

# Problem Set 1: EDEIR Model Calibration to Switzerland

February 22, 2020

Due date and time: Monday, March 30, at 8:00am (prior to the tutorial)  
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This problem set asks you to adapt the EDEIR model from Uribe and Schmitt-Grohé (2017) to the economy of Switzerland. The problem set comes in two parts.

**PART I:** The first part of the problem set asks you to construct the relevant data. If you wish to receive early clarification, we recommend that you complete this first part by Saturday, February 29. However, you will only be graded on the submissions by the due date on Monday, March 30, at 8:00am.

**PART II:** The second part of the problem set proceeds in three steps: from model setup as a planner's problem, to preliminary model simulation for Canada, to model calibration for Switzerland. (A model simulation for Switzerland is deferred to the next problem set.)

Please upload your solutions to this problem set (as a **zip** file) to the respective folder on *StudyNet* (Canvas). Your zip file should contain your code, your data set, and a pdf file with your written solution. Please create one folder per question (e.g., a folder "Q1 Data Preparation", etc.). Please name the zip file in the following way: PS1\_surname\_name\_20.zip (e.g., PS1\_Holmes\_Sherlock\_20.zip). After the deadline for submission on Monday, March 30, at 8:00am (prior to the tutorial), the *StudyNet* (Canvas) folder will automatically close and you will not be able to submit your solutions anymore.

For your convenience, scans of Tables 4.1 and 4.2 from Uribe and Schmitt-Grohé (2017) are reproduced at the end of this document in Figures 1 and 2.

## PART I

### 1 Data Preparation

Complete the following data preparations and comparisons to the benchmark open economy.

For this question, feel free to use a software package of your choice, including Excel, Stata or Matlab. For sample code in Matlab or Stata, please see the files at *StudyNet* (Canvas) or [econ.ucsd.edu/muendler/teach/20s/8270](http://econ.ucsd.edu/muendler/teach/20s/8270).

The **deliverable product** for this question has *five* components: a report of a single number (the Swiss mean capital share), a report of higher-order moments for statistics in three country-specific tables, a written discussion of results and their comparisons, a copy of the prepared data, and a copy of the Matlab code (or Stata code, Excel macro/spreadsheet, or the like).

1. **Obtain** *World Development Indicators* (WDI) data for all available countries over the period 1990–2018 and the following time series, at the *annual* frequency:

- NY.GDP.PCAP.KN: Real GDP per capita (constant LCU)  $y_t$ ,
- NE.CON.PRVT.ZS: Households and NPISHs final consumption expenditure (percent of GDP)  $\check{c}_t$  and compute consumption expenditure per capita  $c_t = \check{c}_t y_t / 100$ ,
- NE.GDI.TOTL.ZS: Gross capital formation (percent of GDP)  $\check{i}_t$  and compute investment per capita  $i_t = \check{i}_t y_t / 100$ ,
- NE.CON.GOV.T.ZS: General government final consumption expenditure (percent of GDP)  $\check{g}_t$  and compute government expenditure per capita  $g_t = \check{g}_t y_t / 100$ ,

- NE.IMP.GNFS.ZS: Imports of goods and services (percent of GDP)  $\ddot{m}_t$  and compute imports per capita  $m_t = \ddot{m}_t y_t / 100$ ,
- NE.EXP.GNFS.ZS: Exports of goods and services (percent of GDP)  $\ddot{x}_t$  and compute exports per capita  $x_t = \ddot{x}_t y_t / 100$ ,
- BN.CAB.XOKA.GD.ZS: Current account balance (percent of GDP)  $\ddot{c}_t$  and compute the current account per capita  $ca_t = \ddot{c}_t y_t / 100$ .

You should visit the WDI download portal [datacatalog.worldbank.org/dataset/world-development-indicators](http://datacatalog.worldbank.org/dataset/world-development-indicators). A csv (comma separated values) format might be most useful, as it is understood by most statistical and computational software packages.

2. **Obtain** hours worked per capita  $h_t$  data for all available countries over the period 1990–2018 from the Conference Board’s Total Economy Database [www.conference-board.org/data/economydatabase](http://www.conference-board.org/data/economydatabase), using the series *TEDI, 1950–2019*. (If you prefer not to set up an account, please download the data from *StudyNet* (Canvas).) A csv (comma separated values) format might be most useful. Note that  $h_t$  is total hours worked per capita, not per worker. Merge the time series for  $h_t$  with those from the *World Development Indicators* (WDI) by country and year. As the country variable for the merge, use the ISO-3 code.
3. **Drop** all countries for which at least one variable has less than three non-missing values in the period 1990–2018.
4. For Switzerland, **obtain** the capital share in national income for the period 1995–2018 from the Swiss Federal Statistical Office [www.bfs.admin.ch/bfs/en/home/statistics](http://www.bfs.admin.ch/bfs/en/home/statistics). For this purpose, **use** Swiss gross domestic product under the income approach and compute the annual share of compensation of employees (D.1) in gross domestic product (B.1\*b). Note that the capital share is one less the labor share in national income. **Report** the unweighted mean capital share in national income over the full period 1995–2018.
5. **Detrend** the time series from items 1 and 2. See sample codes *data\_prep\_and\_detrend\_Q1.m* (Matlab) and/or *data\_prep\_and\_detrend\_Q1.do* (Stata).
  - For real output  $y_t$ , consumption  $c_t$ , investment  $i_t$ , government spending  $g_t$  and hours worked  $h_t$  per capita, detrend (separately) the natural logarithms using a log-quadratic trend as in section 1.1 of the Uribe and Schmitt-Grohé (2017) textbook. For example, for log real output per capita  $\ln y_t$ , fit the ordinary-least squares regression  $\ln y_t = \beta_0 + \beta_1(t - 1990) + \beta_2(t - 1990)^2 + \ln y_t^c$ , where the residual  $\ln y_t^c$  is called the cyclical component and the fitted part is called the secular (or trend) component  $\ln y_t^s$ . Store the cyclical component of all variables.
  - For the trade-balance-to-output ratio  $tb_t/y_t = (x_t - m_t)/y_t$  and the current-account-to-output ratio  $ca_t/y_t$  detrend (separately) the levels using a quadratic trend as in section 1.1 of the Uribe and Schmitt-Grohé (2017) textbook. For example, for the current-account-to-output ratio  $ca_t/y_t$ , fit the ordinary-least squares regression  $ca_t/y_t = \beta_0 + \beta_1(t - 1990) + \beta_2(t - 1990)^2 + \epsilon_t$ , where the residual is the cyclical component. Store the cyclical component of all variables.
  - For the level of the trade balance per capita  $tb_t = x_t - m_t$  and the level of the current account  $ca_t$  per capita, first divide them by the secular component of real output per capita  $\exp\{\ln y_t^s\}$ , and then detrend (separately) the levels using a quadratic trend as in section 1.1 of the Uribe and Schmitt-Grohé (2017) textbook. For example, for the trade balance per capita  $tb_t$ , fit the ordinary-least squares regression  $tb_t / \exp\{\ln y_t^s\} = \beta_0 + \beta_1(t - 1990) + \beta_2(t - 1990)^2 + \epsilon_t$ , where the residual is the cyclical component. Store the cyclical component of all variables.
6. **Compute** the standard deviation, the serial correlation coefficient, and the correlation coefficient with the *cyclical* component of GDP per capita ( $\ln y_t^c$ ) for (i) Canada, (ii) Switzerland and (iii) either one poor country or one emerging market for the period 1990–2018 using the *cyclical* components of the detrended variables from item 5. **Report** the results in three separate tables, one per country.
7. **Compare** the results from item 6 for (i)–(iii) with each other (“cross-sectional” analysis), and compare the results for country (i) over the period 1990–2018 to those reported for Canada for the period 1960–2011 in the Uribe and Schmitt-Grohé (2017) textbook, middle panel of Table 4.2, and those in the Mendoza (1991) benchmark paper, left panel of Table 4.2 in the textbook (“panel” analysis). **What** is the ranking of volatilities in countries (i)–(iii) during our period?

## PART II

### 2 Decentralized Economy and Planner Problem

Using the first-order conditions and equilibrium relationship from the decentralized version of the EDEIR model, derive the planner's version of the model as presented in the Uribe and Schmitt-Grohé (2017) textbook. For all derivations, assume for simplicity that households and firms have perfect foresight, and *omit the expectations operator*.

The **deliverable product** for this question has *one* component: a written derivation of the planner's version of the model from the decentralized economy version.

For this question, recall the following conventions on notation:

- Elasticity of intertemporal substitution:  $\bar{\sigma}$  in decentralized economy (lecture notes) and Obstfeld and Rogoff (1996) but  $\sigma \equiv 1/\bar{\sigma}$  in planner problem of Uribe and Schmitt-Grohé (2017);
- Net foreign wealth  $b_t$  in decentralized economy (lecture notes) and Obstfeld and Rogoff (1996) but  $d_{t-1} \equiv -b_t$  in planner problem of Uribe and Schmitt-Grohé (2017);
- Interest rate quoted today for returns tomorrow  $r_t$  in decentralized economy (lecture notes) and Obstfeld and Rogoff (1996) but  $r_{t-1} = (r^* + p(d_{t-1}))$  in planner problem of Uribe and Schmitt-Grohé (2017);
- Firm's maximized (ex-dividend) value  $v_t$  in decentralized economy (lecture notes) and Obstfeld and Rogoff (1996) but  $p_t^s$  in planner problem of Uribe and Schmitt-Grohé (2017);
- Equity shares  $\theta_t$  in decentralized economy (lecture notes) but  $s_t$  in planner problem of Uribe and Schmitt-Grohé (2017);
- Dividend  $div_t = u_t k_t - i_t - \frac{\phi}{2}(k_{t+1} - k_t)^2$  in decentralized economy (lecture notes) but  $\pi_t$  in Uribe and Schmitt-Grohé (2017).

1. For the representative household's dynamic programming problem, explain the Bellman function

$$U(b_s, \theta_s) = \max_{b_{s+1}, \theta_{s+1}, h_s} [u(c_s, h_s) + \beta U(b_{s+1}, \theta_{s+1})]$$

under the intertemporal budget constraint  $c_s = (1 + r_s)b_s - b_{s+1} - v_s(\theta_{s+1} - \theta_s) + div_s \theta_s + w_s h_s$ .

2. Derive the first-order conditions, including the one for labor supply, and state the transversality conditions for global bond holdings (net foreign wealth) and domestic equity. Why can the transversality conditions be considered first-order conditions in the decentralized economy?
3. Assume complete home bias in equity so that  $\theta_t = 1$  in equilibrium. Derive the Euler equation for consumption (global bond holdings) and the intertemporal optimality condition for equity holdings from the preceding first-order conditions.
4. Define  $\lambda_t \equiv u_c(c_s, h_s)$ . From the above results, derive the first-order conditions (4.5), (4.7) and (4.8) as well as the equilibrium conditions (4.17) and (4.19) for the planner's problem in Uribe and Schmitt-Grohé (2017, Ch. 4).
5. In the setup of the decentralized economy, there are two production sectors. In one sector, firms produce and rent out capital goods to other producers. Denote the rental rate for a unit of capital with  $u_t$ . For a capital accumulation function  $k_{s+1} = (1 - \delta)k_s + i_s$  and under quadratic adjustment costs  $\frac{\phi}{2}(k_{s+1} - k_s)^2$ , the Bellman equation can be written as

$$V(k_s) = \max_{k_{s+1}} \left[ u_s k_s - i_s - \frac{\phi}{2}(k_{s+1} - k_s)^2 + \frac{1}{1 + r_s} V(k_{s+1}) \right].$$

Explain why.

6. In the other production sector, final-goods manufacturers combine capital and labor under a Cobb-Douglas production function with capital intensity  $\alpha$  and a Hicks-neutral productivity factor  $A_t$ . Derive the final-goods manufacturer's first-order conditions for capital and labor demand.

7. Derive the capital producing firms' dividends in terms of returns on capital at the final-goods manufacturers.
8. Derive the capital providing firms' intertemporal optimality condition. With this result and  $\lambda_t \equiv u_c(c_s, h_s)$ , derive the first-order condition (4.10) as well as the equilibrium condition (4.18) for the planner's problem in Uribe and Schmitt-Grohé (2017, Ch. 4), using the specific functional form for quadratic adjustment costs from above.
9. Use the final-goods manufacturers' first-order conditions together with the household's first-order condition for optimal labor supply to derive the first-order conditions (4.9) and (4.11) for the planner's problem in Uribe and Schmitt-Grohé (2017, Ch. 4), with the specific functional form for Cobb-Douglas production but without any parametric assumption on optimal labor supply.
10. Use the expression for optimal dividends from above in the intertemporal budget constraint  $c_s = (1 + r_s)b_s - b_{s+1} - v_s(\theta_{s+1} - \theta_s) + div_s\theta_s + w_s h_s$  together with Euler's Theorem to derive the equilibrium conditions (4.16), (4.20), and (4.21) for the planner's problem in Uribe and Schmitt-Grohé (2017, Ch. 4).

### 3 Simulating the EDEIR model for Canada

Simulate the EDEIR model for the Canadian economy, using the calibrated values from the Uribe and Schmitt-Grohé (2017) textbook.

For this question use Matlab. Most economists would arguably complete this simulation step in Matlab. For sample code in Matlab, similar to that at [www.columbia.edu/~mu2166/book](http://www.columbia.edu/~mu2166/book) by Uribe and Schmitt-Grohé, please see the files at *StudyNet* (Canvas) or [econ.ucsd.edu/muendler/teach/20s/8270](http://econ.ucsd.edu/muendler/teach/20s/8270). Note that you do *not* need to reprogram or adjust any Matlab file for this question. Matlab files with names that end in “.Q3.m” are used only in question 3.

The **deliverable product** for this question has *one* component: a written discussion of the ability of the model to explain observed business cycle patterns in Canada.

1. This step is already completed in the code but still listed for completeness. Set the following parameters without a relationship to specific country data for 1990–2018, following Mendoza (1991) (also reported in Table 4.1 of the Uribe and Schmitt-Grohé (2017) textbook):
  - the parameter  $\sigma$  (the inverse of the intertemporal elasticity of substitution),
  - the depreciation rate  $\delta$ ,
  - the world interest rate  $r^*$ ,
  - and the subjective discount factor  $\beta = 1/(1 + r^*)$ .
2. This step is already completed in the code but still listed for completeness. Set the following parameters as in Table 4.1 of the Uribe and Schmitt-Grohé (2017) textbook:
  - the capital elasticity  $\alpha$  of the Cobb-Douglas production function,
  - the parameter  $\omega$ , which determines the wage elasticity of labor supply  $1/(\omega - 1)$ ,
  - the parameter  $\phi$ , which governs capital adjustment costs,
  - the parameter  $\psi$ , which regulates the sensitivity of the real interest rate to a country's net wealth,
  - the persistence of the technology shock  $\rho$ , and
  - the volatility of the technology shock  $\eta$ ,

For this purpose, approximate the equilibrium dynamics up to first order using the Matlab procedure from sections 4.5 and 4.6 of the Uribe and Schmitt-Grohé (2017) textbook.

3. **Compute** the model-implied (theoretical) second moments as in the Uribe and Schmitt-Grohé (2017) textbook, right-most panel of Table 4.2. **Comment** on the ability of the model to explain observed business cycle patterns in Canada between 1990 and 2018, using the standard deviation, the serial correlation coefficient, and the correlation coefficient with the cyclical component of GDP per capita ( $\ln y_t^c$ ) for Canada from item 5 in question 1 above.

## 4 Calibrating the EDEIR model to Switzerland

Calibrate the EDEIR model of the Uribe and Schmitt-Grohé (2017) textbook to the Swiss economy.

For this question use Matlab. For sample code in Matlab beyond the textbook-provided code (a loop over the steady-state simulation), please see the files at *StudyNet* (Canvas) or [econ.ucsd.edu/muendler/teach/20s/8270](http://econ.ucsd.edu/muendler/teach/20s/8270). Note that you do need to reprogram or adjust the Matlab files with names that end in “\_Q4.m”.

The **deliverable product** for this question has *three* components: a copy of your edited Matlab code, a report of five calibrated parameter values, and a written discussion of the ability of the model to explain observed business cycle patterns in Switzerland.

1. This step is already completed in the code but still listed for completeness. Set the following parameters without a relationship to the Swiss data for 1990–2018, following Mendoza (1991) (also reported in Table 4.1 of the Uribe and Schmitt-Grohé (2017) textbook):
  - the parameter  $\sigma$  (the inverse of the intertemporal elasticity of substitution),
  - the depreciation rate  $\delta$ ,
  - the world interest rate  $r^*$ ,
  - and the subjective discount factor  $\beta = 1/(1 + r^*)$ .
2. **Set** the following parameters to match the first moments of the Swiss data:
  - the capital elasticity of the production  $\alpha$  to one less the average labor share in national income for Switzerland for the period 1995–2018,
  - the composite parameter  $\bar{b}/y \equiv -\bar{d}/y$  so that  $-\bar{b}/y = \bar{d}/y = (tb/y)/r^*$ , where  $tb/y$  is the raw ratio (*not* detrended) from the Swiss data for 1990–2018,  $r^*$  is as calibrated above, and steady-state output will then be determined by the model’s parameters ( $y = [(1 - \alpha)\kappa^{\alpha\omega}]^{1/(\omega-1)}$  and  $\kappa = [\alpha/(r^* + \delta)]^{1/(1-\alpha)}$ ), similar to the procedure in section 4.5 of the Uribe and Schmitt-Grohé (2017) textbook.
3. From your answer to item 5 in question 1 above, **use** the following seven higher moments of the Swiss data for 1990–2018 as target values for calibration:
  - the standard deviation of (the cyclical component of) hours worked  $h_t$ ,
  - the standard deviation of (the cyclical component of) investment  $i_t$ ,
  - the serial correlation of (the cyclical component of) investment  $i_t$ ,
  - the standard deviation of (the cyclical component of) the trade-balance-to-output ratio  $tb_t/y_t = (x_t - m_t)/y_t$ ,
  - the serial correlation of (the cyclical component of) the trade-balance-to-output ratio  $tb_t/y_t = (x_t - m_t)/y_t$ ,
  - the standard deviation of (the cyclical component of) output  $y_t$ , and
  - the serial correlation of (the cyclical component of) output  $y_t$ .

**Adjust** the Matlab code that loops over the steady-state simulations and minimizes the deviation of the model-produced seven moments from the empirical seven moments above. The Matlab iteration routine sets and resets the following five parameters to match the preceding seven higher moments:

- the parameter  $\omega$ , which determines the wage elasticity of labor supply  $1/(\omega - 1)$ ,
- the parameter  $\phi$ , which governs capital adjustment costs,
- the parameter  $\psi$ , which regulates the sensitivity of the real interest rate to a country’s net wealth,
- the persistence of the technology shock  $\rho$ , and
- the volatility of the technology shock  $\eta$ .

For the steady-state computations, approximate the equilibrium dynamics up to first order using the Matlab procedure described in sections 4.5 and 4.6 of the Uribe and Schmitt-Grohé (2017) textbook but feed the calibrated values for the Swiss economy into each iterative call of the steady-state computation. As starting values for the Swiss economy, use the Canada-calibrated parameters as in Table 4.1 of the Uribe and Schmitt-Grohé (2017) textbook.

4. **Report** the calibrated parameter values for  $\omega$ ,  $\phi$ ,  $\psi$ ,  $\rho$ , and  $\eta$ .
5. **Compute** the model-implied (theoretical) second moments as in the Uribe and Schmitt-Grohé (2017) textbook, right-most panel of Table 4.2, but now for the calibration to Switzerland.
6. **Comment** on the ability of the model to explain observed business cycle patterns in Switzerland between 1990 and 2018.

## 5 Sensitivity of Calibrated Parameters to Target Moments

Calibrate the EDEIR model of the Uribe and Schmitt-Grohé (2017) textbook to the Swiss economy with two alterations, to assess the sensitivity of calibrated parameters to target moments.

Reuse your Matlab code from question 4 and alter the target moments as stated below.

The **deliverable product** for this question has *three* components: a copy of your edited Matlab code, a report of five calibrated parameter values, and a written discussion of the sensitivity of the calibrated parameters to alterations of the moments.

1. From your seven higher moments of the Swiss data for 1990–2018 in item 3 of question 4 above, **raise** the standard deviation of (the cyclical component of) hours worked  $h_t$  to 140 percent of its actual value in the data. As in item 3 of question 4 above, launch the Matlab iteration routine to find the following five parameters under the new target:  $\omega$ ,  $\phi$ ,  $\psi$ ,  $\rho$ , and  $\eta$ . **Report** the calibrated parameter values and **explain** why they differ from the prior calibration.
2. From your seven higher moments of the Swiss data for 1990–2018 in item 3 of question 4 above, **reduce** the standard deviation of (the cyclical component of) investment  $i_t$  to half its actual value in the data. As in item 3 of question 4 above, launch the Matlab iteration routine to find the following five parameters under the new target:  $\omega$ ,  $\phi$ ,  $\psi$ ,  $\rho$ , and  $\eta$ . **Report** the calibrated parameter values and **explain** why they differ from the prior calibration.

## References

- Mendoza, Enrique G., “Real Business Cycles in a Small Open Economy,” *American Economic Review*, September 1991, 81 (4), 797–818.
- Obstfeld, Maurice and Kenneth Rogoff, *Foundations of international macroeconomics*, Cambridge, Mass. and London: MIT Press, 1996.
- Uribe, Martín and Stephanie Schmitt-Grohé, *Open economy macroeconomics*, Princeton and Oxford: Princeton University Press, 2017.

## Reproduction of Textbook Tables

### 4.6 Approximating Equilibrium Dynamics

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Table 4.1 Calibration of the EDEIR SOE-RBC Model

| Parameter | $\sigma$ | $\delta$ | $r^*$ | $\alpha$ | $\bar{d}$ | $\omega$ | $\phi$ | $\psi_1$ | $\rho$ | $\tilde{\eta}$ |
|-----------|----------|----------|-------|----------|-----------|----------|--------|----------|--------|----------------|
| Value     | 2        | 0.1      | 0.04  | 0.32     | 0.7442    | 1.455    | 0.028  | 0.000742 | 0.42   | 0.0129         |

Figure 1: Table 4.1 from Uribe and Schmitt-Grohé (2017, p. 85)

### 4.7 The Performance of the Model

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Table 4.2 Empirical and Theoretical Second Moments

| Variable       | Canadian Data  |                       |                     |                |                       |                     | Model          |                       |                     |
|----------------|----------------|-----------------------|---------------------|----------------|-----------------------|---------------------|----------------|-----------------------|---------------------|
|                | 1946–1985      |                       |                     | 1960–2011      |                       |                     | $\sigma_{x_t}$ | $\rho_{x_t, x_{t-1}}$ | $\rho_{x_t, GDP_t}$ |
|                | $\sigma_{x_t}$ | $\rho_{x_t, x_{t-1}}$ | $\rho_{x_t, GDP_t}$ | $\sigma_{x_t}$ | $\rho_{x_t, x_{t-1}}$ | $\rho_{x_t, GDP_t}$ |                |                       |                     |
| $y$            | 2.81           | 0.62                  | 1                   | 3.71           | 0.86                  | 1                   | 3.08           | 0.62                  | 1                   |
| $c$            | 2.46           | 0.70                  | 0.59                | 2.19           | 0.70                  | 0.62                | 2.71           | 0.78                  | 0.84                |
| $i$            | 9.82           | 0.31                  | 0.64                | 10.31          | 0.69                  | 0.80                | 9.04           | 0.07                  | 0.67                |
| $h$            | 2.02           | 0.54                  | 0.80                | 3.68           | 0.75                  | 0.78                | 2.12           | 0.62                  | 1                   |
| $\frac{tb}{y}$ | 1.87           | 0.66                  | -0.13               | 1.72           | 0.76                  | 0.12                | 1.78           | 0.51                  | -0.04               |
| $\frac{ca}{y}$ |                |                       |                     |                |                       |                     | 1.45           | 0.32                  | 0.05                |

Sources: Empirical moments for the period 1946–1985 are taken from Mendoza (1991) and for the period 1960–2011 are based on the authors' calculations using data from WDI (GDP, consumption, investment, imports, and exports) and Statistics Canada (hours worked).

Notes: Empirical second moments are based on annual, per capita, and quadratically detrended data. Standard deviations are measured in percentage points. Theoretical moments are produced by running the Matlab code `edeir_run.m`.

Figure 2: Table 4.2 from Uribe and Schmitt-Grohé (2017, p. 89)