND at least one firm has enough money to hire a worker)

    SET a random list of "active" firms (that is, with open vacancies)

    FOR each firm (according to the random order)

        observe a random subset of unemployed workers
        choose the worker asking for the lowest wage
        IF (firm's capital ≥ worker's wage)
            firm's workers = firm's workers + 1
            firm's capital = firm's capital – worker's wage
        ENDIF

    ENDFOR

ENDWHILE

net workers' wage = (1 - *tau*) * workers' wage

tax revenues = sum(*tau* * workers' wage)

%%% wage updating rule %%%

FOR each worker

    IF employed at time t
        worker's wage (t+1) = worker's wage * (1 + *alpha* * U(0,1))
    ELSE (if unemployed)
        worker's wage (t+1) = worker's wage * (1 – *alpha* * U(0,1))
    ENDIF

workers' wage(t+1) = max(workers' wage, *wagemin**(1+*tau*)*max(prices))

ENDFOR

%%% dividends to households %%%

cash = cash(t-1) + a fraction of total dividends proportional to individual wealth

%%% consumption %%%

workers' consumption = *c1* * net workers' wage + *c2* * (deposit + cash)

workers' consumption = max(workers' consumption, max(prices))

workers' consumption = min(workers' consumption, net workers' wage + deposits + cash)

%%% production %%%

Firms' production = phi * firms' workers + inventories

%%% Updating rule for prices %%%

FOR each firm

      IF (no inventories AND positive production in the previous period)
          price(t+1) = price(t) * (1 + *alpha* * U(0,1))
      ELSE
          price(t+1) = price(t) * (1 – *alpha* * U(0,1))
      ENDIF

END

price = max(price, firms' unitary cost)

%%% GOODS MARKET MATCHING %%%%%%%%%%%%%%%%%%%%%%%%%%

firms' with goods to be sold = firm's production + inventories

WHILE (firms have unsold goods AND there is at least a household with enough money to buy goods)

      SET a random list of "active" households (that is, with money to be spent)

      FOR each household (according to the random order)

          observe a random subset of firms for which firms' with goods to be sold > 0

           choose the firms asking for the lowest price
           IF (household's money ≥ price of a single good)
                household's money = household's money – price
                firm's goods to be sold = firm's goods to be sold – 1
           ENDIF

      ENDFOR

ENDWHILE

firms' inventories = firms' goods to be sold (at the end of the goods market matching)

households' expenditure = sum(prices of goods bought from firms)

households' savings = net worker wage – households' expenditure + interests on deposits

%%% Public deficit and debt

public deficit = public expenditures (public workers' wage) + interests on public debt (+ eventually bailouts) – tax revenues – transfer of interests from the CB

public debt = public debt(t-1) + public deficit

%%% private banks and public debt

FOR each bank with residual available money (residual "k2")

      IF public debt > 0 AND sum(banks' residual credit supply) ≥ public debt
          banks' government bonds are a share of public debt proportional to bank size
      ELSEIF public debt > 0 AND sum(banks' residual credit supply) < public debt
          banks' government bonds = a portion of public dedt equal to banks' residual credit
          supply
      ELSE
          banks' government bonds = 0
      ENDIF

IF sum(banks' government bonds) < public debt
      CB's government bonds = public debt – sum(banks' government bonds) % that is, the
      central bank is committed to buy outstanding government securities
ENDIF

%%% DEPOSIT MARKET %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

FOR each bank

    IF bank exhausted credit supply (by lending to private agents and to the government) in t-1
        bank's offered interest rate on deposits = (bank's offered interest rate on deposits(t-1)
        * (1 + $alpha$*U(0,1))
    ELSE
        bank's offered interest rate on deposits = bank's offered interest rate on deposits(t-1)
        * (1 – $alpha$*U(0,1))
    ENDIF

banks' offered interest rate on deposits = min(banks' offered interest rate on deposits, rCB)

ENDFOR

FOR each household

    IF household's deposit in t-1 > 0
        households' required interest rate on deposits = households' required interest rate on
        deposits (t-1) * (1 + $alpha$*U(0,1))
    ELSE
        households' required interest rate on deposits = households' required interest rate on
        deposits (t-1) * (1 – $alpha$*U(0,1))

ENDFOR

%%% deposit market matching

WHILE min(households' required interest rate on deposits) > max(banks' offered interest rate on deposits)

    SET a random list of banks

    FOR each bank (according to the random order)

        observe a random subset of households (with savings > 0)
        choose the household with the lowest required interest rate
        bank's deposit = bank's deposits + (this) household's deposit (net of wealth tax)

    ENDFOR

ENDWHILE

households' cash = money not deposited in banks

%%% firms' profits

firms' gross profits = revenues from selling goods – wage bill – interest paid on bank loans

FOR each firm

       IF firm's gross profit > 0
            firm's profit tax = *tau* * firm's gross profit
            firm's net profit = firm's gross profit – firm's profit tax
       ELSE
            firm's net profit = firm's gross profit
            negative profits will be subtracted from next profits to compute the tax
       ENDIF

%%% firms' dividend policy

FOR each firm

       IF (firm's inventories = 0 AND firms' production >0)
            firms' dividend share = firms' dividend share(t-1) * (1 – *alpha**U(0,1))
       ELSE
            firms' dividend share = firms' dividend share(t-1) * (1 + *alpha**U(0,1))
       ENDIF

ENDFOR

firms' dividend share = min(firms' dividend share,1)

firms' dividends = firms' dividend share * firm's net positive profit

firms' profit after dividends = firm's net profit – firms' dividends

firms' net worth = firms' net worth(t-1) + firms' profit after dividends

FOR each firm

       IF firm's net worth > *parpatr* * average price
            firm's net worth = (1 – *taupatr*) * firm's net worth
       ENDIF

ENDFOR

%%% banks' profit

banks' profit = interests on loans + interests on public debt – interests paid on deposits – interests on money from the CB – bad debt (non-performing loans according to the LGD rate of bankrupted firms)

FOR each bank

    IF bank's gross profit > 0
        bank's profit tax = *tau* * bank's gross profit
        bank's net profit = bank's gross profit – bank's profit tax
    ELSE
        bank's net profit = bank's gross profit
        negative profits will be subtracted from next profits to compute the tax
    ENDIF

%%% banks' dividend policy

FOR each bank

    IF the bank did not manage to lend all the credit supply
        banks' dividend share = banks' dividend share(t-1) * (1 + *alpha**U(0,1))
    ELSE
        banks' dividend share = banks' dividend share(t-1) * (1 + *alpha**U(0,1))
    ENDIF

ENDFOR

banks' dividend share = min(banks' dividend share,1)

banks' dividends = banks' dividend share * bank's net positive profit

banks' profit after dividends = bank's net profit – banks' dividends

banks' net worth = banks' net worth(t-1) + banks' profit after dividends

FOR each bank

    IF bank's net worth > *parpatr* * average price
        bank's net worth = (1 – *taupatr*) * bank's net worth
    ENDIF

ENDFOR

%%% households' wealth

FOR each household

    IF default of the related bank
        Household's wealth decreases due to loss deposits, according to the LGD rate
    ENDIF

ENDFOR

ENDFOR (end of main program)