# BCAppIt! User Guide*
# (Preliminary and Incomplete)
# Version 0.002a

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# Chapter 1

# Business Cycle Accounting

In this chapter we briefly summarize the Business Cycle Accounting (BCA) procedure developed by Chari, Kehoe and McGrattan (Econometrica, 2007).

## 1.1 Prototype Economy

The protype economy is described in Chari, Kehoe and McGrattan (2007). We here report the full-fledged model by making use of the functional form assumptions $F(k, Zl) = k^{\alpha}(Zl)^{1-\alpha}$ and $U(c, 1-l) = \lambda c + (1-\lambda)(1-l)$.

### 1.1.1 Variables (in per capita terms)

$Z$: labor-augmenting technical change ($Z = z(1+g_z)^t$)
$c$: consumption
$g$: government consumption
$k$: net capital stock
$l$: labor
$x$: investment
$y$: output
$s$: state of the world at time $t$
$\tau_l$: labor tax
$\tau_x$: tax on investment

### 1.1.2 Parameters

$g_n$: population growth rate of labor-augmenting technological process
$g_z$: growth rate of labor-augmenting technological process
$\alpha$: parameter which determines the share of (and weight on) net capital stock in the Cobb-Douglas CRS production function
$\beta$: subjective discount factor, reflecting the time preference of the household
$\delta$: depreciation rate of net capital stock
$\lambda$: share of (and weight on) consumption (versus leisure) in Cobb-Douglas utility function

### 1.1.3 Full-Fledged Model

The model's variables are expressed in per capita terms and detrended $\left(\hat{v} \equiv \frac{V_t}{N_t(1+g_z)^t} \equiv \frac{v_t}{(1+g_z)^t}\right)$.

- CRS Production Function

$$\hat{y}_t(s^t) = \hat{k}_t(s^{t-1})^\alpha \left(z_t l_t(s^t)\right)^{1-\alpha} \tag{1.1}$$

- Aggregate Resource Constraint

$$\hat{y}_t(s^t) = \hat{c}_t(s^t) + \hat{g}_t + \hat{x}_t(s^t) \tag{1.2}$$

- Capital Accumulation Law

$$(1+g_n)(1+g_z)\hat{k}_{t+1}(z^t) = (1-\delta)\hat{k}_t(z^{t-1}) + \hat{x}_t(z^t) \tag{1.3}$$

- F.O.C. Labor

$$\frac{1-\lambda}{\lambda}\frac{\hat{c}_t(s^t)}{1-l_t(s^t)} = (1-\tau_{l,t})(1-\alpha)\hat{k}_t(s^{t-1})^\alpha z_t^{1-\alpha} l_t(s^t)^{-\alpha} \tag{1.4}$$

- F.O.C. Capital

$$1 = \tilde{\beta}\ \mathbb{E}_t\left\{\frac{\hat{c}_t(s^t)}{\hat{c}_{t+1}(s^{t+1})}\left[\frac{(1+\tau_{x,t+1})(1-\delta) + \alpha\hat{k}_{t+1}(s^t)^{\alpha-1}\left(z_{t+1}l_{t+1}(s^{t+1})\right)^{1-\alpha}}{1+\tau_{x,t}}\right]\right\}, \tag{1.5}$$

where $\tilde{\beta} = \beta/(1+g_z)$.

## 1.2 Business Cycle Accounting

In this section we describe in more detail the steps which involve the estimation of the wedges and the simulation of the different prototype economies in which only a subset of the wedges is allowed to vary.

### 1.2.1 Wedges Measurement and Estimation

The efficiency, labor, investment and government wedge are defined as $\{z_t, (1-\tau_{l,t}), \frac{1}{1+\tau_{x,t}}, g_t\}$. Note that while the efficiency, labor and government wedge can be obtained directly from equations (1.1), (1.4) and (1.2) respectively, it is not that immediate to back out the investment wedge since (1.5) involves expectations. This is why we need to estimate the stochastic process driving expectations (and the wedges).

It is assumed that the state $s_t$ follows a Markov process of the form $\mu(s^t|s^{t-1})$ and that the wedges in period $t$ can be used to uncover the event $s^t$ uniquely, in the sense that the mapping from event $s^t$ to the wedges $\{z_t, (1-\tau_{l,t}), \frac{1}{1+\tau_{x,t}}, g_t\}$ is one to one and onto. Given this assumption, without loss of generality, let the underlying event $s_t = (s_{At}, s_{lt}, s_{xt}, s_{gt})$, and let $\log z_t(s^t) = s_{At},\ \tau_{l,t}(s^t) = s_{lt},\ \tau_{x,t}(s^t) = s_{xt}$, and $\log g_t(s^t) = s_{gt}$. Given the unique mapping between $s_t$ and the wedges following auxiliary choices were made in the full-fledged equilibrium conditions presented above: $z_t = z(s^t);\ \tau_{l,t} = \tau_l(s^t);\ \tau_{x,t} = \tau_x(s^t);\ \hat{g}_t = \hat{g}_t(s^t)$.

Note that we have effectively assumed that agents use only past wedges to forecast future wedges and that the wedges in period $t$ are sufficient statistics for the event in period $t$. More precisely, the VAR representation of the underlying state $s_t$ is modeled as follows

$$s_{t+1} = P_0 + Ps_t + Q\varepsilon_{s,t+1},$$

where $\varepsilon_{s,t+1} \sim N(0, I)$.

In order to estimate the matrices $P_0,\ P$ and $Q$ via maximum likelihood, CKM (2007) proceed as follows. First, the log-linear decision rules of the prototype economy are derived, then the model is put in state-space form (its full representation can be found in CKM's (2007) appendix) and last, data series on (log-linearly detrended and per capita) output, labor, (log-linearly detrended and per capita) investment, and (log-linearly detrended and per capita) government consumption plus net exports are used.

### 1.2.2 Simulation

The next step involves the actual *accounting* exercise part of the methodology. Several experiments are performed in order to isolate the marginal effects of the wedges. This is because the methodology seeks to understand which wedges should be included in a model in order to replicate movements in macroeconomic aggregates. Note that the wedges have both a distortionary and a forecasting role. On the one hand they distort equilibrium conditions and on the other hand their past values are used to build expectations over next period's wedges. In the experiments where only a subset of the wedges is allowed to fluctuate as they do in the data it is important to separate these two effects. CKM (2007) design their experiments so as to eliminate the direct effect (this is done by setting the subset of the wedges which are *not* allowed to fluctuate to constants, typically their steady state values) and to retain the forecasting effect. In this way they ensure that expectations are the same in the different simulated economies and, thus, that the differences in simulated data across different experiments (e.g., only efficiency wedge on vs only investment wedge one economies) are uniquely attributable to the direct effect coming from the fluctuations of the wedges which are active in those particular experiments.

# Chapter 2

# BCAppIt! Workflow

In this chapter we present the interface of BCAppIt! using U.S. data from 1980Q1-2014Q1 extracted from `OECD.stat`.

## 2.1 BCAppIt! Master Control Panel

In order to use BCAppIt! open Matlab, type in its command window `masterpanel` and press enter. This will open the master panel of BCAppIt!


Figure 2.1: Master Control Panel of BCAppIt!

The master panel features six buttons. The three buttons in the left column cover the three main steps you will need to go through to carry out the BCA exercise, namely (i) loading the data and calibrating the prototype economy model, (ii) estimating the stochastic process $s_t = P_0 + P s_{t-1} + Q\varepsilon_t$, where $\varepsilon_t \sim\sim N(0, I)$ and (iii) simulating the different (one-wedge-on vs one-wedge-off) prototype economies. The three buttons in the right column give you the opportunity to (i) load a previously saved workfile, (ii) save the current workfile and (iii) quit the current session at any stage of your work.

## 2.2 Data and Calibration

Click on Data and Calibration in the Master Control Panel to open the Data and Calibration Panel.

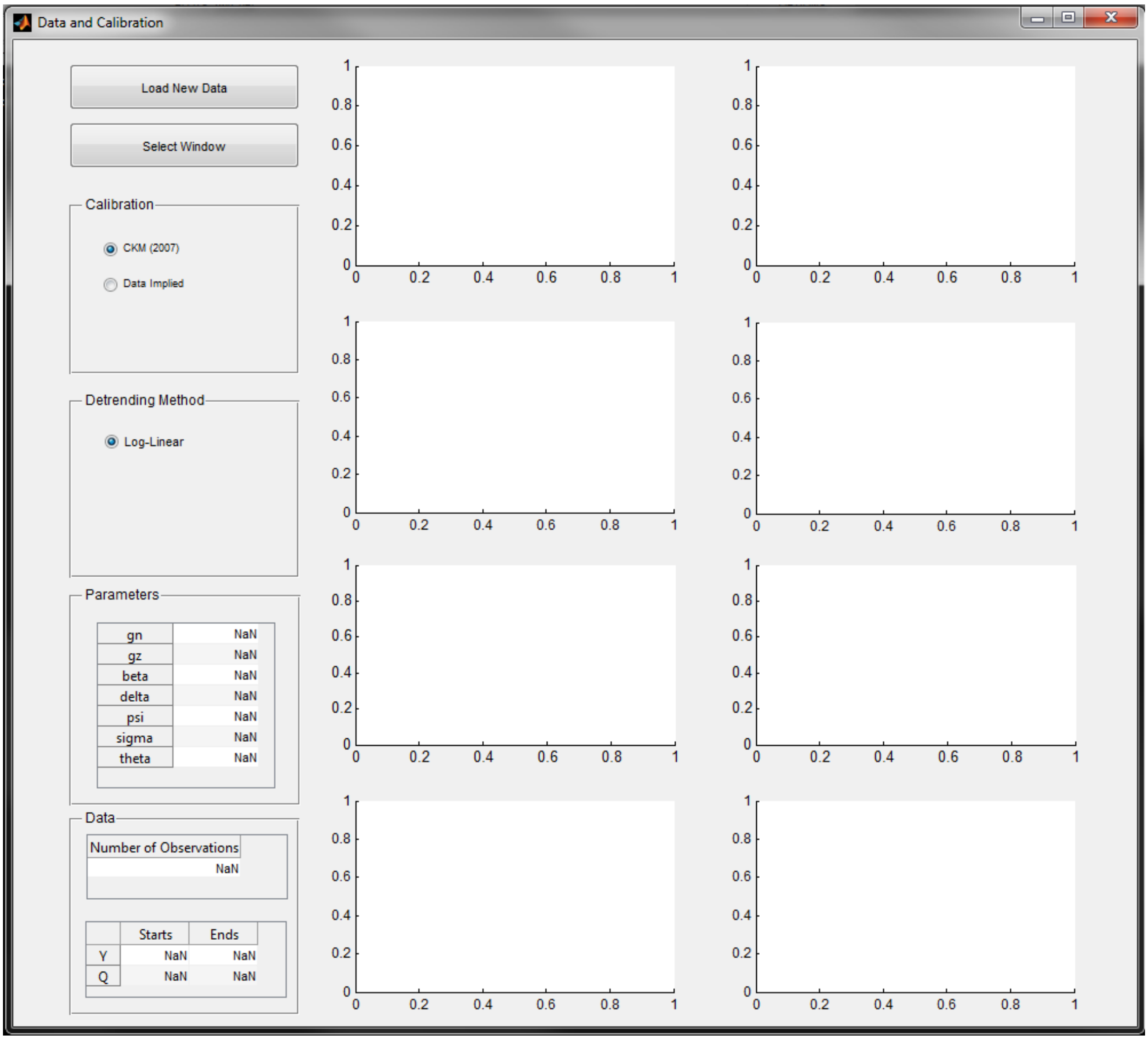



Figure 2.2: Data and Calibration Panel of BCAppIt!

We provided you with a file that maps the raw, quarterly OECD data to the working datafile which contains a matrix whose columns are $[t, ypc, xpc, hpc, gpc, iP]$, i.e., a time vector, output per capita, investment per capita, hours per capita, (government consumption + net exports) per capita, population. This is the data that you can upload by clicking the Load New Data button. It will open your file browser and you will be able to upload `.dat`, `.mat` and `.txt` files containing the data as described before.

Once you have chosen the datafile (sticking to our U.S. example this would be `USA_OECD.dat`) the following pop-up window will appear and ask you to choose a base year and quarter*. This is an important choice: The base year will correspond to the initial date of the time period you will use in estimation and it should thus correspond to the initial date of the episode you seek to investigate. Indeed, if you seek to look at both the great recession and at the oil crisis period in the U.S. you will need to reload the data and select different base years in the two cases.

*The app is also able to recognize the frequency of the data and to deal with annual data. In this case, you will be asked to select a base year only.

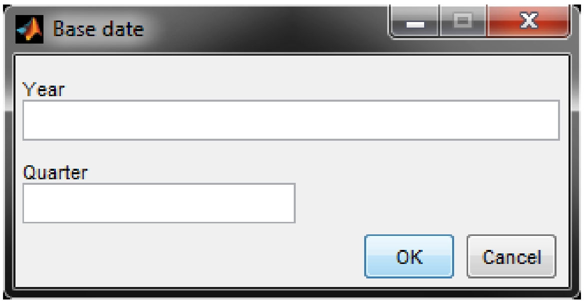



Figure 2.3: Data and Calibration Panel Pop Up Window: Base Year Choice.

Once you have chosen the base year this how the panel will look like.


Figure 2.4: Data and Calibration Panel when data have been loaded.

The left column shows raw data while the right columns detrended data. Note that for all plots in BCAppIt! our timing convention is as follows: Year X Quarter 4 = X+1, Year X Quarter 1 = X + 0.25 and so on (e.g., 2007Q4 = 2008 and 2008Q1 = 2008.25). The detrending method involves taking away the trend $\left[\log\left(1+g_z\right)^t\right]$, $t = 0, ..., T-1$ from (log) output, (log) investment (normalized by base year output) and (log) government consumption plus net exports (normalized by base year output). In line with the theoretical model, hours are not detrended. You are given the option to select the starting date and window size of the plots just described by clicking the button Select Window and typing the desired choice in the pop-up window.

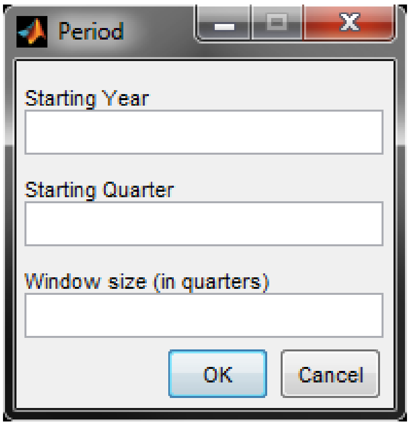



Figure 2.5: Data and Calibration Panel Pop Up Window: Choice of Data Plots Window.

You can choose between two different calibrations. The first calibration corresponds to the one used in CKM (2007) while the second (i) uses population data to compute $g_n$, (ii) computes $g_z$ such that mean detrended output is equal to zero and (iii) leaves the other parameters as in CKM (2007). The bottom left part of the panel provides you with information on (i) the parameters implied by your calibration choice and (ii) the starting and end date of loaded data.

You can now either keep the panel open or close it and then move to the estimation panel.

## 2.3 Estimation

To open the estimation panel click on `Wedge Accounting` in the Master Control Panel.

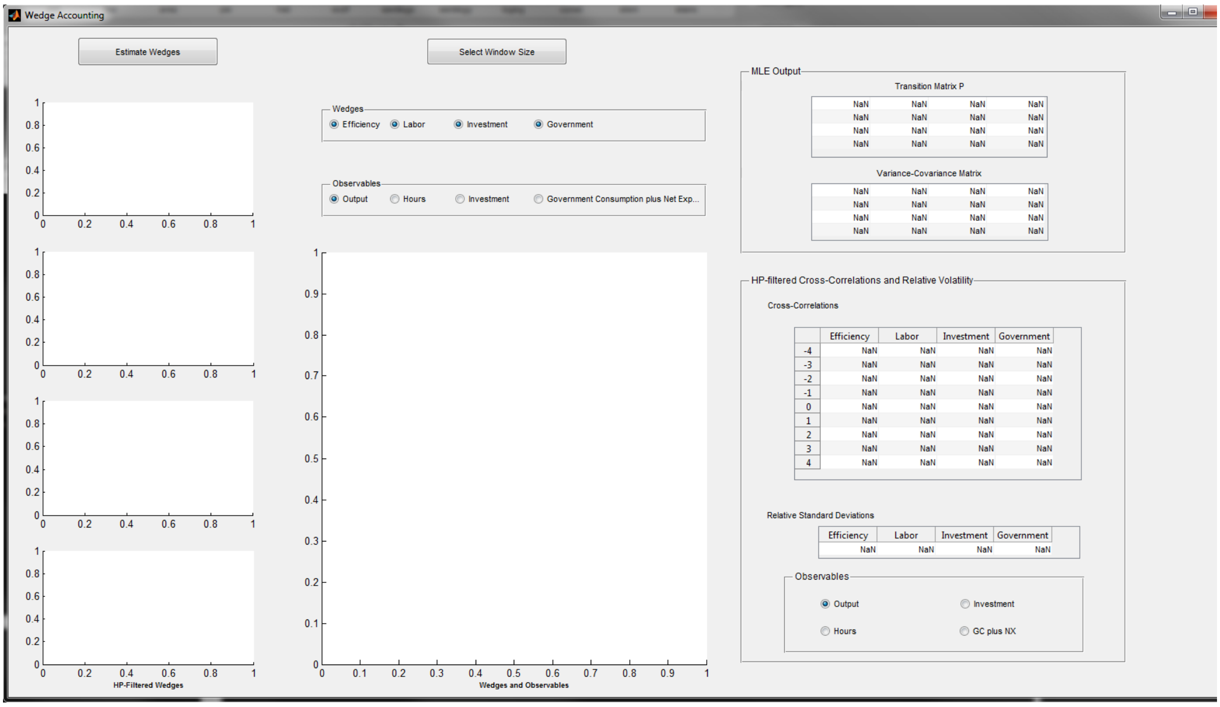



Figure 2.6: Wedge Accounting Panel of BCAppIt!

To estimate the stochastic process underlying the wedges click on the button `Estimate Wedges` in the top left part of the panel. A progress bar keeps you updated on the progress of the maximum likelihood estimation. Once the stochastic process has been estimated and the wedges calculated, their HP filtered series are plotted in the left column of the panel.

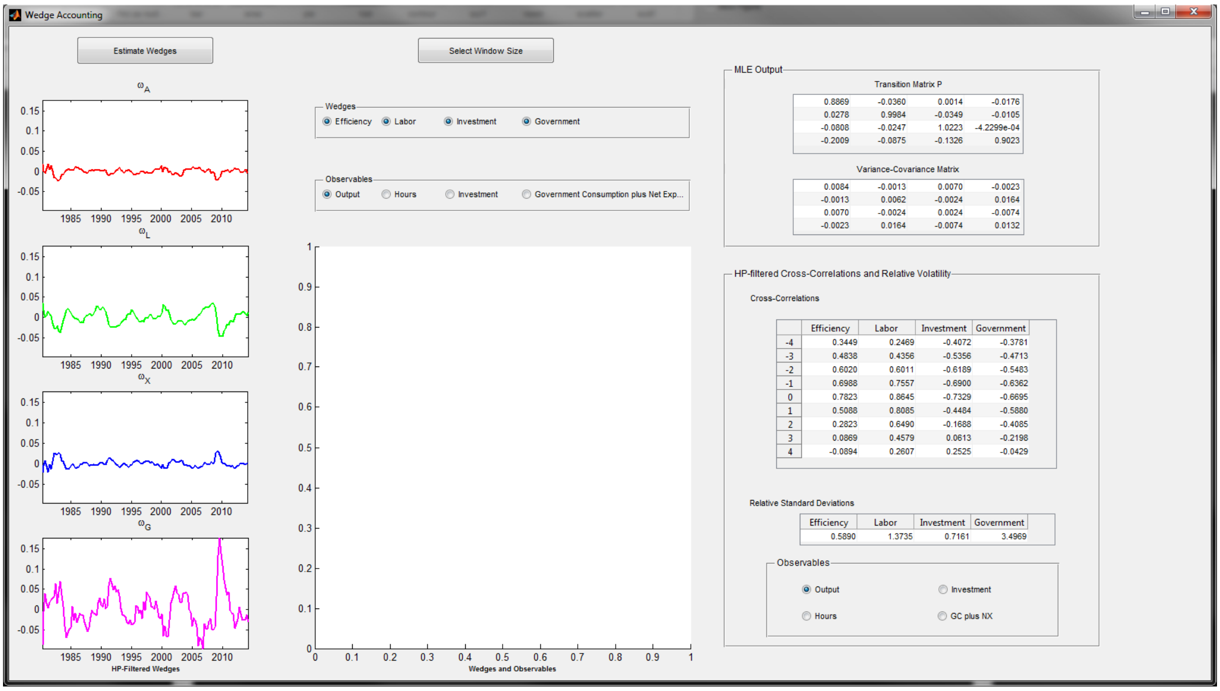



Figure 2.7: Wedge Accounting Panel when wedges have been estimated.

Next, you can select the window size for the plot of the measured wedges. The window size has to be entered in terms of the frequency of the data. For instance, if you want to cover six years of data you will have to enter $6 \times 4 = 24$ if you have quarterly data vs. 6 if you have annual data.

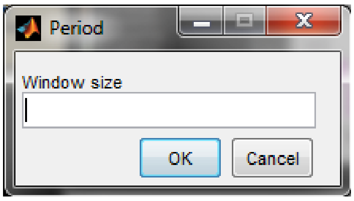



Figure 2.8: Wedge Accounting Panel Pop Up Window: Choice of Wedges Plots Window.

The middle button group allows you to choose which observables and which wedges you want to plot. By default, BCAppIt! plots the four wedges against output.

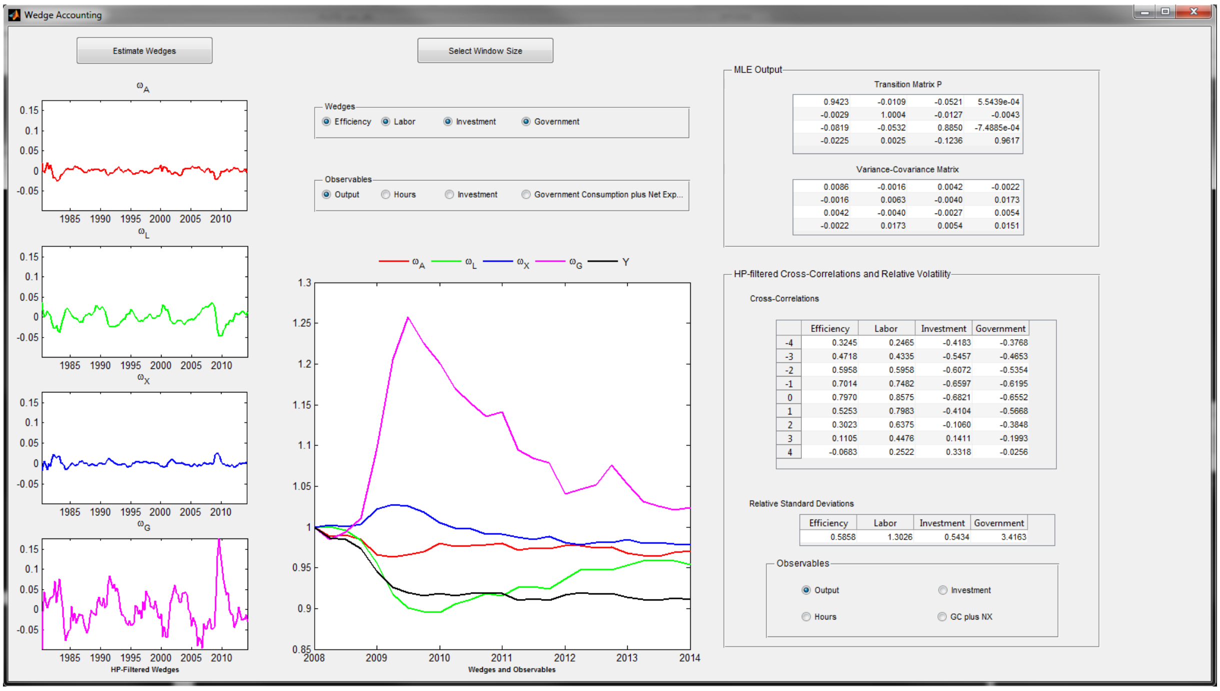



Figure 2.9: Wedge Accounting Panel when choice of wedges plots window has been made.

The right column features two panels which report (i) MLE results, namely the estimated matrix P and Q of the stochastic Markov process and (ii) cross-correlations and relative standard deviations between HP-filtered wedges and observables. Note that in the second panel you are given the (exclusive) choice of the observable for which you want the moments to be computed.

Also in this case you can either keep the panel open or close it and then move to the simulation panel.

## 2.4 Simulation

Click on Simulation in the Master Control Panel to open the Simulation Panel. By default, it will directly plot the different one-wedge-on (left column) and one-wedge-off (right column) simulated output data against observed output. You are free to choose the simulated economy you are interested in (e.g., you may want to plot just the efficiency wedge-on and -off economy and the investment wedge-on and -off economy). The choice of the simulated data is exclusive (you can not plot simulated hours and simulated output data contemporaneously). By the way that the *accounting* procedure is set up, simulated data in the different economies (efficiency wedge on (off), investment wedge on (off), labor wedge on (off) and government wedge on (off)) sum up (almost perfectly) to the observed data. Clicking on Select Window Size will open a pop-up window in which you can choose the window size for the plots just like in the previous panel.

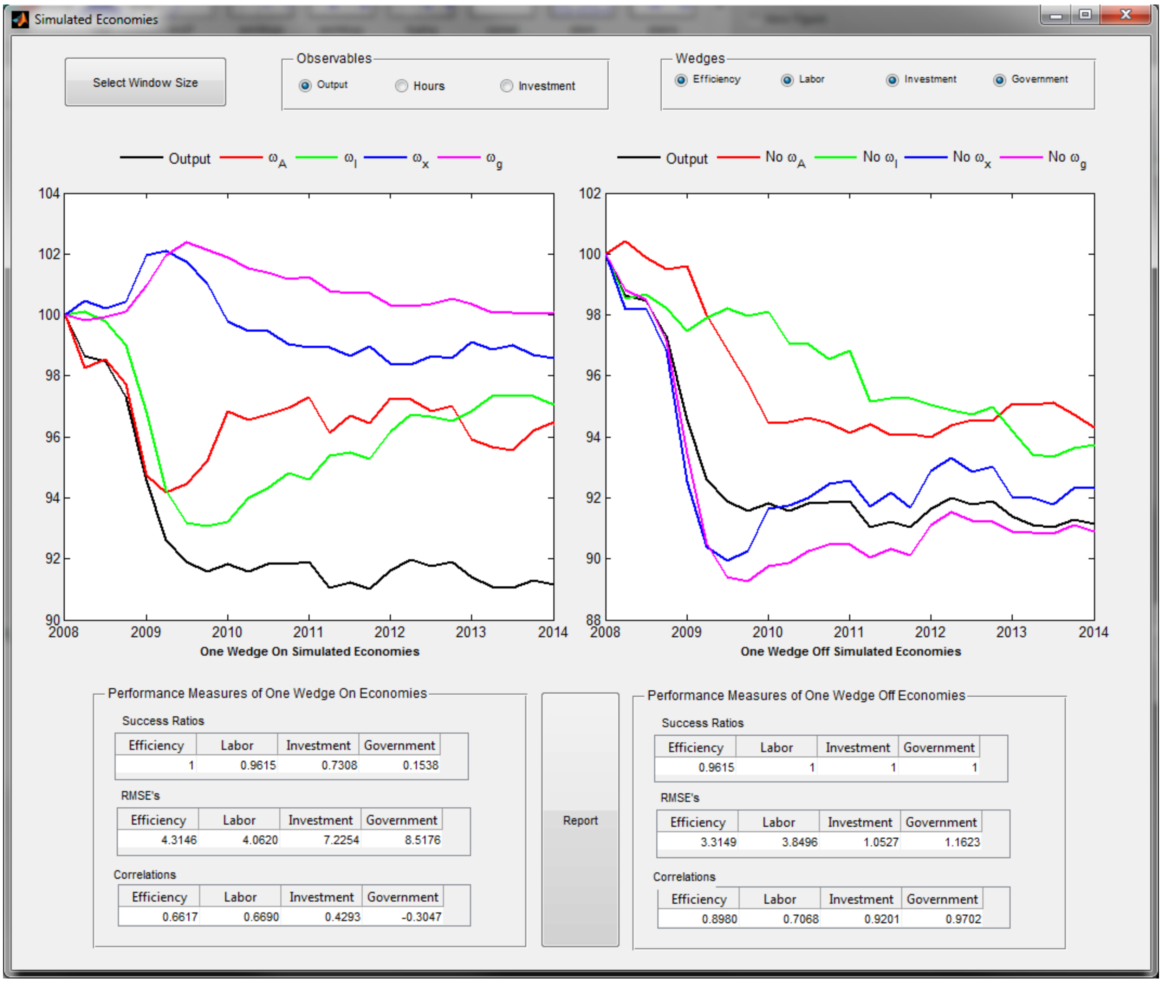
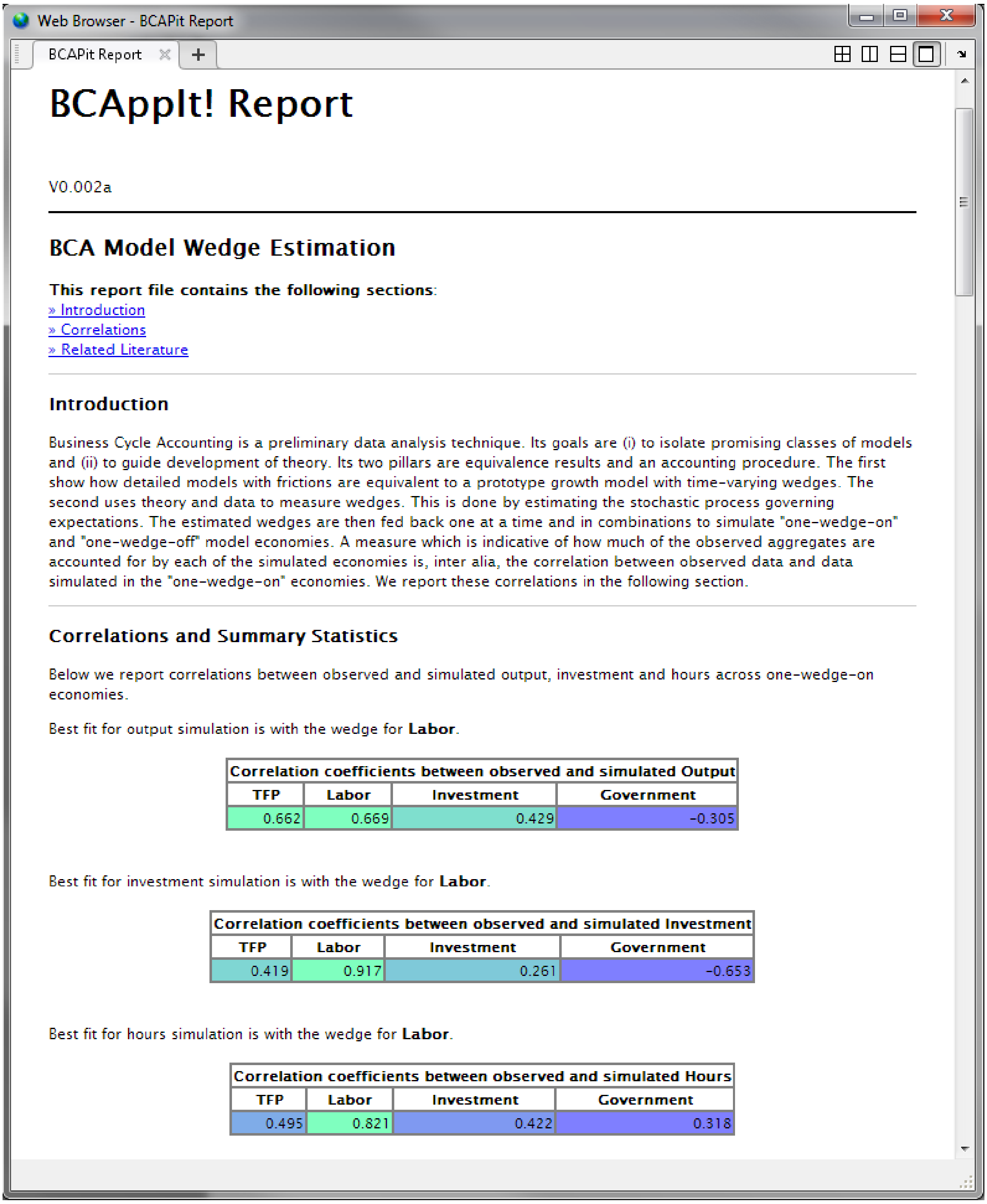



Figure 2.10: Simulation Panel of BCAppIt!

The bottom part of the panel reports performance measures of the simulated economies: (i) Success Ratio's which describe the percentage of times when simulated and observed data had the same sign, (ii) Root Mean Square Errors (RMSE's) between simulated and observed data and (iii) Correlations between simulated and observed data.

## 2.5 Report

By clicking on the Report button BCAppIt! will generate a report summarizing some important results of the BCA exercise and providing a comprehensive list of related literature.



Web Browser - BCAPit Report

BCAPit Report

# BCAppIt! Report

V0.002a

## BCA Model Wedge Estimation

**This report file contains the following sections:**
» Introduction
» Correlations
» Related Literature

### Introduction

Business Cycle Accounting is a preliminary data analysis technique. Its goals are (i) to isolate promising classes of models and (ii) to guide development of theory. Its two pillars are equivalence results and an accounting procedure. The first show how detailed models with frictions are equivalent to a prototype growth model with time-varying wedges. The second uses theory and data to measure wedges. This is done by estimating the stochastic process governing expectations. The estimated wedges are then fed back one at a time and in combinations to simulate "one-wedge-on" and "one-wedge-off" model economies. A measure which is indicative of how much of the observed aggregates are accounted for by each of the simulated economies is, inter alia, the correlation between observed data and data simulated in the "one-wedge-on" economies. We report these correlations in the following section.

### Correlations and Summary Statistics

Below we report correlations between observed and simulated output, investment and hours across one-wedge-on economies.

Best fit for output simulation is with the wedge for **Labor**.

| Correlation coefficients between observed and simulated Output | | | |
|---|---|---|---|
| **TFP** | **Labor** | **Investment** | **Government** |
| 0.662 | 0.669 | 0.429 | -0.305 |

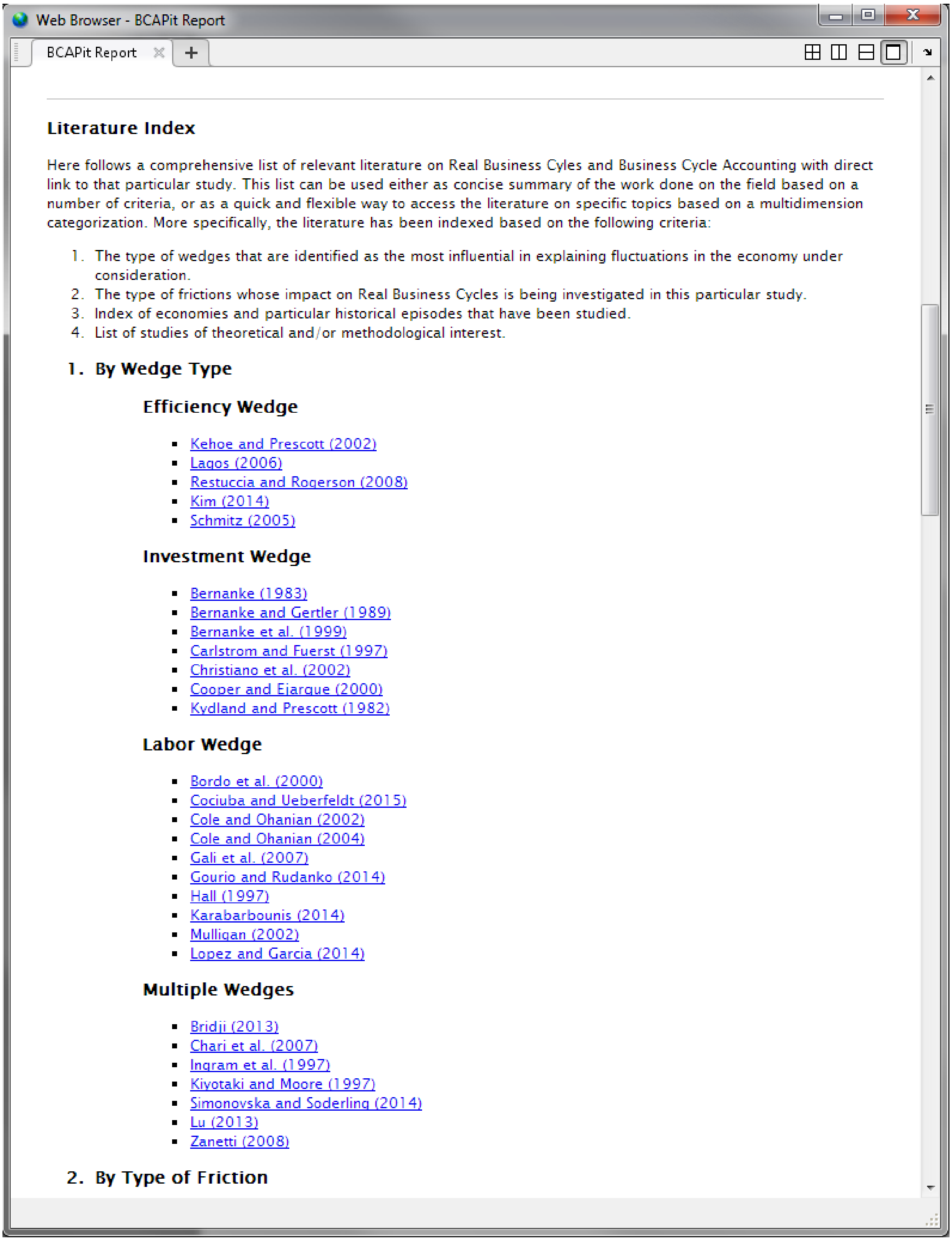
Best fit for investment simulation is with the wedge for **Labor**.

| Correlation coefficients between observed and simulated Investment | | | |
|---|---|---|---|
| **TFP** | **Labor** | **Investment** | **Government** |
| 0.419 | 0.917 | 0.261 | -0.653 |

Best fit for hours simulation is with the wedge for **Labor**.

| Correlation coefficients between observed and simulated Hours | | | |
|---|---|---|---|
| **TFP** | **Labor** | **Investment** | **Government** |
| 0.495 | 0.821 | 0.422 | 0.318 |

Figure 2.11: Extract I from the report produced by BCAppIt!



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BCAPit Report

### Literature Index

Here follows a comprehensive list of relevant literature on Real Business Cyles and Business Cycle Accounting with direct link to that particular study. This list can be used either as concise summary of the work done on the field based on a number of criteria, or as a quick and flexible way to access the literature on specific topics based on a multidimension categorization. More specifically, the literature has been indexed based on the following criteria:

1. The type of wedges that are identified as the most influential in explaining fluctuations in the economy under consideration.
2. The type of frictions whose impact on Real Business Cycles is being investigated in this particular study.
3. Index of economies and particular historical episodes that have been studied.
4. List of studies of theoretical and/or methodological interest.

#### 1. By Wedge Type

##### Efficiency Wedge

- Kehoe and Prescott (2002)
- Lagos (2006)
- Restuccia and Rogerson (2008)
- Kim (2014)
- Schmitz (2005)

##### Investment Wedge

- Bernanke (1983)
- Bernanke and Gertler (1989)
- Bernanke et al. (1999)
- Carlstrom and Fuerst (1997)
- Christiano et al. (2002)
- Cooper and Ejarque (2000)
- Kydland and Prescott (1982)

##### Labor Wedge

- Bordo et al. (2000)
- Cociuba and Ueberfeldt (2015)
- Cole and Ohanian (2002)
- Cole and Ohanian (2004)
- Gali et al. (2007)
- Gourio and Rudanko (2014)
- Hall (1997)
- Karabarbounis (2014)
- Mulligan (2002)
- Lopez and Garcia (2014)

##### Multiple Wedges

- Bridji (2013)
- Chari et al. (2007)
- Ingram et al. (1997)
- Kiyotaki and Moore (1997)
- Simonovska and Soderling (2014)
- Lu (2013)
- Zanetti (2008)

#### 2. By Type of Friction

Figure 2.12: Extract II from the report produced by BCAppIt!