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Article

Technology Shocks and Employment in Open Economies

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Appendix (Technology Shocks and Employment in Open Economies)

This appendix provides background information as to how the Matlab file (technologyshock.m) that solves the model is written and how to replicate Figure 1. First, I briefly describe the method used for solving the model. Then, I attempt to provide guidance as to how to install the necessary files for running the file that solves the model. I also describe the file's key part so readers can e.g. investigate how responsive the main results of the paper are to changes in key parameter values. In addition, the model and the file can easily be used to analyse a number of questions related to the international transmission of technology shocks. In the final part, I lay out the log-linearised versions of the model's equations, to allow for an in-depth understanding of the model's foundations.

The File

The model is solved using the algorithm developed by Klein (2000)[1] and McCallum (2001)[2]. The equations of the model are written in matrix form $AE_t x_{t+1} = Bx_t + Cz_t$, where $E_t x_{t+1}$ denotes the expectation of x_{t+1} formed in time t and x_t is a vector of endogenous variables, $x_t = [y_t' \; k_t']'$, where k_t is predetermined and y_t is non-predetermined. A and B are $n \times n$ matrices, C is $n \times 1$ matrix and z_t is a vector of exogenous variables determined by an AR(1) process.

The core file that solves the model is called technologyshock.m. This file uses software written by McCallum (2001). To be able to run the file, the first step is to install the needed Matlab files (See McCallum 2001, 1-2). The necessary files, solvek.m, impo.m, sim33p.m, qzswitch.m, reorder.m, autocor.m, dlsim.m and dimpulse.m, are available for download from Bennett McCallum's web page.

The next step is to start Matlab and to copy/paste the files to the specified path. The files should be installed as .m files, not as .txt files. Choose File and then Set Path from the menu bar. A new window opens showing all folders accessible by Matlab. Choose Add Folder to specify the desired folder and then press Save to save this setting for future sessions. The Matlab

[1] Klein, P. (2000). Using the Generalized Schur Form to Solve a Multivariate Linear Rational Expectations Model. *Journal of Economic Dynamics and Control* 24 (10): 1405–1423.

[2] McCallum, B. (2001). Software for RE Analysis. Computer software available at http://wpweb2.tepper.cmu.edu/faculty/mccallum/research.html

toolboxes have been changed since McCallum wrote the above-mentioned software package. The problems that may arise due to these changes, can be dealt with as follows: Start the m-file editor to edit the file[3] dimpulse.m and for the first line of the code, after the comments, write nargin = 6;. Save the dimpulse.m file. Then you should be able to run the technologyshock.m file. One way to do this is to type *technologyshock* in the Command Window and then press enter. The file automatically generates Figure 1.

The file that solves the model is divided into two separate parts. The first part of the file (rows 1-444) solve the LCP version of the model and the second part (rows 456-) solves the PCP version. First, parameter values are specified. The number of the period plotted is chosen in row 62 (and 468).[4] Variables are specified in rows 71-116. Equations are written in rows 127-330 (See McCallum 2001, 4). Rows 385-444 create Figure 1. After completing these specifications, the file solves the PCP version of the model.

The file is simple to apply to, e.g., an analysis of the sensitivity of the results to changes in key parameter values. Suppose, for example, that one would like to study how the results change, if a technology shock is transitory and the persistence of a technology shock is 0.8. This can be projected as follows. Replace ark 1.0; with ark = 0.8; (in rows 55 and 464), then save the file and run it again.

Equations

Equilibrium of the log-linear version of the LCP model can be described by the following equations

$$\hat{\delta}_t + \hat{P}_{t+1} + \hat{C}_{t+1} = \hat{P}_t + \hat{C}_t \tag{A1}$$

$$\hat{\delta}^*_t + \hat{P}^*_{t+1} + \hat{C}^*_{t+1} + \hat{E}_{t+1} = \hat{P}^*_t + \hat{C}^*_t + \hat{E}_t \tag{A2}$$

$$\hat{\ell}_t = \hat{w}_t - \hat{C}_t - \hat{P}_t \tag{A3}$$

$$\hat{\ell}^*_t = \hat{w}^*_t - \hat{C}^*_t - \hat{P}^*_t \tag{A4}$$

$$-\hat{P}_t = \frac{1}{\epsilon}\hat{C}_t + \frac{\beta\hat{\delta}_t}{\epsilon\,(1-\beta)} \tag{A5}$$

[3] Choose File and Open from the menu bar.

[4] Note that if $\gamma = 0.75$ the economies do not reach the new steady state after ten periods.

$$-\hat{P}_t^* = \frac{1}{\epsilon}\hat{C}_t^* + \frac{\left(\hat{\delta}_t^* + \hat{E}_{t+1} - \hat{E}_t\right)\beta}{\epsilon(1-\beta)} \tag{A6}$$

$$\hat{y}_t = \hat{a}_t + \hat{\ell}_t \tag{A7}$$

$$\hat{y}_t^* = a_t^* + \hat{\ell}_t^* \tag{A8}$$

$$\hat{x}_t(z) = -\theta\left(\hat{b}_t(z) - \hat{P}_t\right) + \hat{C}_t \tag{A9}$$

$$\hat{v}_t(z) = -\theta\left(\hat{b}_t^*(z) - \hat{P}_t^*\right) + \hat{C}_t^* \tag{A10}$$

$$\hat{v}_t^*(z^*) = -\theta\left(\hat{b}_t(z^*) - \hat{P}_t\right) + \hat{C}_t \tag{A11}$$

$$\hat{x}_t^*(z^*) = -\theta\left(\hat{b}_t^*(z^*) - \hat{P}_t^*\right) + \hat{C}_t^* \tag{A12}$$

$$\hat{y}_t = n\hat{x}_t + (1-n)\hat{v}_t \tag{A13}$$

$$\hat{y}_t^* = n\hat{x}_t^* + (1-n)\hat{v}_t^* \tag{A14}$$

$$\hat{a}_t = \rho\hat{a}_{t-1} + \epsilon_t \tag{A15}$$

$$\hat{a}_t^* = \rho\hat{a}_{t-1}^* + \varepsilon_t^* \tag{A16}$$

$$\hat{P}_t = n\hat{b}_t(z) + (1-n)\hat{b}_t(z^*) \tag{A17}$$

$$\hat{P}_t^* = n\hat{b}_t^*(z) + (1-n)\hat{b}_t^*(z^*) \tag{A18}$$

$$\hat{b}_t(z) = (1-\gamma)\sum_{s=t}^{\infty}\gamma^{s-t}\hat{p}_s(z) \Rightarrow \hat{b}_t(z) = \gamma\hat{b}_{t-1}(z) + (1-\gamma)\hat{p}_t(z) \tag{A19}$$

$$\hat{b}_t^*(z) = \gamma\hat{b}_{t-1}^*(z) + (1-\gamma)\hat{p}_t^*(z) \tag{A20}$$

$$\hat{b}_t(z^*) = \gamma\hat{b}_{t-1}(z^*) + (1-\gamma)\hat{p}_t(z^*) \tag{A21}$$

$$\hat{b}_t^*(z^*) = \gamma \hat{b}_{t-1}^*(z^*) + (1-\gamma)\hat{p}_t^*(z^*) \tag{A22}$$

$$\hat{p}_t(z) = \beta\gamma\hat{p}_{t+1}(z) + (1-\beta\gamma)(\hat{w}_t - \hat{a}_t) \tag{A23}$$

$$\hat{q}_t(z) = \beta\gamma\hat{q}_{t+1}(z) + (1-\beta\gamma)(\hat{w}_t - \hat{a}_t - E_t) \tag{A24}$$

$$\hat{q}_t(z^*) = \beta\gamma\hat{q}_{t+1}(z^*) + (1-\beta\gamma)(\hat{w}_t^* - \hat{a}_t^*) \tag{A25}$$

$$\hat{p}_t(z^*) = \beta\gamma\hat{p}_{t+1}(z^*) + (1-\beta\gamma)(\hat{w}_t^* - \hat{a}_t^* + E_t) \tag{A26}$$

$$\beta\hat{D}_t = n\left(\hat{x}_t(z) + \hat{b}_t(z)\right) + (1-n)\left(\hat{E}_t + \hat{v}_t(z) + \hat{b}_t^*(z)\right) - \hat{D}_{t+1} - \hat{P}_t - \hat{C}_t \tag{A27}$$

$$-\hat{\delta}_t = -\hat{\delta}_t^* + \hat{E}_{t+1} - \hat{E}_t. \tag{A28}$$

Equations (A1)-(A6) are the log-linearised versions of the first-order conditions. Equations (A7) and (A8) are the production functions. Equations (A9)-(A11) show the demand for goods. Equations (A12)-(A13) show the population-weighted composition of total output. Equations (A14)-(A15) depict technology shocks. Equations (A16)-(A17) are aggregate price indices. Equations (A19)-(A22) show Calvo-weighted price indexes. Equation (A19), for example, is the Calvo-weighted price index of domestic goods sold in the domestic market. Equations (A23)-(A26) are the optimal pricing rules. Equation (A27) is the consolidated budget constraint of the domestic economy and equation (A28) is uncovered interest parity.

28 variables remain to be determined $\hat{C}$, $\hat{C}^*$, $\hat{P}$, $\hat{P}^*$, $\hat{\delta}$, $\hat{\delta}^*$, $\hat{\ell}$, $\hat{\ell}^*$, $\hat{w}$, $\hat{w}^*$, $\hat{D}$, $\hat{x}(z)$, $\hat{v}(x)$, $\hat{x}^*(z^*)$, $\hat{v}^*(x^*)$, $\hat{y}$, $\hat{y}^*$, $\hat{p}(z)$, $\hat{q}(x)$, $\hat{p}^*(z^*)$, $\hat{q}(x^*)$, $\hat{b}(z)$, $\hat{b}^*(z)$, $\hat{b}^*(z^*)$, $\hat{b}(x^*)$, $\hat{E}$, $\hat{a}$ and $\hat{a}^*$. The 28 equations that jointly determine them are (A1)-(A28). Note that the foreign consolidated budget constraint is left out because one equation is redundant by Walras' law. In the Matlab file that solves the model, a number of other variables require specifying (e.g. predetermined variables and exchange rate expectations). As a result the file contains 38 variables that are determined by 38 equations.

To simplify the file that solves the model, define $-\tau_t = \hat{P}_t + \hat{C}_t$. Then equations (A1) can be written as

$$\hat{\delta}_t = -\tau_t + \tau_{t+1}. \tag{A29}$$

Using this equation and the definition of τ, the money demand function (A5) can be written as

$$\frac{\beta}{1-\beta}\tau_{t+1} = (\varepsilon - 1)\hat{P}_t + \frac{1}{1-\beta}\tau_t. \tag{A30}$$

Equilibrium of the log-linear version of the PCP model can be described by the following equations

$$\hat{\delta}_t + \hat{P}_{t+1} + \hat{C}_{t+1} = \hat{P}_t + \hat{C}_t \tag{A31}$$

$$\hat{\delta}_t^* + \hat{P}_{t+1}^* + \hat{C}_{t+1}^* + \hat{E}_{t+1} = \hat{P}_t^* + \hat{C}_t^* + \hat{E}_t \tag{A32}$$

$$\hat{\ell}_t = \hat{w}_t - \hat{C}_t - \hat{P}_t \tag{A33}$$

$$\hat{\ell}_t^* = \hat{w}_t^* - \hat{C}_t^* - \hat{P}_t^* \tag{A34}$$

$$-\hat{P}_t = \frac{1}{\epsilon}\hat{C}_t + \frac{\beta\hat{\delta}_t}{\epsilon(1-\beta)} \tag{A35}$$

$$-\hat{P}_t^* = \frac{1}{\epsilon}\hat{C}_t^* + \frac{\left(\hat{\delta}_t^* + \hat{E}_{t+1} - \hat{E}_t\right)\beta}{\epsilon(1-\beta)} \tag{A36}$$

$$\hat{y}_t = \hat{a}_t + \hat{\ell}_t \tag{A37}$$

$$\hat{y}_t^* = a_t^* + \hat{\ell}_t^* \tag{A38}$$

$$\hat{y}_t(z) = -\theta\left(\hat{b}_t(z) - \hat{P}_t\right) + n\hat{C}_t + (1-n)\hat{C}_t^* \tag{A39}$$

$$y_t^*(z^*) = -\theta\left(\hat{b}_t^*(z^*) - \hat{P}_t^*\right) + n\hat{C}_t + (1-n)\hat{C}_t^* \tag{A40}$$

$$\hat{a}_t = \rho\hat{a}_{t-1} + \epsilon_t \tag{A41}$$

$$\hat{a}_t^* = \rho\hat{a}_{t-1}^* + \varepsilon_t^* \tag{A42}$$

$$\hat{P}_t = n\hat{b}_t(z) + (1-n)\hat{b}_t^*(z^*) + (1-n)\hat{E}_t \tag{A43}$$

$$\hat{P}_t^* = n\hat{b}_t(z) - n\hat{E}_t + (1-n)\hat{b}_t^*(z^*) \tag{A44}$$

$$\hat{b}_t(z) = \gamma\hat{b}_{t-1}(z) + (1-\gamma)\hat{p}_t(z) \tag{A45}$$

$$\hat{b}_t^*(z^*) = \gamma\hat{b}_{t-1}^*(z^*) + (1-\gamma)\hat{p}_t^*(z^*) \tag{A46}$$

$$\hat{p}_t(z) = \beta\gamma\hat{p}_{t+1}(z) + (1-\beta\gamma)(\hat{w}_t - \hat{a}_t) \tag{A47}$$

$$\hat{q}_t(z^*) = \beta\gamma\hat{q}_{t+1}(z^*) + (1-\beta\gamma)(\hat{w}_t^* - \hat{a}_t^*) \tag{A48}$$

$$\beta\hat{D}_t = \hat{y}_t(z) + b_t(z) - \hat{D}_{t+1} - \hat{P}_t - \hat{C}_t \tag{A49}$$

$$-\hat{\delta}_t = -\hat{\delta}_t^* + \hat{E}_{t+1} - \hat{E}_t. \tag{A50}$$

The PCP version of the model contains 20 unknown variables ($\hat{C}, \hat{C}^*, \hat{P}, \hat{P}^*$, $\hat{\delta}, \hat{\delta}^*, \hat{\ell}, \hat{\ell}^*, \hat{w}, \hat{w}^*, \hat{D}, \hat{y}, \hat{y}^*, \hat{p}(z), \hat{q}(x^*), \hat{b}(z), \hat{b}^*(z^*), \hat{E}, \hat{a}$ and $\hat{a}^*$) that are determined by 20 equations (A31)-(A50). As above, the foreign consolidated budget constraint is left out (Walras' law). In the Matlab file a number of other variables have to be specified. Thus, the part of the file that solves the model in the case of PCP contains 28 variables that are determined by 28 equations.