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Business Cycle Accounting: What Have We Learned So Far?*

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Abstract

What drives recessions and expansions? Since it was introduced in 2007, there have been hundreds of business cycle accounting (BCA) exercises, a procedure aimed at identifying classes of models that hold quantitative promise to explain a certain period of economic fluctuations. First, we exemplify the procedure by studying the U.S. recessions in 1973 and 1990 using and reflect upon the critiques BCA has been subject to. Second, we look into the many equivalence theorems that the literature has produced and that allow BCA practitioners to identify the theories that are quantitatively relevant for the economic period under study. Third, we describe the methodological extensions that have been brought forth since BCA's original inception. We end by providing some broad conclusions regarding the relative contribution of each wedge: GDP and aggregate investment are usually driven by an efficiency wedge, hours of work are closely related to the labor wedge and, in an open economy, the investment wedge helps to explain country risk spreads on international bonds. Larger changes in interest rates and currency crises are usually associated with the investment and/or the labor wedge. Finally, we contribute with a graphical user interface that allows practitioners to perform business cycle accounting exercises with minimal effort.

Keywords: Business Cycle Accounting, business cycles, wedges
JEL Classification: E27, E30, E32, E37

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1 Introduction

Business cycles fluctuations have been analyzed by a multitude of different approaches. From the theoretical modeling side, the first generation of Dynamic Stochastic General Equilibrium models (DSGE) was the Real Business Cycle theory, where fluctuations are driven by technology shocks and nominal variables have no effect on the real side of the economy. When confronted with the data, a mismatch sometimes emerges between model predictions and empirical regularities. One hypothesis for this mismatch is that "data is wrong". That is, mismeasurement of aggregate data leads researchers to wrong conclusions. However, it also possible that in order to better grasp the complexity of the empirical world, DSGE models need to be extended to encompass, for instance, nominal price rigidity, frictions in the labor markets and financial frictions.

The question then arises about which is the best friction to be introduced. Does it change throughout time, or across countries? The importance of DSGE modeling in understanding business cycles called for some guidance to help researchers in developing their models. The Business Cycle Accounting (henceforth BCA) method intends to fulfill this need. Resembling growth accounting, data is confronted with a prototype economy which features four main macroeconomic decisions: production, the intratemporal choice between labor and leisure, the intertemporal choice between consumption and savings and how to satisfy the resource constraint. Each decision is distorted by a wedge, respectively the efficiency wedge, the labor wedge, the investment wedge and the government consumption wedge.

By construction, all four wedges account for all the variation in the data. After estimating the four wedges, a (linear) decomposition is done to assess which wedge, or combination of wedges, is more important. In order to do that, the path of the variables of interest (e.g., output) is simulated allowing one wedge to be active at a time, holding the remaining wedges constant. The comparison of simulations with different wedges identifies the relative importance of each distortion. This is the first contribution of BCA: the accounting dimension.

After understanding the drivers of short-run movements, the next contribution of BCA is related to establishing equivalences. Indeed, for a given wedge being introduced into the prototype economy, it is possible to find its mapping to different detailed economies. For instance, an efficiency wedge in the prototype economy may arise from input-financing frictions in a detailed economy (Kiyotaki & Moore, 1997; Mendoza, 2010), a labor wedge from nominal rigidity and monetary policy shocks (Bordo et al., 2000), a investment wedge from credit markets with agency costs (Carlstrom & Fuerst, 1997) and a government consumption wedge from constraint on foreign borrowing (Chari et al., 2005).

The literature then evolved to speak to other dimensions by extending the basic framework. These approaches are known as monetary BCA, open-economy BCA and international BCA. The reasoning remains the same: the predictions of a detailed model with micro-founded distortions are confronted with data, though the prototype economies in these extended approaches are different in that they allow for more wedges. For instance, monetary BCA incorporates price rigidity and deals with deviations from monetary policy rules and inflation. In open-economy BCA , the set up for the prototype model is a small open economy. Finally, international BCA analyses international linkages in a two-country framework. All extensions introduce new wedges and maintain the four original wedges (with possible changes).

The contribution of this paper is threefold. First, it presents the methodology while discussing extensions and limitations to the non-specialist and practitioners. Second, it demonstrates the application of BCA in the context of three U.S. recessions (1973 and 1990) and offers a discussion on the relative importance of each wedge during expansions and recessions. Finally, it surveys the vast literature on BCA and reviews it systematically. The variety of countries (developed and emerging markets) and episodes (e.g., the Great Depression, currency crises and the Great Recession) provide a rich sample to assess whether there is a pattern in the relative importance of each wedge.

The results from BCA for the U.S. suggest the efficiency wedge is the most important in both of them, accounting for at least 50% of output movements during both recessions. The secondary most important wedge is the labor wedge.

After revewing the literature, we can draw some broad conclusions. Even though the relative importance of each wedge changes from one episode to another, it is safe to affirm that the efficiency wedge has an important role in output fluctuations and the dynamics of aggregate investment accross countries and episodes. The labor wedge, on the other hand, is closely related to hours of work. Investment wedges, in an open-economy set up, can explain country risk spreads on foreign debt. Moreover, larger changes in interest rates and currency crises are usually associated with the investment wedge and/or the labor wedge – the former usually for emerging markets whereas the latter may be important for both developed and emerging economies. The government consumption wedge is usually not as important as the other wedges. Its ability of explaining economic fluctuations is very often either very small or nil.

This paper is organized as follows. The next section introduces BCA by presenting the prototype economy, how to implement the procedure and its limitations. Section 2.3 addresses the mappings from different classes of detailed models into the prototype economy with wedges. Section 2.4 presents the extensions of the method: monetary business BCA, open-economy BCA and international BCA. Section 2.5 discusses what the literature found in applications of business cycle accounting and in its extensions for developed and emerging market economies. Finally, Section 2.6 offers concluding remarks.

2 Business Cycle Accounting

Real Business Cycle (RBC) modeling of macroeconomic fluctuations was pioneered by Kydland & Prescott (1982). Though it is an important contribution to economics, sometimes the neoclassical model needed to be modified for a better fit to data.[1] When building quantitative models, researchers thus had to make choices, sometimes departing from the perfectly-competitive-markets model in order to reproduce key features of data. But what are the best choices to make?

BCA is one method to guide researchers in making those choices. In the same spirit as growth accounting, in which economic growth is decomposed into accumulation of production factors and a residual, BCA analyzes the sources of macroeconomic fluctuations as a function of change endogenous variables and four residuals.[2]

The starting point is the so-called neoclassical growth model.[3] An extensive body of research has devoted its efforts to creating models departing from the neoclassical framework. For instance, some models introduce nominal price rigidity, wage rigidity and labor unions.[4] But which distortion is better? Does the answer change from one episode to another? The BCA literature helps to answer these questions, and sheds some light on how to proceed further.

BCA was introduced by Chari et al. (2002) and consolidated in Chari et al. (2007a) (henceforth CKM).[5] In an economy composed by firms and consumers, agents behave rationally and choose how to allocate resources in each period t, given the state of the economy and the history of events. There is a probability associated with each possible state, and the initial state is taken as given. Four

[1] For instance, Christiano & Eichenbaum (1992) identify the need to modify RBC models to account for the correlation between hours of work and productivity.

[2] The growth accounting literature was pioneered by Abramovitz (1956) and Solow (1957).

[3] The neoclassical growth model goes back to the works of Ramsey (1928), Cass (1965) and Koopmans (1965), in which savings decisions are endogenous, rather than exogenous as in Solow (1957), for instance.

[4] Mankiw (1990) presents an overview of how literature evolved by encompassing different features in macroeconomic modeling.

[5] In Chari et al. (2002) there were only three wedges (efficiency, labor and investment).

exogenous variables are introduced in the neoclassical growth model (all of them functions of the state of the economy). By doing this, equilibrium conditions of the neoclassical growth model are distorted. Each distortion is per se variable over time. There are four distortions (*wedges*): the *efficiency* wedge, the *labor* wedge, the *investment* wedge and the *government consumption* wedge. They are named after the four equilibrium conditions they distort.

The efficiency wedge is related to the utlitlization of production factors. It is represented by a technology parameter in the production function. The labor wedge creates a departure from the optimal labor choice. It is important to note that distortions to labor supply (consumers) and labor demand (firms) are measured together and cannot be separately identified. The labor wedge manifests itself in the form of a time-varying tax on the marginal product of labor.

The investment wedge is related to the intertemporal choice between present and future consumption (the combination of the representative consumer's and firm's Euler equation). It also appears in the form of a time-varying tax on investment, distorting intertemporal allocation of resources across of the world. Finally, the government consumption wedge changes the economy's resource constraint and manifests itself in the form of government expenditure. In the case of an open-economy, it also encompasses net exports.

2.1 The Prototype Economy

At any time t the probability of a given state of nature s_t is denoted by $\pi_t(s^t)$ where $s^t = (s_0, ..., s_t)$ is the history of events up to and including period t. The initial state s_0 is given. Consumers maximize expected lifetime utility over per capita consumption (c_t) and labor (l_t) for each t and s^t

$$\sum_{t=0}^{\infty} \sum_{s^t} \pi_t(s^t) \beta^t U(c_t(s^t), l_t(s^t)) N_t,$$

subject to the budget constraint for all t and s^t:

$$c_t(s^t) + (1 + \tau_{xt}(s^t))x_t(s^t) = (1 - \tau_{lt}(s^t))w_t(s^t)l_t(s^t) + r_t(s^t)k_t(s^t) + T_t(s^t)$$

Following Brinca et al. (2016), adjustment costs $\phi(\frac{x_t(s^t)}{k_t(s^{t-1})})$ are added to the the law for capital (k_t) accumulation:

$$(1 + \gamma)k_{t+1}(s^t) = (1 - \delta)k_t(s^{t-1}) + x_t(s^t) - \phi(\frac{x_t(s^t)}{k_t(s^{t-1})}),$$

where $(1 - \tau_{l,t})$ is the labor wedge, $1/(1 + \tau_{x,t})$ is the investment wedge, β is the discount factor, $U(.)$ stands for the utility function, N_t is the population (which has a growth rate of γ_N), x_t is per capita investment, w_t is the real wage rate, r_t is the rate of return on capital, δ is the depreciation rate, T_t is per capita lump-sum transfers from the government to households, γ is the technological growth rate and $\phi(\frac{x_t(s^t)}{k_t(s^{t-1})}) = \frac{a}{2}(\frac{x_t(s^t)}{k_t(s^{t-1})} - b)^2$, with $b = \delta + \gamma + \gamma_N$, representing the steady-state value of the investment-capital ratio. At the same time, firms gather capital and labor in perfectly competitive markets to maximize profits Π_t, given the production function $y_t(s^t) = F(k_t(s^{t-1}), (1 + \gamma)^t l_t(s^t))$, which is distorted by the efficiency wedge $A_t(s^t)$:

$$\max_{k_t, l_t} \Pi_t(s^t) = y_t(s^t) - r_t(s^t)k_t(s^{t-1}) - w_t(s^t)l_t(s^t).$$

Combining the optimal decisions of both consumers and firms, the production technology and the resource constraint, the four equilibrium conditions of the model are obtained:

$$y_t(s^t) = A_t(s^t)F(k_t(s^{t-1}), (1+\gamma)^t l_t(s^t)), \tag{1}$$

$$-\frac{U_{l,t}(s^t)}{U_{c,t}(s^t)} = (1-\tau_{l,t}(s^t))A_t(s^t)(1+\gamma)F_{l,t}, \tag{2}$$

$$U_{c,t}(s^t)(1+\tau_{x,t}(s^t)) = \tag{3}$$

$$\beta \sum_{s^{t+1}} \pi_t(s^{t+1}|s^t)[U_{c,t+1}(s^{t+1})(A_{t+1}(s^{t+1})F_{k,t} + (1-\delta)(1+\tau_{x,t+1}(s^{t+1})) + \phi_{k_{t+1}}],$$

$$y_t(s^t) = c_t(s^t) + x_t(s^t) + g_t(s^t), \tag{4}$$

where $U_{c,t}$, $U_{l,t}$, $F_{l,t}$, $F_{k,t}$ and $\phi_{k_{t+1}}$ are the derivatives of the utility function, the production function and adjustment costs with respect to their arguments and g_t is the government consumption wedge. The four equations above are used in the BCA exercises.

Finally, the government defines taxes and transfers in a way that satistfies its budget constraint

$$G_t(s^t) + T_t(s^t) = \tau_{x,t}(s^t)x_t(s^t)N_t + \tau_{l,t}(s^t)w_t(s^t)l_t(s^t)N_t,$$

where G is the government spending.

2.2 Applying Business Cycle Accounting

After solving the model to get the equilibrium conditions (equations 1-4), it is useful to rewrite them so we can express the wedges. The efficiency wedge is given by

$$A_t(s^t) = \frac{y_t(s^t)}{F(k_t(s^{t-1}), (1+\gamma)^t l_t(s^t))}, \tag{5}$$

whereas the labor wedge is defined as

$$(1-\tau_{l,t}(s^t)) = -\frac{U_{l,t}(s^t)}{U_{ct}(s^t)}(A_t(s^t)(1+\gamma)F_{l,t})^{-1}, \tag{6}$$

the investment wedge is defined by

$$\frac{1}{(1+\tau_{x,t}(s^t))} =$$
$$U_{c,t}(s^t)(\beta \sum_{s^{t+1}} \pi_t(s^{t+1}|s^t)[U_{c,t+1}(s^{t+1})(A_{t+1}(s^{t+1})F_{kt} + (1-\delta)(1+\tau_{x,t+1}s^{t+1}) + \phi_{k_{t+1}}])^{-1}, \tag{7}$$

and finally we have the government consumption wedge

$$g_t(s^t) = y_t(s^t) - c_t(s^t) - x_t(s^t). \tag{8}$$

In order to compute optimal decisions, we must assume some functional forms. Following Chari et al. (2007a), the production function has a Cobb-Douglas form, $F(k,l) = k^{\alpha}l^{1-\alpha}$, the utility function is $U(c,l) = \ln c + \psi \ln(1-l)$, the share of capital in the production function $\alpha = 0.35$, the time allocation parameter $\psi = 2.24$, the depreciation rate of net capital stock $\delta = 0.0118$ (so that the annualized depreciation is 5%), and the discount factor $\beta = 0.993$ (implying a 2.8% rate of time preference). Moreover, $\gamma = 0.004$ and $\gamma_N = 0.0039$ are calculated from data and the parameter in the adjustment costs function, $a = 12.574$, is taken from Brinca et al. (2016).[6]

Let us call y_t^D, l_t^D, x_t^D and g_t^D the data for output, hours of work, investment and government consumption, respectively. Let us equate actual data and the values prescribed by the model. From equations (2.5), (2.6) and (2.8) we can compute directly the values of the wedges. However, in equation (2.7) there is an expectation term, calling for some assumptions regarding the stochastic process for $\pi_t(s^t)$.

Let us assume that expectations follow a first order Markov process of the type $\pi_t(s_t|s^{\tau-1}) = \pi_t(s_t|s_{t-1})$. That is, the probability of state s_t given the history of events $s^{\tau-1}$ is equal to the probability of state s_t given the state s_{t-1}. Moreover,

[6]Following Brinca et al. (2016) and Chari et al. (2007a), the technological growth rate is such take the mean of the log of GDP per working age population over the sample is equal to zero.

we also assume that agents rely only on previous realizations of the wedges to forecast future wedges and that the wedges are sufficient statistics for a time t event s_t. Furthermore, the mapping from the event s_t to the wedges is assumed to be one to one. Therefore, $s_t = (A_t, (1-\tau_{l,t}(s^t)), 1/(1+\tau_{xt}(s^t)), g_t)$ follows a vector autoregressive process:

$$s_{t+1} = P_0 + Ps_t + \epsilon_{t+1}, \tag{9}$$

where P_0 is the vector of constants, P is the matrix of coefficients and ϵ_{t+1} is the i.i.d. shock with zero mean and covariance matrix V, which is positive semidefinite by construction.[7] This implies that there are spillovers from wedges through the matrix of coefficients P and the correlations of innovations in V. Usually, the Kalman filter is used to get the maximum likelihood estimator for the coefficients.[8] Therefore, we can have a one-period ahead prediction, which is necessary for the evolution of the system.[9]

Using real data on output (y_t^D), hours of work (l_t^D), investment (x_t^D), private (c_t^D) and government (g_t^D) consumption, we can equate the outcome of the model with observed data for each variable e.g. for output we equate $y_t(s_t, k_t) = y_t^D$ and write the following system of equations:

$$\begin{aligned} y_t(s_t,k_t) &= y_t^D, & l_t(s_t,k_t) &= l_t^D, \\ x_t(s_t,k_t) &= x_t^D, & g_t(s_t,k_t) &= g_t^D, \\ c_t(s_t,k_t) &= c_t^D, & k_{t+1} &= (1-\delta) + x_t^D, \end{aligned}$$

with $k_0 = x_0^D$. In order to estimate the wedges we need to solve the system above.

[7] Bäurle & Burren (2011) presents necessary and sufficient conditions for assuming that wedges follow a VAR process. Šustek (2011) finds that for the U.S., a first order VAR process is enough.

[8] Brinca et al. (2018) analyze whether BCA and its monetary extension - see Section 2.4 - suffer from identification failures. They conclude that if estimation is restricted to latent variables, then the main economic conclusions are not jeopardized by parameter uncertainty driven by identification issues. The same is not true if also the deep parameters of the model are estimated.

[9] See Chari et al. (2006) for further technical details.

By construction, the four wedges account for all data movements, i.e., if we feed the wedges into the system above we recover the original data. Define $Y_t = [y_t(s_t, k_t), l_t(s_t, k_t), x_t(s_t, k_t), c_t(s_t, k_t)]$ and $X_t = [k_t, A_t, \tau_{l,t}, \tau_{x,t}, g_t]$. The previous system of equations can be rewritten in the state-space form, as follows:

$$Y_t' = DX_t' + \varepsilon_{Y,t}', \quad X_{t+1}' = MX_t' + B\varepsilon_{X,t+1}',$$

where B, D and M are coefficient matrices and ε_Y and ε_X' are the vectors of error terms. After the estimation of the wedges, the accounting exercise is done by simulating the economy to see the relative contribution of each wedge to variation in the data. This allows us to understand the channels of each episode.[10]

2.2.1 A Tale of Two Recessions

The BCA literature on U.S. recessions has covered the Great Depression, the 1981 recession and the Great Recession.[11] This paper aims to fill the gap with other two recessions: 1973 and 1990.[12] With that in mind, the BCA exercises use OECD data for the U.S. from 1960 to 2014. All variables are at quarterly frequency, except for population data, which is available annually and transformed to quarterly frequency by linear interpolation. Below is the list of variables (see Appendix A for more details):

- GDP, private final consumption expenditure, gross fixed capital formation, government final consumption expenditure, exports of goods and services and imports of goods and services (market prices value and deflators for each component and total GDP);
- Hours worked per employee;

[10] Otsu (2012) raises the question of whether BCA is a good procedure when instead of analyzing a specific episode, one would like to account for business cycles properties such as cross-correlation of variables and volatility persistence. He argues that instead of a maximum likelihood estimator, one should use a moments-based estimator.

[11] Chari et al. (2007a), Brinca et al. (2016)

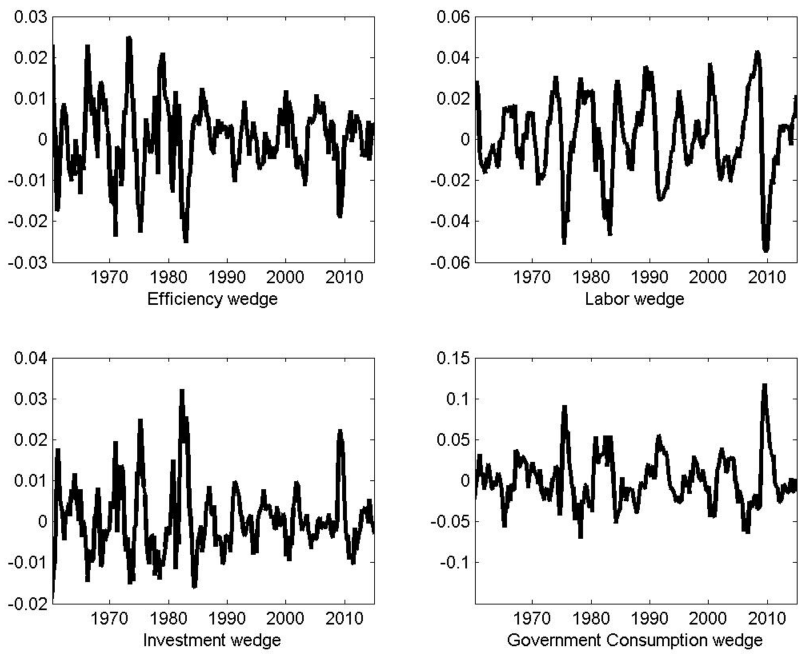
[12] See Federal Reserve Bank (2017) for the dates of U.S. recessions.

- Working age population.

Durable goods are accounted as investment rather than consumption, due to the fact that such goods keep yielding returns throughout time in the same fashion as capital expenditure, thus decisions association with that kind of spending are more related to the investment dynamics, as in Chari et al. (2007a) and Brinca et al. (2016).

Using the previous data, the first step of BCA is to estimate the wedges. The distortions are filtered using the HP-filter, with smoothing parameter equals to 1.600 (Hodrick & Prescott, 1997), and are presented in Figure 1. We use the BCAppIt for the wegde estimation and the BCA simulation[13] It is easy to see that the labor wedge is the more volatile distortion. Moreover, its fall (i.e., a decrease in the marginal value of labor), is associated with recessive periods in the United States.

Figure 1: Estimated HP-filtered wedges for the U.S. economy



[13]The app can be downloaded here: `https://pedrobrinca.pt/software/bcappit-2/`. The user guide is in the appendix.

The volatility of the efficiency wedge decreases throughout time. Up until the end of the 1990s the distortion varied more than after the 2000s. The same pattern is observed in the variability of the investment and the government consumption wedges. This lower volatility is consistent with the Great Moderation. From the prototype model, all the result decisions of economic agents rely on the realization of the wedges. It is important to note that not necessarily the wedge with the largest magnitude or with the largest variability is the one that is going to explain the data best. Indeed, this depends on how the wedge propagates through the model. So, how do we find which distortion is more important? Following Chari et al. (2007a), the marginal effect of each wedge is obtained as follows. First, we let fluctuate the wedge in whose contribution we are interested in (e.g., efficiency wedge), while keeping the others fixed (labor, investment and government).[14] Next, we simulate data from this one-wedge-on economy and see how much the model with only one distortion active can explain the behaviour of actual data. The procedure also works by letting a combination of wedges varying throughout time as well.

The 1973 Recession

The U.S. economy went through a recession of 16 months after the first oil shock. BCA helps us to understand the drivers of the episode. For a matter of comparison, all three aforementioned recessions will be evaluated in a 10 quarters window from its pre-recession peak. Figure 2 presents simulations for both "one wedge economies", when only one wedge is allowed to fluctuate, and "one wedge off economies", when only one wedge remains constant. The prescribed path of output is confronted with the observed data. For instance, the expected output path from the model with only the efficiency wedge follows closely observed data until the third quarter of 1974, corroborating with hypothesis of a

[14]The wedges are fixed ($\bar{S}$) at $\bar{S} = P_0 \cdot (I - P)^{-1}$, with P_0 and P coming from maximum likelihood estimation and I standing for the identity matrix.

recession driven by the efficiency wedge, whereas after that quarter, the model prescribes a faser recovery, meaning that the distortion alone is not able to capture the full 10-quarters window episode.

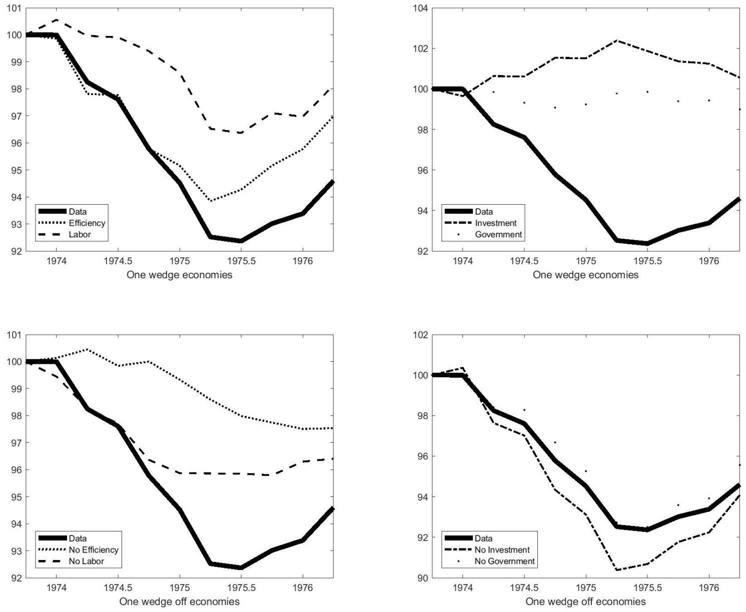
The model with only a labor wedge tells a different story. With only that distortion the recession would be milder, with a lower initial fall and a faster recovery. The model with only the investment wedge, on the other hand, prescribes that output would actually rise and its fall (still above the initial value) would occur only after the first half of the sample period. Finally, output from a model with only the government consumption wedge would have a smoother and almost monotonic downward trend.

The literature has worked with a few statistics in order to make the choice of the better model more rigorous, for instance, the success ratio, the root mean square error (RMSE), Theil's U and the linear correlation coefficient. Output is normalized to a given initial value and the statistics are calculated. For the contribution of each wedge to the movements of the variables of interest (in this paper the focus is the output dynamics), Brinca et al. (2016) use a ϕ statistic, rather than the four presented before, to evaluate each model. The statistic decomposes output fluctuation as follows:

$$\phi_i^y = \frac{1/\sum_t (y_t - y_{i,t})^2}{\sum_j (1/\sum_t (y_t - y_{i,t})^2)}$$

where i is the subscript for output prescribed by each model and j is the total of models considered. The statistics lies between 0 and 1 and the closest the value is to 1, the better. As can be seen in Table 1, the efficiency wedge alone is responsible for 62% of output movements, with a secondary role for the labor wedge (28%). The investment wedge plays almost a nil role (explaining only 4%) as well as the government consumption wedge (6%). When considering all but one wedge, the simulated economy without the government consumption wedge has the highest statistics and accounts for 89% of output movement.

Figure 2: Model vs Data: output during the 1973 recession

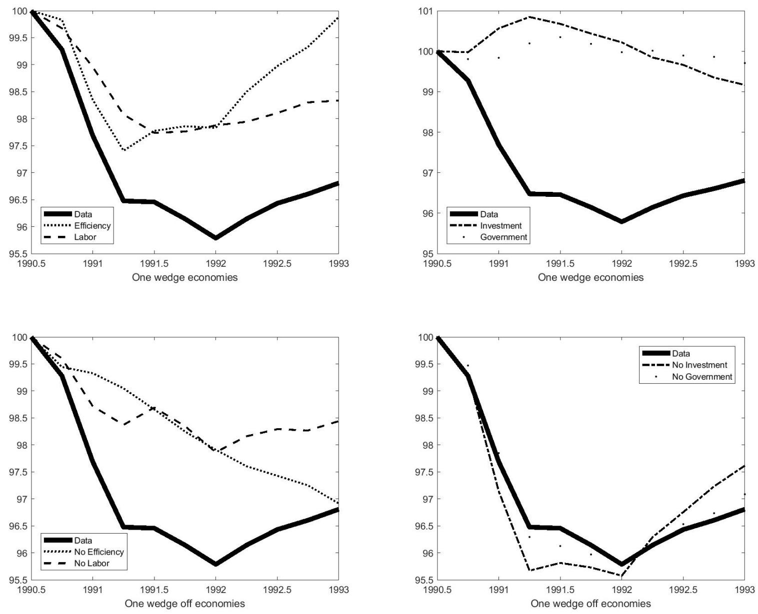


Note: 1973Q1=100.

The 1990 Recession

According to the NBER, the 1990 recession was shorter than the one in 1973, with a duration of eight months. Not only the length is different, but also the drivers of the recession. For instance, even though the efficiency wedge still plays the most important role (explaining 50% of the output fluctuation), the other contributions are higher. With only a distortion in production, the model prescribes an earlier recovery. In the model with only the labor wedge, which accounts for 34% of output dynamics during the 10-quarters window, the recession would begin after the actual start and would be milder. For the remaining two wedges, the investment-wedge alone model prescribes a delayed and softer recession, whereas for the model with only the government consumption wedge, output would almost keep steady. Figure 3 presents simulations for both "one wedge economies" and "one wedge off economies" and the statistics are available in Table 1.

Figure 3: Model vs Data: output during the 1990 recession



Note: 1990Q2=100.

Table 1: The contribution of each wedge in the three episodes (%)

Statistic	ϕ_e	ϕ_l	ϕ_x	ϕ_g
1973 recession				
One wedge economies	62.23	27.63	3.82	6.32
One wedge off economies	37.77	72.37	96.18	93.68
1990 recession				
One wedge economies	50.31	33.97	6.38	9.24
One wedge off economies	49.69	66.03	93.61	90.66

Notes: The values of the table represent the ϕ statistic for the "one wedge economies" and the $1-\phi$ statistic for the "one wedge off" economies for the four distortions: efficiency wedge (ϕ_e), the labor wedge (ϕ_l), the investment wedge (ϕ_x) and the government consumption wedge (ϕ_g).

2.2.2 The Drivers of Recessions and Expansions

Does the contribution of each wedge change from recessions to expansions? Defining a recession (expansion) as a peak to trough (trough to peak) change in GDP (defined by NBER) we may separate the decomposition of the contribution of each wedge (using the ϕ_i^y statistic) in these two groups. As can be seen in Table 2, on one hand, the relevance of the efficiency wedge is higher in recessions than in expansions, accounting for 84% of output movements in the former and 63% in the latter. On the other hand, the contribution of the labor wedge seems to increase in expansions (21%) and decrease in recessions (10%).

The investment wedge does not seem relevant to account for output movements in the U.S.. Either in recessions and/or expansions, its contributions is almost nil (2% and 6%, respectively), a result similar to the one in Chari et al. (2007a). The government consumption wedge, however, has no straightforward conclusion. Even though it has played at best a tertiary role (accounting for 10% of output movements in expansions and only 4% in recessions), the results for the 2001 recession remind us to be careful when discarding that distortion[15].

Table 2: The contribution of each wedge in recessions and expansions (%)

Statistic	ϕ_e	ϕ_l	ϕ_x	ϕ_g
One wedge economies				
Expansions	63.00	21.15	5.75	10.09
Recessions	83.95	9.99	2.29	3.76
One wedge off economies				
Expansions	37.00	78.85	94.25	89.91
Recessions	16.05	90.01	97.71	96.24

Notes: The values of the table represent the ϕ statistic for the "one wedge economies" and the $1-\phi$ statistic for the "one wedge off" economies for the four distortions: efficiency wedge (ϕ_e), the labor wedge (ϕ_l), the investment wedge (ϕ_x) and the government consumption wedge (ϕ_g). Recessions (expansions) defined as a negative (positive) change in GDP (quarter over quarter).

With BCA a researcher aiming to model business cycles would have a proper guide to which classes of models to pursue. However, there may be some caveats

[15]The government consumption played any important role in explaining the behavior of macroeconomic variables using BCA only in a few papers, as can be seen in Section 2.5.

worth to be highlighted, regarding the limitations of the method.

2.3 Methodological Issues and Limitations of BCA

After presenting the benefits of BCA in helping researchers to find the best model to analyze different episodes, it is important to highlight possible pitfalls. The technique has two main caveats: one about the model and the other concerning the data used in the model. In the former, BCA (and its extensions analyzed in Section 2.4) used what seems to be the common ground for DSGE modeling: a production function, labor supply and demand, capital accumulation and a resource constraint. But what if the basic framework is wrong? Even though everything can be mapped into the neoclassical growth model with wedges, the mappings rely on the definition of the prototype economy, in particular, its parametric assumptions and calibration choices. Furthermore, the model is solved by first order and can thus have a hard time in capturing nonlinear dynamics that may arise in recessions. The robustness of the method in such cases is discussed in section 2.3.3. Finally, another note of caution is related to the fact that measuring output, consumption, investment, net exports and government spending in real terms may be a difficult and, more important, an imprecise task.

2.3.1 What If the Model Is Wrong?

Christiano & Davis (2006) raise two concerns regarding BCA approach. First, the structure of wedges and the dynamics of innovations may impose some problems. Since BCA does not identify the source of the shocks, but rather its transmission mechanisms (Chari et al., 2007a), the authors argue that, due to this fact, some spillovers are left out, compromising the method and letting it applicable only to a small subset of reality. Moreover, a wedge could arise from a combination of shocks, rather than from market imperfection itself.

The second concern is related to the specification of the investment wedge.

They argue that small changes in the environment may harm BCA robustness. For instance, in Chari et al. (2007a) financial frictions manifest themselves as efficiency rather than investment wedges. This feature would leave some classes of models out of the prominent candidates' list. They argue that this is due how the wedge is defined and propose an alternative setting: a capital wedge. They support their claim by showing differences in relative contribution of the investment wedge with and without adjustment costs of investment. From a small role in Chari et al. (2007a) to an important role in Christiano & Davis (2006) with the investment wedge accounting up to 52% of output fluctuations.

Instead of a wedge that looks like a time-varying tax on investment, the capital wedge looks like a tax (τ_t^k) on the gross rate of return on capital ($1 + R_{t+1}^k$):

$$(1 + R_{t+1}^k)(1 - \tau_t^k)$$

Under this new specification, they advocate in favor of models such as Bernanke et al. (1999) and Carlstrom & Fuerst (1997), since Christiano & Davis (2006) claim that not only this wedge represents better their detailed economy, but also under this new set up, this wedge plays a more important role in explaining short-run fluctuations. They are also concerned that BCA ignores possible spillover effects of financial shocks onto other wedges. Furthermore, it is precisely by not accounting for these spillovers that investment wedges play only a small role in accounting for output fluctuations.

Chari et al. (2007b) respond to Christiano & Davis (2006) in three fronts. First, they show that equilibrium allocations are the same with either an investment or a capital wedge. Moreover, the investment wedge is equivalent to the capital wedge if the probability distribution of the former is equal under the two representations. With linearized models this frequently will not be case. The results in Chari et al. (2007b) and Šustek (2011), however, corroborate Chari et al. (2007a) by showing that there are no important differences between both specifications

(Brinca, 2014).

Second, they compare Chari et al. (2007a) with Christiano & Davis (2006) methodology and conclude that CKM's have better theoretical foundations. Christiano & Davis (2006) methodology changes the way forecasts of investment paths are made, by letting other wedges to vary, and thus its relative importance.

Finally, they argue that VAR decomposition with a financial shock shows a modest impact of the shock through the investment wedge, reinforcing the results obtained by business cycle decomposition. Aware of the debate between Christiano & Davis (2006) and Chari et al. (2007b), some works using BCA (or its extensions), presented in Section 2.4, verify whether their conclusions are robust to changes in specification, with either an investment or a capital wedge.

2.3.2 What If Data Is Wrong?

BCA assumes that the fact the neoclassical growth models is not able to account for data movements is due to some distortions in optimal decisions. But what if data is wrong? There is the possibility that measured wedges are a product of mismeasurement. Real GDP is obtained by calculating nominal GDP and its the deflator (the same is true for GDP components used in BCA). While nominal GDP imposes less difficulties, calculating price indices may be a real challenge. Feldstein (2017) analyses the implications for real GDP calculation and concludes that the way price indexes are obtained (via marginal costs or hedonic regressions) usually does not encompass necessary quality changes, biasing the estimations of productivity. Moreover, the author highlights that there is a delay for incorporating new products into GDP accounting.

Another example of mismeasurement relies on intangible capital. In McGrattan (2015), using a multi-sector general equilibrium model and input-output data for the U.S., the author tackles this issue by questioning what is the impact of accounting for intangible capital in national accounts. She finds that without accounting for intangible capital, one might (wrongly) assume that there is a distortion, whereas it is only a matter of proper accounting. For instance, not considering spending with R&D, software and brand construction as investments might lead to the wrong account of aggregate investment and the other GDP components. The list goes on and other important components of GDP might be poorly accounted for, such as the financial sector.

Usually, DSGE models are confronted with national accounts data which takes into account only official statistics. But what about the economic activities that may occur in the "shadows". Schneider et al. (2010) identifies a few influencing the shadow economy: taxes and social contributions, regulation, public sector services, the state of the official economy and the labor market. Schneider & Enste (2013) present a survey on the subject.

2.3.3 Robustness Checks and Diagnostics

Almost all exercises implementing BCA were conducted using log-linearization techniques, but no assessment is typically made regarding the robustness of the results to the approximation error. Brinca et al. (2018) show that for the Great Recession, changes in observables reached such magnitudes that BCA implemented using log-linearization techniques imply very inaccurate approximations, leading to wrong conclusions regarding the relative importance of each wedge. Brinca et al. (2018) develop a simple test to assess this which does not involve solving higher-order approximations to the model. The test consists in: comparing the true labor wedge, which can easily be computed from the labor-leisure first order condition, with the labor wedge implied by the linear state-space; and feeding the true labor wedge to the linear state-space approximation and comparing the simulated economies with the ones obtained with the original procedure. If the differences are economically meaningful, Brinca et al. (2018) recommend using higher order approximations and repeat the procedure, until the difference between the simulations using the true labor wedge are not significant.

After identifying possible pitfalls in BCA method, the next section addresses the mappings presented in the literature.

3 From Accounting to Modeling

One of the main contributions of BCA is helping researchers to identify relevant distortions in the neoclassical growth model that explain output changes (Chari et al., 2007a). Once the important wedges are found, the next step is to identify which models are the best candidates to explain data movements. For each wedge there is a large class of detailed models that are equivalent to a prototype model with one or more time-varying wedges that distort the equilibrium decisions. The literature has dealt with these mappings and the results are presented in this section.

3.1 Efficiency Wedge

As explained before, the efficiency wedge distorts production decisions. A rise stimulates the demand for production factors by increasing its marginal product whereas a fall has the opposite effect. There are several modifications in the prototype that can be mapped into an efficiency wedge. For instance, the efficiency wedge arises when there are heterogeneous establishments subject to idiosyncratic shocks. In Lagos (2006), they arise from a frictional labor market (so different firms may have distinct hiring opportunities, impacting its own productivity) and in Restuccia & Rogerson (2008) they are due to different prices faced by individual producers. In both cases, output is obtained by aggregating individual firms and TFP would be a result of average productivity.

Another example of a model with an efficiency wedge is Schmitz Jr (2005). In his model, productivity emerges from changes in work practices. For instance, by increasing operational time of machines there is a increase in marginal product of labor. The change in work rules relocates capital, reduces overstaffing and increases productivity.

An efficiency wedge may arise from the credit market dynamics. In Kiyotaki & Moore (1997), production depends not only on its factors, but how they are financed. Therefore, durable assets play a dual role: not only they are production factors, but also work as collateral for loans. Even temporary shocks to technology or income distribution can generate large and persistent fluctuations in output due to this link. Moreover, the distortions in the firms' and consumers' Euler equation create an investment wedge.

Other sources of financial intermediation are explored in Lu (2013), within a slightly different framework (a computable neoclassical model). He concludes that improvements in financial efficiency generally results in higher steady state output. The reason is that there is a higher percentage of household savings intermediated, not an increase in savings rates per se. In his model, the distortions from the neoclassical equilibrium are materialized into efficiency and investment wedges.

Finally, open-economy variables may be responsible for the efficiency wedge. For instance, Kim (2014) studies import-price shocks on output and productivity, applied to the Korean Crisis (1997-1998). He finds that prices of imported goods relative to the prices of domestic goods impacts output and productivity. Therefore, import-prices and tariffs create distortions that can be expressed as an efficiency wedge. In Brinca & Costa-Filho (2018b), an international crisis can be transmitted via an efficiency wedge due to the share of imported intermediate goods in the domestic output. The Great Recession in Mexico is an example of it. In Chari et al. (2005) a model of sudden stops generates an efficiency wedge by introducing a advance-payment constraining. If wages are paid before production and the realization of shocks, a distortion on production arises, as well as a labor wedge.

3.2 Labor Wedge

Increases in the labor wedge stimulate the labor supply via greater marginal income associated with it. As stated before, BCA does not separate supply and demand shocks. For instance, an economy with sticky wages is equivalent to the prototype model with labor wedges. In the work of Bordo et al. (2000), lagged wage adjustment (*à la* Taylor contracts) played a significant role in intensifying the downturn during the Great Depression. Countries that remained on the gold standard were forced to tight monetary policy, whereas sticky nominal wages produced larger increases in real wages for the gold bloc countries and therefore greater output contraction. Their economy, with sticky wages and monetary shocks, is equivalent to the neoclassical growth model with a labor wedge.

In the economy of Cole & Ohanian (2001), unions and antitrust policy shocks generate a labor wedge. Focusing on the policies implemented as part of the New Deal program, the authors find that the monopolistic power of labor unions may have caused more harm than good during the Great Depression, according the authors. By trying to balance out the impact of the contraction in output, the unions rouse real wages (by not allowing nominal wages to fall as much as inflation), diminishing the demand for labor even more. In the neoclassical growth model, this is equivalent of a distortion on the intratemporal decision of work.

There is also the possibility of a labor wedge from intangible capital. For instance, the investments made in the relationship between firm and its customer may generate a procyclical distortion in labor-leisure decisions as in Gourio & Rudanko (2014).

In Gali et al. (2007), a measure of the deviation from the efficient-level output is created. This "gap", as the authors call it, is decomposed into a price markup and a wage markup. They show the wage markup accounts for the greatest part of the variation. They find that the wage markup is important to account for data movements and they produce equilibrium allocations similar to the ones from a prototype economy with a labor wedge.

Another possibility for generating a labor wedge is by introducing search and matching frictions. By introducing preference shifts, Hall (1997) creates a model with a labor wedge. The introduction of technology shifts and changes in government purchases also influence output, via an efficiency and a government consumption wedge, respectively. In order to understand labor wedge variation, Cheremukhin & Restrepo-Echavarria (2014) and Skibińska (2016) decompose the distortion. Cheremukhin & Restrepo-Echavarria (2014) finds that the wedge is to a large extent explained by the matching efficiency. For instance, an inefficient labor market in Poland and financial frictions in Czech republic explain the labor wedge volatility in Skibińska (2016). Complementary, Mulligan (2002) creates measures for labor-leisure that are base on taxes and subsidies, labor market regulation, monopoly unionism and search frictions.

If we introduce household production as in Karabarbounis (2014), a labor wedge may arise from the between marginal utility due to the consumption of market produced and household produced goods and services. Finally, a model with gender and marital status heterogeneity may also generate a labor wedge and, as Cociuba & Ueberfeldt (2015) show, it is able to account for the trends in hours of work in the U.S..

3.3 Investment Wedge

In a general equilibrium set up, the intertemporal choice between present and future consumption provides the optimal amount of capital supplied. If there is a friction in the investment market, households may increase the supply of capital due to an increase in the marginal income associated with it. Carlstrom & Fuerst (1997) present a computable general equilibrium model with credit market frictions arising from agency costs and equilibrium allocations are similar to a benchmark economy with an investment wedge. However, according to Inaba & Nutahara (2009), this is only the case if adjustment costs are introduced. They find that distortions in the intertemporal decisions (without adjustment costs) only delay the propagation of shocks, while the efficiency wedge is behind output fluctuations.

Adjustment costs in a "time-to-build" dynamics as in Kydland & Prescott (1982) also produce an investment wedge. In a general equilibrium set up, investment takes time to be available as a production factor (capital). Under this modification, they can explain the cyclical variances of a set of economic time series, and the covariance between real output and the others series. The model seems to fit post-war data for the U.S. economy. Typically, BCA is now done with adjustment costs (see Brinca et al. 2016).

Credit market, money and price stickiness into a DSGE model produces an financial accelerator dynamics. For instance, Bernanke et al. (1999) find that financial intermediation influence aggregate fluctuations due to shocks on the capital accumulation process, as in Cooper & Ejarque (2000), an investment wedge arises. When borrowers face different agency costs of financing investment due to its net worth, the amplified effect on output in both upturns and downturns arises from distortions a la investment wedges as in Bernanke (1995).

International financial markets may also produce investment wedges. For example, in Chari et al. (2005) a model with endogenous collateral constraints on foreign debt may distort the Euler equation.

Finally, Tutino (2011) explores the possibility that investment and labor wedges arising from rational inattention. If people pay little attention to wealth changes at a high frequency, this would imply their intertemporal choices, as well as intratemporal ones, would deviate from the optimal path designed by rational expectations. This could be the cause if information processing is constrained.

3.4 Government Consumption Wedge

In the neoclassical growth model used as the benchmark for business cycle accounting, the government consumption enters in the resource constrain, distorting the division of output between consumption and investment. In a open-economy set up, the wedge is equal to government spending plus next exports.

Despite the direct introduction of the wedge in the resource constraint, the literature has developed other ways for the government consumption wedge to manifest itself. For instance, in Chari et al. (2005), the wedge appears when introducing country's collateral constraint on foreign borrowing. By analyzing the effects of sudden stops via constraints on foreign borrowing, the authors show that a sudden stop defined by the increase in net exports would induce a rise in the government wedge. Either state-contingent or uncontingent foreign debt as in Mendoza (2006) might produce a government wedge too.

Finally, the introduction of capital adjustment costs and intermediate imported goods as in Brinca & Costa-Filho (2018b) also produces a government consumption wedge that is not only government spending. The literature on mapping wedges into detailed economies is summarized in tables 3 and 4.

4 Beyond Business Cycle Accounting

BCA opened an avenue of research. Some authors extended CKM's approach to other dimensions, analyzing monetary issues (BCA deals only with the real side of the economy, though it can be mapped to monetary models) and other frameworks such as open economies and the relationship between economies.

4.1 Monetary Business Cycle Accounting

Šustek (2011) prosed an extension of BCA that accounts for the interaction between the real and nominal sides of the economy (BCA deals only with real variables) by introducing inflation and the short-term interest rate into the benchmark economy. The reasoning is the same: assume the basic framework with what is as close as it can be of a consensus and use the distortions for accommodating the idiosyncrasies of each economy. Departing from the same utility maximization problem as in Chari et al. (2007a), the household's budget constraint is modified to encompass real bond holdings as follows:

$$\begin{aligned} &c_t(s^t) + (1+\tau_{xt}(s^t))x_t(s^t) + (1+\tau_{bt}(s^t))\left(\frac{b_t}{(1+R_t)p_t} - \frac{b_{t-1}}{p_t}\right) = \\ &(1-\tau_{lt}(s^t))w_t(s^t)l_t(s^t) + r_t(s^t)k_t(s^t) + T_t(s^t), \end{aligned} \tag{10}$$

where τ_{bt} is the asset market wedge, b stands for bond holdings, R represents the nominal interest rate and p is the price level. The rest is the same as before. Furthermore, the central bank follows a nominal interest rate rule according to:

$$R_t(s^t) = (1-\rho_y)[R + \omega_y(\ln y_t(s^t) - \ln y) + \omega_\pi(\pi_t(s^t) - \pi)] + \rho_R R_{t-1}(s^{t-1}) + \tilde{R}_t(s^t), \tag{11}$$

where ρ_R is the weight of the nominal interest rate at $t-1$, and ρ_y is the weight of both output gap ($\ln y_t - \ln y$) and deviations of inflation ($\pi_t(s^t) = \ln p_t(s^t) - \ln p_{t-1}(s^{t-1})$) from the steady state level (π), given central banks sensitivity of both (captured by the parameters ω_y and ω_π, respectively), plus the Taylor rule wedge, $\tilde{R}_t(s^t)$. The equilibrium is thus given by equations (2.1), (2.2) and (2.4), the nominal interest rate rule, a production function and the optimal decision for bond holdings:

$$\sum_{s^{t+1}} \beta \frac{U_{c,t+1}(s^{t+1})}{U_{c,t}(s^t)} \frac{1+\tau_{b,t+1}(s^{t+1})}{1+\tau_{b,t}(s^t)} \frac{p_t(s^t)}{p_{t+1}(s^{t+1})} [1 + R_t(s^t)] = 1, \tag{12}$$

Šustek (2011) then analyzes what types of distortions explain the observed dynamics of inflation and the short-term interest rate. He also studies the lead-lag relationship of interest rate and inflation with output. This prototype framework encompasses a large class of monetary business cycle models.[16] Notice that after introducing two additional equations, two more wedges emerged: the asset market wedge and the monetary policy wedge.

The asset market wedge distorts the Euler equation for nominal bonds as if it was a tax on nominal holdings. The monetary policy wedge arises from deviation from the Taylor rule. If the Central Bank is worried with something else rather than only inflation and output gap, the wedge emerges. For instance, it may arise from a regime change due to a time-varying inflation target as in Gavin et al. (2007). These two wedges affect only nominal variables, whereas the original four affect both nominal and real variables.

Šustek (2011) finds that inflation and interest rates are negatively correlated with future output and positively with the past one. Moreover, the drivers of inflation and interest rates are the same. Interestingly though, he concludes that sticky prices are not the determinant of the lead-lag dynamics. Furthermore, the efficiency and the asset market wedges are the most promising to capture the dynamics of U.S. data.

The author also provides some mappings. For instance, models with sticky prices generate labor and investment wedges. The idea is that imperfect competition in final goods market distorts the markets for production factors given that factor prices are no longer equal to its marginal product. Inflation is affected in two ways. First, for instance, a negative demand shock that propagates in the economy as an increase in the labor wedge. This would reduce the labor supply (due to the higher tax on labor), increasing inflation. Second, a rise in the investment wedge would decrease aggregate investment, reducing inflation.

[16] E.g. McGrattan (1999); Ireland (2004); Smets & Wouters (2007).

Calvo-style price setting generates efficiency, investment and labor wedges. If we add adjustment costs, the model has also a government consumption wedge.

Finally, according to Šustek (2011), in order to have an asset market wedge, one could introduce a limited participation in asset markets a la Christiano & Eichenbaum (1992), where some agents are excluded from the money market. The wedge acts like taxes on nominal bond holdings and distorts the Euler equation for bonds.[17]

4.2 Open-Economy Business Cycle Accounting

Another modification of BCA is to consider the prototype model as a small open-economy. As in original BCA, the idea is to depart from a basic common ground and introduce distortions in optimal decisions. However, neoclassical small open-economy models may have a problem. The steady state may have a random walk component, which not only implies that temporary shocks have long-run effects, but also imposes computational hurdles (Schmitt-Grohé & Uribe, 2003). For avoiding this issue, some modifications should be done to introduce stationarity. Otsu (2010b), Lama (2011) and Hevia (2014) chose adjustment costs.[18]

There is some difference between Lama (2011) and Hevia (2014). For example, the former uses annual data, while the latter uses quarterly data. More important though is the fact that Lama (2011) assumes that the wedges follow an AR processes, rather than a VAR process as in Hevia (2014), removing possible spillovers amongst wedges.

Departing from the same utility maximization problem as in Chari et al. (2007a), the household's budget constraint is modified to encompass foreign

[17] See Fuerst (1992) for this so-called "liquidity effect".

[18] See Schmitt-Grohé & Uribe (2003) for the models specification and the discussion of the induction of stationarity in small open-economy models. Otsu (2010b) has a slightly different specification then Lama (2011).

debt holdings as follows:

$$c_t(s^t) + (1 + \tau_{xt}(s^t))x_t(s^t) + d_t(s^t) + \Phi(d_{t+1}) + \Theta(\frac{x_t}{k_t})k_t(s^t) = \\ (1 - \tau_{lt}(s^t))w_t(s^t)l_t(s^t) + r_t(s^t)k_t(s^t) + \frac{\Gamma d_{t+1}(s^{t+1})}{R(1 + \tau_{d,t}(s^t))} + T_t(s^t), \tag{13}$$

where d is foreign debt, R is the world interest rate, $\Phi(.)$ represents the debt adjustment costs, $\Theta(.)$ stands for capital adjustment costs, γ_N is the population growth rate, γ is the technological progress and $\Gamma = (1 + \gamma_N)(1 + \gamma)$. The rest is the same as before. The trade balance is defined as

$$tb_t(s^t) = d_t(s^t) - \frac{\Gamma d_{t+1}(s^{t+1})}{R(1 + \tau_{d,t}(s^t))} + \Phi(d_{t+1}). \tag{14}$$

The resource constraint that in BCA is represented by equation (2.4) is augmented to encompass the open-economy set up:

$$c_t(s^t) + x_t(s^t) + g_t(s^t) + tb_t(s^t) + \Theta(\frac{x_t}{k_t})k_t(s^t) = y_t(s^t). \tag{15}$$

The equilibrium is thus given by equations (2.1) and (2.2), the definition of trade balance, the resource constraint, a production function, the capital Euler equation (equation (2.3) adjusted to considerer adjustment costs in debt and capital) and the Euler equation in foreign debt:

$$\sum_{s^{t+1}} \beta U_{c,t+1}(s^{t+1}) = U_{c,t}(s^t)(\frac{\Gamma}{R(1 + \tau_{d,t}(s^t))} - \Phi_d(d_{t+1})). \tag{16}$$

Under this framework, the country is a net debtor, paying interests on debt. Therefore, a new wedge arises: the bond wedge, a premium on foreign bonds interest rate.[19] If the bond wedge rises, borrowing abroad becomes more expensive, so there is less capital inflow and, holding everything else constant,

[19] Otsu (2010b) calls it foreign debt wedge.

financial account balance should diminish, while trade balance improves (Otsu, 2010b). A rise in the borrowing costs decreases consumption and leisure, since return on investment must be equal to the international borrowing cost. If leisure decreases, the amount of labor increases, hence a rise in the bond wedge augments output.

In an open-economy business cycle accounting (OBCA), the efficiency wedge may arise from models with working capital constraint, such as Christiano et al. (2004). Even without technological change, the interest rate and import prices alone generate an efficiency wedge (Lama, 2011). Otsu (2010b) highlights that an intermediate-good structure within a small open economy may also generate an efficiency wedge, as well as labor reallocation from more productive sectors to less productive led to a decline in TFP, as in Benjamin & Meza (2009).

A labor wedge may arise by introducing working capital on labor. If firm's borrowing is related to demand of labor, labor costs will depend also on gross interest rates, not only on the wage rate as in Neumeyer & Perri (2005). Also, a model with cash-in-advance constraint on consumption goods and monetary shocks as Cooley & Hansen (1989) creates the wedge.

The investment wedge, as well as in the BCA model, arises from financial frictions. Credit market distortions, financial accelerators and agency costs produce the distortion in the neoclassical framework. This wedge maps into the works of Gertler et al. (2007), Bernanke et al. (1999), Christiano & Davis (2006).

The bond wedge emerges from models with collateral constraints. Limits on international borrowing lead to interest rate premiums (the wedge), for instance, in episodes of sudden stops (Mendoza, 2006; Mendoza & Smith, 2006). Finally, a model with financial frictions such as Mendoza (2010) generates the five wedges (Hevia, 2014).

4.3 International Business Cycle Accounting

BCA was also extended to study international linkages between two countries. In Otsu (2010a), a two country version of Chari et al. (2007a) is developed. Besides the four standard wedges, which the author calls CKM wedges, even though he separates government spending from net exports. Departing from the same utility maximization problem as in Chari et al. (2007a), the household's budget constraint is modified to encompass the two-country dynamics for country $i \in \{A, B\}$:

$$c_t^i(s^t) + (1 + \tau_{xt}^i(s^t))x_t^i(s^t) + p_t^i(s^t) \sum_{s_t^{t+1}|s^t} q_t(s_t^{t+1}|s^t)d_{t+1}^i(s_t^{t+1}|s^t) + \Theta\left(\frac{x_t}{k_t}\right)k_t(s^t) =$$
$$(1 - \tau_{lt}(s^t))w_t(s^t)l_t(s^t) + r_t(s^t)k_t(s^t) + p_t^i(s^t)d_t^i(s^t) + T_t(s^t), \tag{17}$$

where q_t is the price of one-period contingent claims and the rest is the same as before. The introduction of an international financial market imposes the following constraint:

$$\begin{aligned} &[q_t(s_t^{t+1}|s^t)d_{t+1}^A(s_t^{t+1}|s^t) - d_t^A(s^t)] + \\ &[q_t(s_t^{t+1}|s^t)d_{t+1}^B(s_t^{t+1}|s^t) - d_t^B(s^t)] = \tau_{tb,t}(s^t), \end{aligned} \tag{18}$$

where $\tau_{tb,t}$ is the international trade wedge. International balance implies:

$$tb_t^A(s^t) + tb_t^B(s^t)/p_t(s^t) = \tau_{tb,t}, \tag{19}$$

where $p_t(s^t)$ is the international price wedge, defined as follows:

$$p_t(s^t) = \frac{p_t^B(s^t)}{p_t^A(s^t)}. \tag{20}$$

The international price wedge disturbs cross-country risk sharing, by not allowing marginal utility of consumption to be equal across countries due to, for instance, trade or transactions costs. The international trade wedge is a distortion on the international resource constraint, capturing what is in the aggregate trade balance, evaluated at international prices, that is not accounted for the model, e.g., trade with other countries.

The international price wedge may arise from a limitation on international risk sharing due to incomplete capital markets as in Baxter & Crucini (1995). A two-country, two-good model such as Backus et al. (1994), Stockman & Tesar (1995) or Wen (2007) can also generate this wedge. Rewrite The resource constraint is defined as below:

$$c_t^i(s^t) + x_t^i(s^t) + g_t^i(s^t) + tb_t^i(s^t) + \Theta\left(\frac{x_t^i(s^t)}{k_t^i(s^t)}\right)k_t^i(s^t) = y_t^i(s^t). \quad (21)$$

Under this set up, some features observed in the data are replicated in Otsu (2010a). For instance, the low cross-country consumption correlation, due to distortions in the international financial market. By adding labor and investment wedges one could avoid production factors perfect mobility. If the international price wedge increases, the price of domestic relative to foreign resources also increases, creating a negative domestic wealth effect. Therefore, consumption and leisure will fall at home, while consumption and leisure will arise abroad. Moreover, domestic labor will increase, augmenting output.

A rise in international trade wedges works similarly as an increase in the government wedge, affecting the resource constraint, but at a global level. If the wedge soars, international claims accumulation decreases (that can be seen as an outflow of savings), diminishing consumption and leisure, stimulating labor and output.

This section presented the extensions of BCA. Even though the original Chari et al. (2007a) wedges can be mapped into different models accounting for nominal and real variables, changing the basic framework to incorporate small open-economy dynamics and the economic relationship between countries seems to be a step further on the decomposition of original wedges (see tables 3 and 4 for the literature mappings for BCA and its extensions). Monetary BCA helps to understand the transmission of monetary policy shocks, for instance. In Open-economy BCA, the impact of sudden stops and the reasoning for current account balance improvements are better explored. Moreover, by separating government consumption from net exports, we have an additional international transmission channel.

The use of BCA on business cycles analysis has grown fast throughout time. The next section is dedicated to a detailed analysis of the results literature has found so far. With a broad sample of papers working with BCA (and its extensions), with a diversity of countries and episodes studied, we can explore possible patters on the relative contribution of wedges.

Table 3: Wedges and mappings: efficiency and labor wedges

Wedge	**Mapping**	**Reference**
Efficiency	Production units subject to idiosyncratic shocks.	Lagos (2006)
Efficiency	Establishments with different productivity.	Restuccia & Rogerson (2008)
Efficiency	Productivity arising from work practices.	Schmitz Jr (2005)
Efficiency	Credit limits and asset prices amplifying shocks.	Kiyotaki & Moore (1997)
Efficiency	Labor and investment frictions with technology shocks.	Zanetti (2008)
Efficiency	Import-price shocks impacting output and productivity.	Kim (2014)
Efficiency	More efficient financial intermediation enhancing growth.	Lu (2013)
Efficiency	Intermediate imported goods.	Brinca & Costa-Filho (2018b)
Efficiency	Working capital constraint (OBCA).	Christiano et al. (2004)
Efficiency	Advance-payment Constraint.	Chari et al. (2005)
Efficiency	Financial frictions (OBCA).	Mendoza (2010)
Labor	Sticky wages.	Bordo et al. (2000)
Labor	Unions and antitrust policy shocks.	Cole & Ohanian (2001)
Labor	Price markup and a wage markup.	Gali et al. (2007)
Labor	Search frictions.	Hall (1997), Cheremukhin & Restrepo-Echavarria (2014), Skibińska (2016)
Labor	Household production.	Karabarbounis (2014)
Labor	Intangible capital.	Gourio & Rudanko (2014)
Labor	Taxes and subsidies influencing labor-leisure decisions.	Mulligan (2002)
Labor	Working capital on labor (OBCA).	Neumeyer & Perri (2005)
Labor	Cash-in-advance constraint on consumption goods (OBCA).	Neumeyer & Perri (2005)
Labor	Advance-payment Constraint.	Chari et al. (2005)
Labor	Financial frictions (OBCA).	Mendoza (2010)

Table 4: Wedges and mapping: investment, government, asset markets, bond and international price

Wedge	**Mapping**	**Reference**
Investment	Credit market with agency costs.	Carlstrom & Fuerst (1997)
Investment	Adjustment costs.	Inaba & Nutahara (2009) and Kydland & Prescott (1982)
Investment	Financial accelerator: credit market, money and price stickiness.	Bernanke et al. (1999), Gali et al. (2007)
Investment	Shocks on the capital accumulation process.	Cooper & Ejarque (2000)
Investment	Rational inattention.	Tutino (2011)
Investment	Financial frictions (OBCA).	Mendoza (2010)
Investment	Investment-specific technological change.	Greenwood et al. (1997)
Investment	Bank collateral constraints.	Kiyotaki & Moore (1997), Gertler et al. (2010)
Investment	Collateral constraints on foreign debt.	Chari et al. (2005)
Government	Constraint on foreign borrowing	Chari et al. (2005)
Government	Uncontingent	Mendoza (2006)
Asset market	Tax on nominal holdings.	McGrattan (1999), Ireland (2004), Smets & Wouters (2007)
Asset market	Limited participation in asset markets.	Christiano & Eichenbaum (1992)
Monetary policy	Deviations from the Taylor rule.	McGrattan (1999), Ireland (2004), Smets & Wouters (2007)
Monetary policy	Time-varying in inflation target of a regime change.	Gavin et al. (2007)
Monetary policy	Financial frictions.	Mendoza (2010)
Bond	Interest rate premium on foreign bonds.	Mendoza (2010)
Bond	Collateral constraint.	Mendoza (2006)
Bond	Financial frictions.	Mendoza (2010)
International price	Limitation on international risk sharing.	Baxter & Crucini (1995)
International price	Two-country, two-good model.	Backus et al. (1994)
International price	Tradable/nontradable separation.	Stockman & Tesar (1995)
International price	Two-country model model with tastes shocks.	Stockman & Tesar (1995), Wen (2007)

The use of BCA on business cycles analysis has grown fast throughout time. The next section is dedicated to a detailed analysis of the results literature has found so far. With a broad sample of papers working with BCA (and its extensions), with a diversity of countries and episodes studied, we can explore possible patters on the relative contribution of wedges.

5 Common findings

Several papers use BCA method to analyze macroeconomic fluctuations and to shed some light on the possible paths for modeling and explaining short-run dynamics. With a few exceptions, the focus has being on explaining downturns and the recoveries after. Table 5 presents BCA applications divided by country.

It is easy to see that BCA and its extensions have been used in two different types of analysis, either a single country, one or a few episodes, or within an international comparison, either in comprehensive studies as Brinca et al. (2016), Brinca (2014) and Gerth & Otsu (2016), or regional comparisons like Lama (2011) and Ohanian et al. (2015).

Table 5: BCA (and extensions) literature by country/groups of countries

Country	Reference
Argentina	Cavalcanti et al. (2008)
Brazil	Graminho (2006); Brinca & Costa-Filho (2018a)
Bulgaria	Vasilev (2017)
Canada	Hevia (2014)
Chile	Simonovska & Söderling (2008)
China	He et al. (2009); Gao & Ljungwall (2009)
France	Bridji (2013)
India	Gao & Ljungwall (2009)
Italy	Orsi & Turino (2014)
Japan	Cunha (2006); Kobayashi & Inaba (2006); Saijo (2008); Chakraborty (2009)
Korea	Sarabia (2007), Hevia (2014), Hirata & Otsu (2011)
Mexico	Meza (2008), Hevia (2014), Sarabia (2008), Brinca & Costa-Filho (2018b)
Paraguay	Hnatkovska & Koehler-Geib (2015)
Portugal	Cavalcanti (2007), Iskrev (2013)
Spain	López & García (2014)
Sweden	Brinca (2013)
Turkey	Elgin & Cicek (2011)
United Kingdom	Kersting (2008), Chadha & Warren (2012)
United States	Chari et al. (2007a), Ohanian (2010), Macnamara (2016)
Asian countries	Hirata & Otsu (2011), Cho & Doblas-Madrid (2013), Otsu (2010a), Ohanian et al. (2015)
BRIC countries	Chakraborty & Otsu (2013)
European countries	Gerth & Otsu (2016)
European Union	Kolasa (2013)
Latin America	Lama (2011), Ohanian et al. (2015)
OECD countries	Brinca et al. (2016), Brinca (2014)

5.1 Developed Economies

The initial efforts on BCA were to explain two major episodes for the U.S. economy: the Great Depression and the 1982 recession. Chari et al. (2007a) concludes that labor and efficiency wedges, respectively, are important to account for the economic fluctuations in both periods. The investment wedge plays a tertiary role, while the government consumption wedge plays none. They change the framework to see the robustness of their conclusions. First, they introduce variable capital utilization. Since the number of workers is constant, the variation comes from the workweek. It does not change the small contribution of investment wedge. Then, they try different labor supply elasticities. This changes the size of the measured labor wedge, but not of the investment wedge. Finally, they introduce investment adjustment costs and there is still a modest role for the investment wedge. Their findings are aligned with the importance of frictions in financial markets for business cycle fluctuations, since input-financing frictions may produce their results via efficiency wedges[20].

The Great Recession in the U.S. was also focus of analysis with BCA. Ohanian (2010) investigates what are the causes of the U.S. 2007-2009 recession that make it not only different from other postwar U.S. recessions, but also from other developed economies recessions. Usually, the driver is the efficiency wedge, but in the 2007-2009 episodes, however, the recession was mainly due to a large decline in labor input (labor wedge). The author raises the hypothesis that economic policy may be behind this. By raising tax on labor, labor supply is affected, diminishing output. When comparing the relevance of wedges for Canada, France, Germany, Italy, Japan and UK, he concludes that the efficiency wedge is behind their recessions.

Instead of proceeding the usual decomposition to access which wedge accounts for most of output movements, Macnamara (2016) is interest in verifying firms entry and exit rates. With that in mind, he uses BCA to construct measures of aggregate shocks and finds that not only labor shocks (wedge) account for movements in entry and exit rates, it also explains the slow recovery in employment after the 2008 financial crisis. The efficiency wedge explanation power is almost null.

Brinca et al. (2016) finds the same result for the U.S. Great Recession: the protagonism of the labor wedge. In a comprehensive study of the Great Recession in 24 OECD countries, the main driver of the recession was the efficiency wedge, whereas for a few exceptions (U.S., Spain, Ireland and Iceland) the labor wedge was the most important distortion.

In a study close to Brinca et al. (2016), Gerth & Otsu (2016) analyze the Great Recession in 29 European countries. The authors find that the efficiency wedge is the main driver of the poor post-crisis performance, with a few exceptions

[20]Before Chari et al. (2007a), some works dealt with business cycle analysis using only a few wedges. For example, Chari et al. (2002) with all but the government wedge, finds an important role for the efficiency wedge, followed by the labor wedge in explaining the Great Depression.

for Southern Europe countries, in which the investment and labor wedges play more important roles. Using cross-country regressions of wedges on financial variables, they find that non-performing loans, market capitalization and house price index are negatively correlated with the efficiency wedge which corroborates with the hypothesis of resource misallocation triggered by a financial crisis.

Kolasa (2013) raises an interesting question. If business cycle synchronization is important within a currency union, what explains differences in business cycles between Central and Eastern European countries and the euro area? He uses BCA for identifying the sources of divergences and convergences between the euro area and Czech Republic, Hungary, Poland, Slovakia and Slovenia[21]. He finds that there has been some convergence, mostly due to synchronization in the efficiency wedge, though the main differences arise from labor and investment wedge. The government wedge does not help to explain data movements.

Still in Europe, Bridji (2013) deals with the Great Depression in France. He finds that the efficiency wedge explains fluctuations in output and most of the fall in labor and investment. Investment and labor wedges played secondary roles. The investment wedge accounts for the fall in consumption and the labor wedge explains why the economy did not get back on track after 1936. Regarding the efficiency wedge, the money multiplier dynamics is the most promising explanation and was responsible for the worsening in the economic activity in 1929-1932 as due to capital underutilization. Moreover, they concluded that the labor wedge decline is due to the wage markup. Financial frictions as in Carlstrom & Fuerst (1997) explain the fall in consumption, augmenting the importance of the investment wedge for explaining consumption movements.

The United Kingdom's 1980 recession was driven by the labor and the efficiency wedges, with a special role of the former during the recovery (Kersting, 2008). The investment wedge plays a minor role by smoothing the fall in the

[21]Some euro area countries were excluded due to data limitations.

labor market. The author concludes that labor market reforms, including those reducing the role of unions in the wage negotiation process, were justified. He says that distortions in the labor market played a large role in causing the recession and his simulations point towards the idea that the recovery was driven by their removals.

Chadha & Warren (2012) also study the UK economy, looking for the causes of UK's Great Recession. The recession was driven by an investment and consumption fall, whereas investment was the main responsible for the recovery. They also perform a counter-factual analysis[22]. By generating artificial data from detailed economy composed by a New Keynesian set up with credit market frictions via Monte Carlo simulation, they find that bubble shocks manifest themselves as an efficiency, rather than and investment wedge.

The efficiency and the labor wedges also help to explain economic growth in Italy since the middle 90s onwards (Orsi & Turino, 2014). The country experienced labor market reforms and changes in tax rates and the authors conclude that this might be the reason behind the fact that euro-area countries grew, while Italy did not. Market reforms that aimed to increase flexibility such as loosening regulation on non-permanent labor contracts affect directly the labor supply (causing the labor wedge). They may also affect allocation of production inputs, which distorts production decisions, creating efficiency wedges. Insufficient R & D investments that cause a fall in productivity may also create this wedge.

In Cavalcanti (2007), the author examines the economic slowdown from 1979 to 1985 and from 1992 to 1996 in Portugal, a period in which the country experience major economic changes, such as joining the European Union. He finds that the recovery in Portuguese output until the first years of the 1990s can be attributed to economic efficiency improvements. The author also finds that less distorted labor policies would help Portuguese growth (a small open-economy

[22]They expand their sample until 2015 using forecast series to avoid usual problems with filtering estimation.

set up does not change the conclusions). Iskrev (2013) also analyze Portuguese business cycles, extending the sample. He also finds that the efficiency wedge is the most important distortion, even though labor wedge is also necessary for explaining short-run fluctuations.

López & García (2014) study the Spanish business cycle during the transition to demacracy in 1977 and the Great Recession. For both episodes, they find the labor wedge is the key component, while the efficiency wedge plays - at most - a secondary role. The other wedges are quantitatively nil. By simulating a DSGE model with shocks to labor and efficiency wedge, they failed to reproduce relative consumption volatility, but they generated a negative correlation between productivity and real wage. Analyzing the causes of the distortion labeled as labor wedge their regressions points towards the importance of unemployment benefits, tax rates and the centralization of collective bargaining.

The Swedish business cycles registered two major recessions: on the early 1990s and 2008 financial crisis. Using MBCA, Brinca (2013) studies the drivers of each episode. He finds that the 1990's real state crisis translated into a structural change in the wedges, pointing towards a domestic-originated episode. In the 2008 crisis, firms idle capacity and costs on firing labor discouraged firms from firing workers even with a lack of demand, leading to a decline in economic activity.. For explaining the business cycles associated with the two episodes, the efficiency, labor, monetary policy wedges are the most important, followed by investment and asset market.

After experiencing a Depression-like dynamics in the 1990s, Ireland recovered fast and its performance during the 1990s draw some attention. Ahearne et al. (2006) use BCA to analyze the Great Depression of Ireland. They find an important role for the efficiency wedge and a medium role for the labor wedge and almost no role for the investment and government consumption wedge, aligned with what Chari et al. (2007a) found for the U.S..

For Japan, the results in Kobayashi & Inaba (2006), using a BCA framework (with perfect foresight), are slightly different than those in Chari et al. (2007a). Using the capital wedge instead of the investment wedge, their contrast is regarding the role of investment/financial wedges in explaining the Great Depression. They conclude that the capital wedge was the driver of the episode.

Contrasting with Kobayashi & Inaba (2006), Chakraborty (2009) and Cunha (2006) finds that output movements in Japan are mainly explained by the efficiency and the investment wedges. Output fall in the 1990s seem to be due to declining productivity, labor market frictions and investment frictions.

Saijo (2008) also finds that besides the importance of the efficiency wedge for explaining output fall, the labor and investment wedges are also important for understanding the slow recovery. He argues that government policies increased firms' monopoly power (markups increase during the depression, generating both labor and investment wedges), while no bargaining power was given to the labor force. If there was no increase in markups, counterfactual evidence implies a output recovery.

Hirata & Otsu (2011) investigate the economic relationship between Japan and Korea and Taiwan. In a IBCA set up a two-country, two-good model in which the efficiency wedge manifest itself as productivity in intermediates goods output, rather than TFP, implying that a relative price change in intermediate goods can distort production decisions, they conclude that growth in the Asian Tigers productivity generated positive spillover effects on Japanese growth via terms of trade. The efficiency wedge is the most important driver, followed by the labor wedge. The international wedges (price and trade) and play a tertiary role, implying that the international link of the positive spillovers did not manifest via international capital markets (international price wedge) or on the quantity dimension of international goods markets (international trade wedge).

Finally, in a more comprehensive paper, with a sample composed by 22

OECD countries, Brinca (2014) analyzes what wedges systematically account for business cycle fluctuations. Instead of focusing on specific episodes, he implements BCA for each country (with same parameters so the differences in the wedges are not due to different parameterization) and calculates the empirical distributions of the averages for the HP-filtered trend and cycle wedges. He finds that the efficiency wedge explains output and aggregate investment movements, whereas the labor wedge is important for modeling the dynamics of hours of work. Wedges cross-country correlations are correlated with geographic distance and trade openness.

5.2 Emerging Markets

The literature has found some differences on the BCA results between developed and emerging markets (EM) short-run fluctuations, specially in volatility. In a prototype economy this is translated into more volatile wedges. Moreover, the relative importance of wedges may change. For instance, Hevia (2014) tackles precisely the question of what are the differences between developed and Emerging Markets fluctuations using an OBCA framework. Using Canada and Mexico, he finds in the former an important role of efficiency and labor wedges, although bond and investment wedges contribute to explain aggregate investment, trade balance and consumption. In the latter, output movements are driven by efficiency, labor and bond wedges. These results are important because even though the efficiency wedge very often is an important driver (see tables 6 and 7), its relative contribution (and of the other wedges) may change not amongst episodes, but also among development stages.

Sudden stops would naturally be associated with a prominent role for the government consumption wedge (Chari et al. (2005) discusses this issue), nevertheless, Sarabia (2008) finds that efficiency and labor wedges are the most important distortions driving short-run output fluctuations in Mexico in periods of crises, in line with the results of Hevia (2014). For the 1995 crisis, the role of the investment wedge is higher than for the 2001 recession, but is still a minor role. Under a variable capital utilization framework, the efficiency wedge still plays the most important role, though it explains a lower fraction of output fluctuations in the 2001 recession. The relative importance of the labor wedge rises in the 1995 crisis, but falls in the 2001 episode.

Meza (2008) complements the analysis of the 1995 GDP Contraction in Mexico by asking what is the role of fiscal policy in the episode. Using a version of BCA that allows for variable capital utilization (i.e., different production function) and a fiscal policy model with government consumption and a tax on consumption to decompose BCA wedges, he quantifies the role of fiscal policy by constructing counterfactual wedges. His conclusion is that fiscal policy has a significant contribution, specially via tax increases.

Brinca & Costa-Filho (2018b) analyze the transmission of international crises and focus on Mexico's 1995 and 2008 crises, complementing Hevia (2014), Meza (2008) and Sarabia (2008). Adjusting investment and consumption data as in Brinca et al. (2016), they find that the efficiency wedge also drives fluctuations in output. An equivalence is proposed between the prototype economy with an efficiency and an investment wedge and an open-economy model with imported goods into the final goods production function in order to understand the episode. Not only the model is able to reproduce output path in both episodes, but also it reveals a "hidden" international transmission mechanism within the efficiency wedge.

Ohanian et al. (2015) questions the usual international-market-frictions explanations for capital inflows in East Asia and Latin America. Using a different type of IBCA, built on a three-country neoclassical DSGE model (with Latin American, East Asia and the rest of the world), they analyze what distortions are relevant for explaining capital inflow in both regions. The conclusion favors domestic rather than international wedges as the main reasons. They find that from the 1950s to 1980s, a lower labor wedge in Latin America reduced the price of labor. A lower cost of labor attracted capital flows. The declining labor wedge was thus the main driver of capital inflows, rather than the characteristics of international markets.

Similarly, Otsu (2010b) also concludes that "domestic wedges" are the drivers even when international capital plays an important role. He studies the Asian crisis in the 90s under the OBCA framework, focusing on the 1998 recession. With a similar model to the working paper version of Lama (2011), he concludes that the efficiency wedge is the most important distortion to capture the dynamics in Honk Kong, Korea and Thailand. The labor wedge has a lesser importance and the investment and asset market wedge a very small role. The results are robust to alternative forms of distortions in the international capital markets, and also to different preferences. When introducing a capital rather than an investment wedge, the distortion has a slightly more important role than investment.

Lama (2011) uses an OBCA set up to study recessions and recoveries in selected Latin American countries during the 1990s and early 2000s. The author concludes that the relevant wedges explaining business cycles in the aforesaid emerging economies are the efficiency wedge and the labor wedge. Even though the bond wedge has some success in accounting for trade balance movements, its contribution for explaining other macroeconomic variables is almost nil. The main conclusions do not change with alternative specifications, such as different preferences, TFP affecting the risk premium, TFP following a unit root process and the introduction of variable capital utilization. The author also provides mappings from models to wedges in the open-economy benchmark model.

In line with Lama (2011), Graminho (2006) also concludes that the efficiency and labor wedges are important to explain Brazilian business cycles from 1980 to 2000. The importance of each wedge was evaluated by simulating the model with each wedge and the outcomes were evaluated with the correlation coefficient and Theil's U. After experiencing one of the fastest average growth rates in the world (GDP grew, on average, at 7,4% per year, from 1950 to 1962 and at 9.0% from 1968 to 1980), Brazilian growth rates became low and the country entered in the so-called "lost decades". The author proposes that labor market changes imposed by the 1988 Constitution with the increase on barriers to competition are the main root behind it.

Brinca & Costa-Filho (2018a) complement Lama (2011) and Graminho (2006) by using quarterly data, adjusting consumption and investment series as in Brinca et al. (2016), extending the sample period and focusing on the 2014-2016 depression. The authors find that the efficiency wedge is the main driver of the episode. Moreover, there seems to be a negative relation between the efficiency wedge and the national bank of development (BNDES – *Banco Nacional de Desenvolvimento Econômico e Social* – in the Portuguese acronym) outlays in the medium run, raising the hypothesis that the "Brazilian quantitative easing" before 2014 may have contributed for the drop. If subsidized lending target low return projects, aggregate productivity might fall. Moreover, a DSGE model with a public development bank accounts for short-run output movements.

Brazil and the other BRIC economies business cycles are analyzed by Chakraborty & Otsu (2013). They found out that for Brazil and Russia, investment wedge plays a key role during the 1990s, while efficiency wedge helps to explain the recovery in the 2000s (labor wedge is also important, with a smaller role). For China and India, the relative importance of wedges is the opposite, i.e., efficiency wedges explain the dynamics during the 1990s, while investment wedges are important for the 2000s, specially over the second half. Their results are robust to changes in the procedure, such as capital adjustment costs, hoarding and a small open economy framework.

Hnatkovska & Koehler-Geib (2015) studies why volatility in Paraguay has increased while it has fallen in other Latin American countries, on average. The authors use VAR models for understanding what was behind that, domestic or international drivers. They find that external shocks are important, specially because agriculture is a relevant sector in the economy. Moreover, in the BCA with a capital wedge and separate agricultural and non-agricultural sectors (each one has its own efficiency wedge) they conjecture that the labor wedge might be influenced by increases in minimum apprentice wages and that capital wedge volatility was mainly driven by financial constraints on households, rather than firms.

Using a slightly different framework for BCA, with capital utilization as result of households' decision, Cavalcanti et al. (2008) analyze business cycles in Argentina during several economic changes, such as the debt crisis (1972-1982) and the exchange rate regime collapse (1991 to 2001), for example. Individually, the efficiency is the most important distortion, with a very small role for the government wedge (which is really only a net exports wedge since data on government spending was not available). By combining wedges, the model with both efficiency and capital wedge fits better the data. The authors limit their work to BCA.

Simonovska & Söderling (2008) study the sources of business cycle fluctuations in Chile [1998-2007]. However important, the efficiency wedge alone is not enough for explaining outpout movements. The labor and investment play a smaller role. Citing OCED (2009), they raise the hypothesis that segmentation in Chilean labor market with respect to age, sex and job tenure may explain the labor and efficiency wedge, by imposing high entry barriers and preventing firms to adjust inputs properly. Furthermore, labor market reforms are likely responsible for increasing employment. Due to the importance of copper to the Chilean economy, they analyze whether their results change by isolating mining investment. Due to lack of proper data, they use mining FDI as a proxy of mining investment, by subtracting it from total investment and adding it to government wedge. The results are similar.

Since the 1950s, Turkey has experienced three military coups and four economics crises, besides usual recessions and expansion periods. Elgin & Cicek (2011) investigates what drives business cycles in the country and finds that the efficiency wedge is the most important distortion for explaining output short-run dynamics. The labor wedge plays a secondary role and the remaining wedges do not drive GDP movements in an important way. The authors separate net exports from government spending, thus they call net exports as "trade wedge".

Short-run fluctuations during the Korea crisis are addressed by Sarabia (2007). He uses BCA and finds that the importance of investment wedge and the financial accelerator model he uses in explaining the episode depends on the parameterization. More specifically, on Tobin's q elasticity. If Tobin's q elasticity is relatively small (around 0.5), then the finance premium that creates the financial accelerator accounts for a great part of the Korean crisis. Larger values for the elasticity imply a lower role for the investment wedge. Moreover, the labor wedge seems to play a secondary role, whereas the efficiency and the government consumption wedge play small and almost nil roles, respectively.

Gao & Ljungwall (2009) use BCA to analyze Indian and Chinese business cycles. Both economies have been experiencing rapid growth and similar development strategies: market-oriented reforms and increasing financial and trade integration. Also, they both began to change their economic structure in the late 1970s, early 1980s. China focused on labor-intensive industries, while India alleviated state interference in its large private sector. The authors find that the efficiency wedge has an important role to explain business cycles in both countries, whereas the other wedges play a small role. Technology advances and infrastructure changes may be behind this result.

He et al. (2009) also analyze Chinese business cycles. Using an OBCA set up, they also conclude that the efficiency wedge is the most important distortions for understanding short-run fluctuations in China. Notwithstanding, the other wedges play a greater role than in Gao & Ljungwall (2009). The bond wedge influence grew due to the increase in Chinese openness, and also as a consequence of external shocks. Efficiency wedges may be a consequence of increases in the price of agriculture products and the labor wedge a result from sticky wages and powerful labor unions.

In Cho & Doblas-Madrid (2013), the authors use BCA to analyze the mechanisms leading output drops in financial crises using a sample of 23 episodes from 13 countries (with different parameters for each country). The evidence points towards deeper and more investment-driven crises in Asia than in other countries. The authors find that the investment wedge plays a role more important than the labor wedge. This may emerge due to some idiosyncrasies of Asian financial markets, i.e., it seems that Asian system is more relation-based whereas in the Western system is more market-based. This implies not only that lending criteria, but also that low return projects may be financed more often in a relation-based environment than in a marjet-based system. In the long-run this difference may cause growth to be lower in Asia, because the system lacks "cleaning", i.e., the removal of inefficient firms. Asian crises have a higher ratio of nonperforming loans.

Finally, Vasilev (2017) uses BCA with a capital wedge for understanding short-run fluctuations in Bulgaria. He finds that the efficiency wedge is the most relevant distortion. The financial crisis hit Bulgaria in 2009 and the country has not recovered since. The efficiency wedge alone would imply a stronger shock and a faster recovery. This calls for a secondary role of the labor wedge to explain better aggregate fluctuations in the sample period. The author finds no role for the investment wedge in Bulgarian macroeconomic fluctuations. They link the efficiency wedge to the credit and housing dynamics and the labor wedge to employee contributions.

From the comprehensive survey on BCA (and its extensions), the first impressions is that is all about the efficiency wedge. A closer look at the literature finds may provide a refinement on that. For instance, financial contagion. Episodes with that nature give more weight to other wedges. For instance, in Bridji (2013), Cho & Doblas-Madrid (2013), Saijo (2008), Sarabia (2007), Sarabia (2008), Simonovska & Söderling (2008), Hirata & Otsu (2011), Lama (2011), the labor wedge explains an important part of short-run fluctuations. Chadha & Warren (2012) and Chakraborty & Otsu (2013) are exceptions, where contagion was present, but instead of the labor wedge capturing movements in data, the investment wedge did.

What explains this pattern? From Kaminsky et al. (2003) we know that financial contagion usually happens if there are three elements: large capital inflows, surprise and a leveraged common creditor. Even though detailed economies with financial markets may be mapped into prototype economies with efficiency wedges, this combination may give more importance for financial accelerator and thus the role of investment wedge becomes higher in periods of crises, as in Sarabia (2007).

Economic policy may also a factor that contributes for different relative importance of wedges. For instance, in emerging markets, major swings in interest rates and currency crises seem to distort more decisions than just production's. In the works of Chakraborty & Otsu (2013), Graminho (2006), Sarabia (2007), Sarabia (2008), Lama (2011) in which currency crises were present, all of them attribute a greater role for either the investment or the labor wedge. Only in Otsu (2010b) the labor wedge plays a small role and the efficiency wedge fully accounts for output movements.

Major events like the Great Depression or the Great Recession may also call for more than one important distortion. See Chari et al. (2007a), Bridji (2013), Saijo (2008), Brinca (2013) for a decisive role of the labor wedge. Brinca et al. (2016) reveals a prevalence of the efficiency wedge during the Great Recession, but for the U.S., the labor wedge is the most important distortion and for Ireland and Spain, it is the investment wedge. Interestingly though, the government consumption usually is not as important as the other wedges. With the exception of the 2001 crisis in U.S. (Section 2.2), Cavalcanti et al. (2008), Kobayashi & Inaba (2006), Gao & Ljungwall (2009) and Šustek (2011), where the government consumption wedge plays a small role, in the other, its capability of explaining economic fluctuations is either very small or nil.

Having presented the BCA literature, the relative role of each wedge changes from one paper to another and are summarized in tables 6 and 7. The next section is dedicated to final remarks.

Table 6: BCA literature findings and the role of each wedge

Paper	**Method**	**Sample**	**Period***	**efficiency**	**labor**	**investment / capital**	**government**
Ahearne et al. (2006)	BCA	Ireland	1973-2002	Important	Medium	Very small/nil	Very small/nil
Bridji (2013)	BCA	France	1986-1939	Important	Medium	Medium	Very small/nil
Cavalcanti (2007)	BCA	Portugal	1979-2000	Important	Medium	Very small/nil	-
Cavalcanti et al. (2008)	BCA	Argentina	1992-2006	Important	Very small/nil	Very small/nil	Small
Chadha & Warren (2012)	BCA	UK	1974-2010	Important	Very small/nil	Medium	Very small/nil
Chakraborty (2009)	BCA	Japan	1980 to 2000	Important	Small	Important	Very small/nil
Chakraborty & Otsu (2013)	BCA	BRICs	1990-2009	Important	Small	Important	Very small/nil
Chari et al. (2007a)	BCA	U.S.	1929-1939; 1959-2004	Important	Medium	Small	Very small/nil
Cho & Doblas-Madrid (2013)	BCA	13 countries	23 episodes	Important	Medium	Small	Very small/nil
Cunha (2006)	BCA	Japan	23 episodes	Important	Very small/nil	Important	-
Graminho (2006)	BCA	Brazil	1980-2000	Important	Important	Very small/nil	Very small/nil
Iskrev (2013)	BCA	Portugal	1998-2012	Important	Small	Very small/nil	Very small/nil
Kersting (2008)	BCA	UK	1979-1989	Important	Important	Small	Very small/nil
Kobayashi & Inaba (2006)	BCA	Japan	1981-2003	Medium	Important	Medium	Small
Kolasa (2013)	BCA	European countries	1995-2011	Important	Medium	Small	Very small/nil
Gao & Ljungwall (2009)	BCA	China and India	1978-2006	Important	Small	Small	Small
López & García (2014)	BCA	Spain	1976-2012	Medium	Important	Very small/nil	Very small/nil
Orsi & Turino (2014)	BCA	Italy	1982-2008	Important	Medium	Very small/nil	Very small/nil
Saijo (2008)	BCA	Japan	1921-1936	Important	Medium	Medium	Very small/nil
Sarabia (2007)	BCA	Korea	1982-2005	Small	Medium	Important	Very small/nil
Sarabia (2008)	BCA	Mexico	1987-2006	Important	Medium	Small	Very small/nil
Simonovska & Söderling (2008)	BCA	Chile	1998-2007	Important	Medium	Medium	Very small/nil
Brinca et al. (2016)	BCA	OECD countries	2008-2015	Important	Medium	Medium	Very small/nil

BCA: Business Cycle Accounting, MBCA: Monetary Business Cycle Accounting, IBCA: International Business Cycle Accounting, OBCA: Open-Economy Business Cycle Accounting

*If periods change due do different data availability, longest data sample is considered.

**The author does not implement BCA decomposition as in CKM, hence one cannot infer what is the relative role for each wedge.

Table 7: BCA literature findings: the role of each wedge

Paper	Method	Sample	Period*	efficiency	labor	investment/ capital	government	bond	asset	monetary policy	international price	International trade
Hirata & Otsu (2011)	IBCA	Japan, Korea and Taiwan	1980-2009	Important	Medium	Very small/nil	Very small/nil	-	-	-	Small	Small
Otsu (2010a)	IBCA	Japan and U.S.	1980-2008	Important	Important	Medium	Very small/nil	-	-	-	Medium	Medium
Brinca (2013)	MBCA	Sweden	1982-2010	Important	Important	Small	Very small/nil	-	Small	Important	-	-
Šustek (2011)	MBCA	U.S.	1958-2004	Important	Very small/nil	Small	Small	-	Important	Important	-	-
He et al. (2009)	OBCA	China	1978-2006	Important	Medium	Medium	Very small/nil	Medium	-	-	-	-
Hevia (2014)	OBCA	Mexico, Canada and Korea	1976-2011	Important	Medium	Small	Very small/nil	Medium	-	-	-	-
Lama (2011)	OBCA	Argentina, Brazil, Chile, Colombia, Mexico and Peru	1990-2006	Important	Important	Very small/nil	-	Very small/nil	-	-	-	-
Otsu (2010b)	OBCA	Hong Kong, Korea and Thailand	1960-2003	Important	Small	Very small/nil	Very small/nil	Very small/nil	-	-	-	-
Brinca (2014)	BCA	23 OECD countries	1970-2011	Important	Medium	Very small/nil	Very small/nil	-	-	-	-	-
Hnatkovska & Koehler-Geib (2015)	BCA	Paraguay	1991-2010	**	**	**	**	-	-	-	-	-
Ohanian et al. (2015)	IBCA***	Latin America and East Asia	1950-2006	Very small/nil	Important	Small	-	-	-	-	Medium***	-
Brinca & Costa-Filho (2018b)	BCA	Mexico	1991-2015	Important	Medium	Medium	Very small/nil	-	-	-	-	-
Elgin & Cicek (2011)	BCA	Turkey	1968-2009	Important	Medium	Very small/nil	Very small/nil	-	-	-	-	-
Vasilev (2017)	BCA	Bulgaria	1999-2014	Important	Medium	Very small/nil	-	-	-	-	-	-
Gerth & Otsu (2016)	BCA	29 European countries	2008-2014	Important	Small	Small	Very small/nil	-	-	-	-	-
Brinca & Costa-Filho (2018a)	BCA	Brazil	1996-2016	Important	Medium	Medium	Very small/nil	-	-	-	-	-
Meza (2008)	BCA	Mexico	1994-2000	Important	Medium	Small	Small	-	-	-	-	-

BCA: Business Cycle Accounting, MBCA: Monetary Business Cycle Accounting, IBCA: International Business Cycle Accounting, OBCA: Open-Economy Business Cycle Accounting

*If periods change due do different data availability, longest data sample is considered.

**The author does not implement BCA decomposition as in CKM, hence one cannot infer what is the relative role for each wedge.

***The international price wedge is not exactly the same as the international capital wedge, given the different framework for IBCA and a multi-country IBCA developed in Ohanian et al. (2015).

6 Final Remarks

What are the drivers of business cycles? A whole research area has devoted much effort in collecting evidence to answer this question. Each episode and each country has its own characteristics, so there is no general model to account for short-run fluctuations. Due to the great supply of detailed DSGE models, it is difficult to narrow the search for the "right" model.

The business cycle accounting method provides an important tool for business cycle modeling. It rests on two pillars. First, the accounting dimension which uses a perfectly competitive prototype model with wedges to assess the relative contribution of each wedge. Once the main channels of macroeconomic fluctuations have been established, equivalence theorems – mappings of frictions into classes of detailed economies – further help research on business cycle fluctuations by guiding modeling efforts.

BCA was extended along several dimensions by introducing: the interaction between nominal and real variables (monetary business cycle accounting), foreign borrowing within a small open economy set up (open-economy business cycle accounting) and cross-country linkages (international business cycle accounting). All extensions rely on the same reasoning, a prototype model with distortions.

Although it seems be an important method for guidance, it has limitations. First, the prototype economy might be wrong. If the framework is wrong this influences the accounting of wedges and, thus, economic conclusions. Moreover, the need for distortions arise only because the neoclassical growth model does not account for data variation. But what if data is wrong? This is the second branch of criticism. What if by not accounting properly for intangible capital or the shadow economy, for instance, we call for distortions where there is only mismeasurement? This paper tried to shed light on the extent that these two pitfalls have been addressed and studied by the literature.

In this paper, we also illustrated the application of BCA by focusing on two U.S. recessions (1973 and 1990). The efficiency wedge was the main driver of both of them, but it was more important during the first oil shock.

Not only this work provides BCA exercises, but also contributes to the literature by surveying common findings from several works using BCA and its extensions. This allows us to identify pattern that are valid across a broad sample of countries and recessions. Generally, hours of work are closely related to the labor wedge. Investment wedges may not only be useful for the path of aggregate investment, but also, in an open-economy set up, for helping to explain the country risk spreads. Therefore, depending on the variables of interest, detailed models equivalent to the prototype economy with an efficiency wedge may be not enough.

By this point, it is clear that the efficiency wedge plays a crucial role in explaining output fluctuations. This conclusion is not a surprise, otherwise RBC models would not become so popular. But what explains differences in the papers that use BCA? There are two factors. First, the mappings. Perhaps the difference is not in which wedge drives short run macroeconomic movements, but actually in what explains that wedge (e.g. is it a credit friction or firms' heterogeneity?). Second, the relative importance of other wedges. What motivates the second factor?

In this paper a few broad conclusions were drawn. First, the efficiency wedge is very often the main mechanism underlying output fluctuations. Second, episodes episodes of financial contagion, the modeling of economic policy, specially in emerging markets, and major events, such as the Great Depression and the Great Financial Crisis are usually associate with a more prominent role of other wedges.

Business cycle accounting theory has so far guided researchers in identifying classes of economic theories and detailed model frictions. It did so with the promise that the channels identified by its procedure carry the ability to better explain business cycle fluctuations during episodes and in countries of interest. In this paper, we shed light on the many efforts done by the literature in these dimensions and pointed out the many important aspects of this methodology, from its building blocks to its caveats. It should serve as a reference to all future research efforts that seek to extend the BCA framework and to apply it to unexplored episodes of economic downturns, as the one we are currently experiencing due to the global repercussions of the Covid-19 outbreak.

Appendix

Data for the business cycle accounting exercises comes mainly from OECD (Economic Outlook No 98 - November 2015), from 1960Q1 to 2014Q4. Below there are the variable descriptions, units (if it is an index the base in parenthesis) and codes in brackets. Output and its components are deflated in BCA.

- Gross domestic product, value, market prices; U.S. Dollar [GDP]
- Gross domestic product, deflator, market prices; index (2009) [PGDP]
- Gross fixed capital formation, total, value. U.S. Dollar [ITISK]
- Gross capital formation, deflator; index (2009) [PITISK]
- Private final consumption expenditure, value, GDP expenditure approach; U.S. Dollar [CP]
- Private final consumption expenditure, deflator; index (2009) [PCP]
- Government final consumption expenditure, value, GDP expenditure approach; U.S. Dollar [CG]
- Government final consumption expenditure, deflator; index (2009) [PGP]
- Imports of goods and services, value, National Accounts basis; U.S. Dollar [MGSD]
- Imports of goods and services,deflator, National Accounts basis; index (2009) [PMGSD]
- Exports of goods and services, value, National Accounts basis; U.S. Dollar [XGS]
- Exports of goods and services, deflator, National Accounts basis; index (2009) [PXGS]
- Hours worked per employee, total economy; Hours [HRS]
- Total employment, Labour force statistics definition; Persons [ET]

The latest version of BCAppIt! can be downloaded here: `https://pedrobrinca.pt/software/bcappit-2/`. The user guide is in the next pages after the bibliography section.

BCAppIt! User Guide
Version 0.003a

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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
τ_l: labor tax
τ_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
α: parameter which determines the share of (and weight on) net capital stock in the Cobb-Douglas CRS production function
β: subjective discount factor, reflecting the time preference of the household
δ: depreciation rate of net capital stock
λ: 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 $s_t = P_0 + Ps_{t-1} + Q\varepsilon_t$, 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.

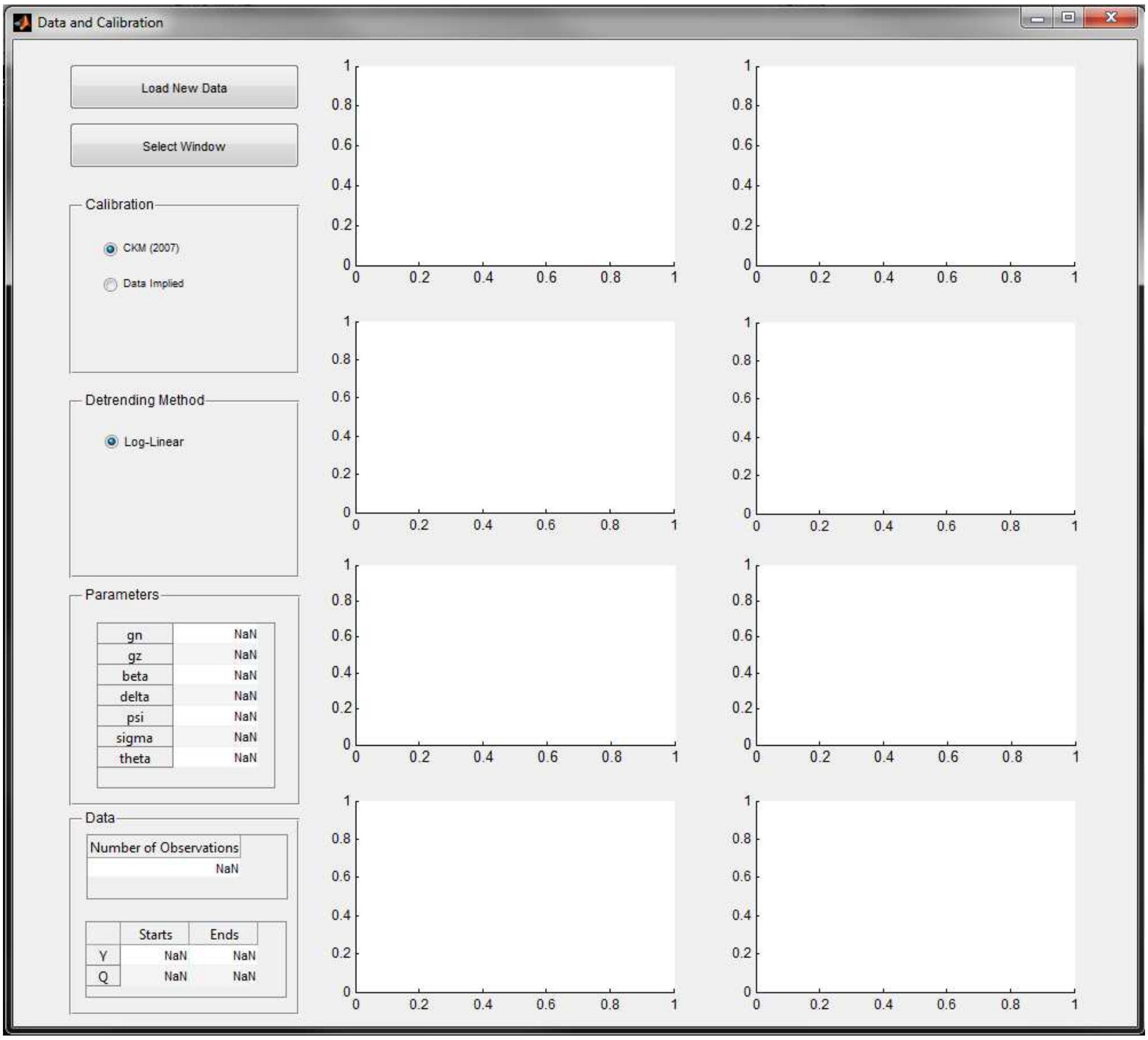


Figure 2.2: Data and Calibration Panel of BCAppIt!

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.

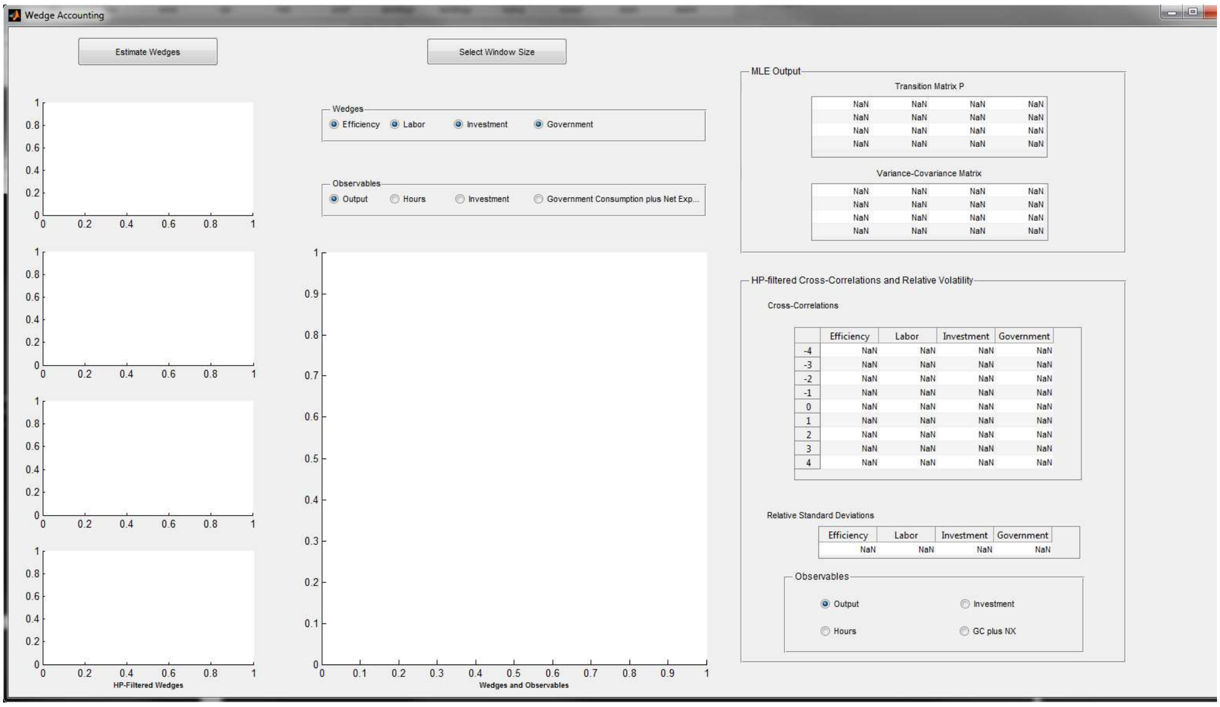


Figure 2.6: Wedge Accounting Panel of BCAppIt!

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.

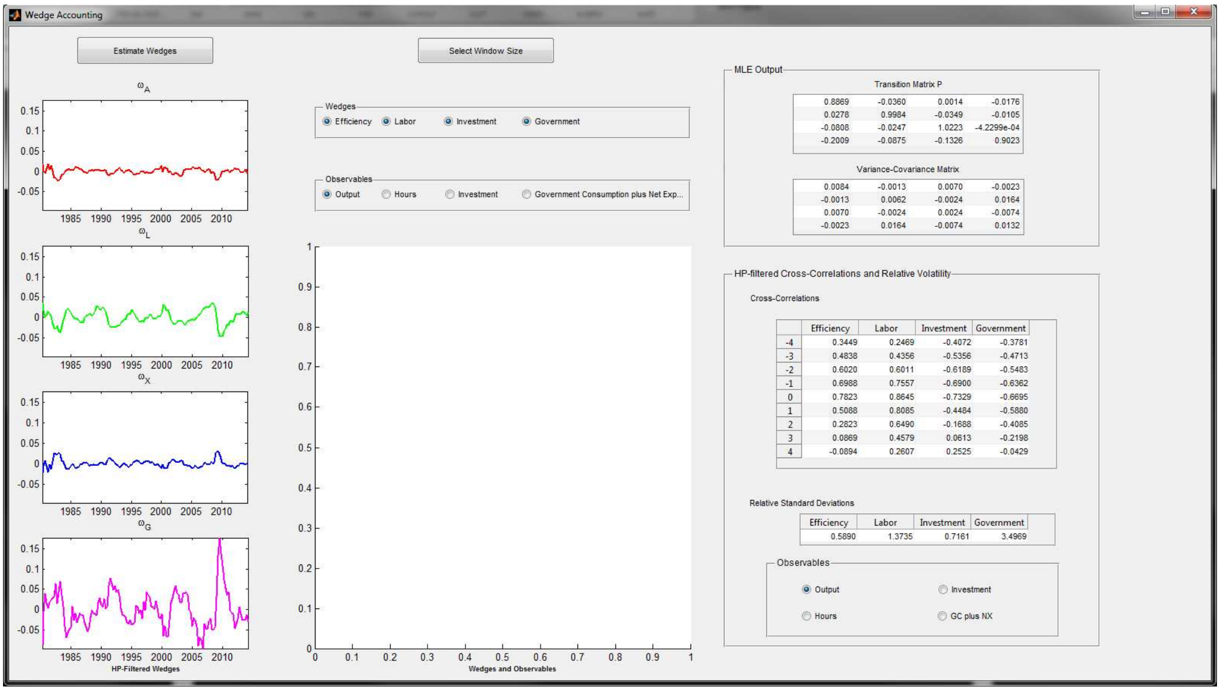


Figure 2.7: Wedge Accounting Panel when wedges have been estimated.

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.

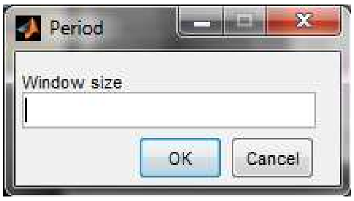


Figure 2.8: Wedge Accounting Panel Pop Up Window: Choice of Wedges Plots Window.

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.

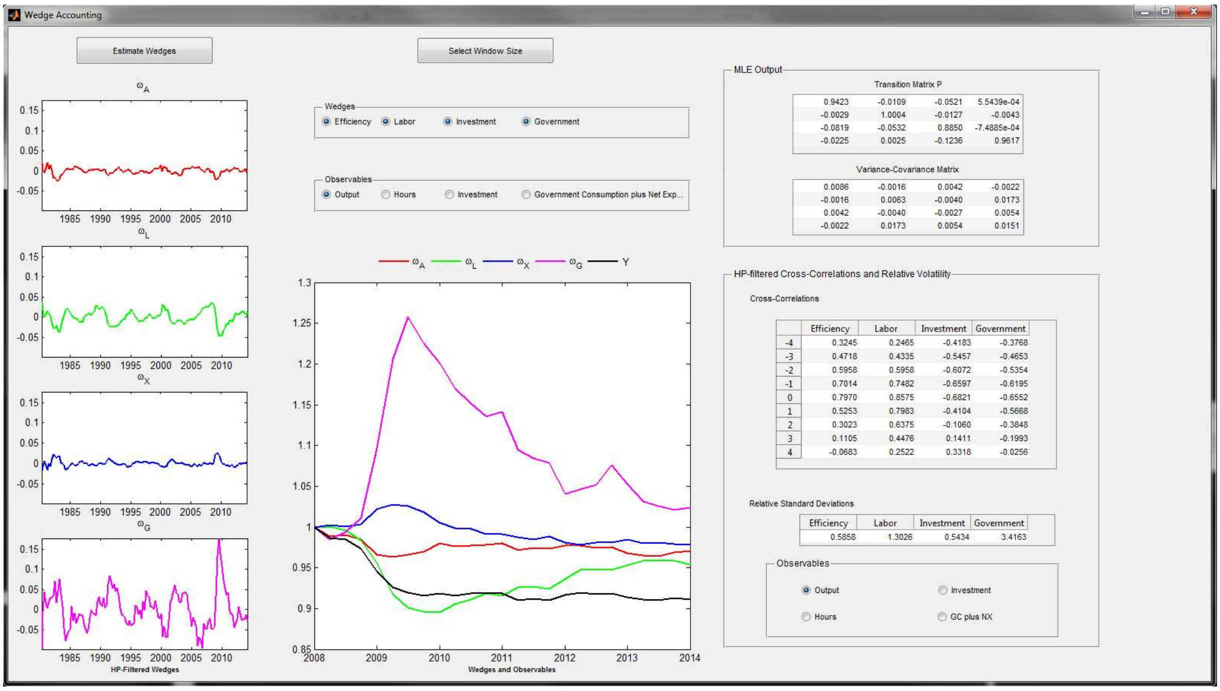


Figure 2.9: Wedge Accounting Panel when choice of wedges plots window has been made.

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.

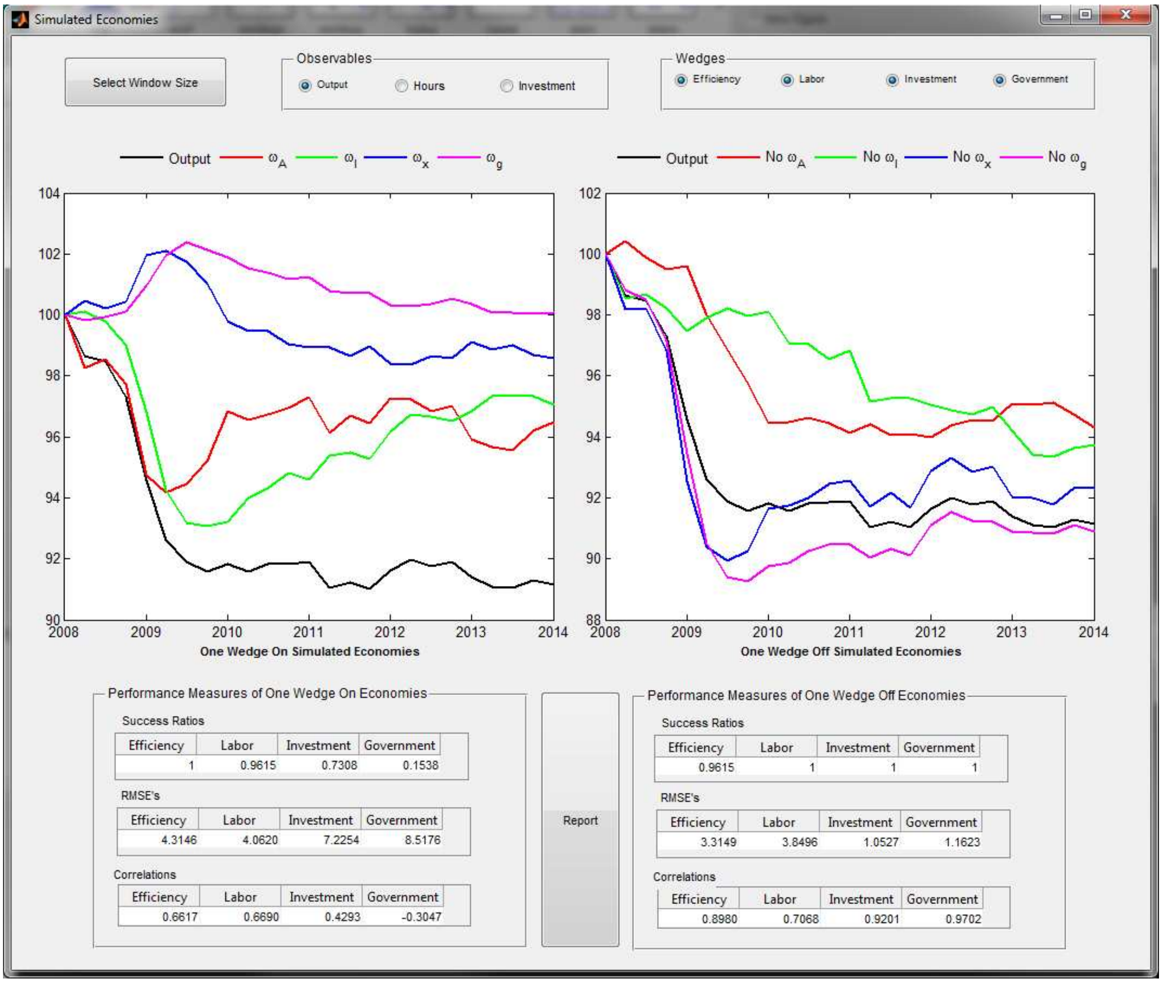
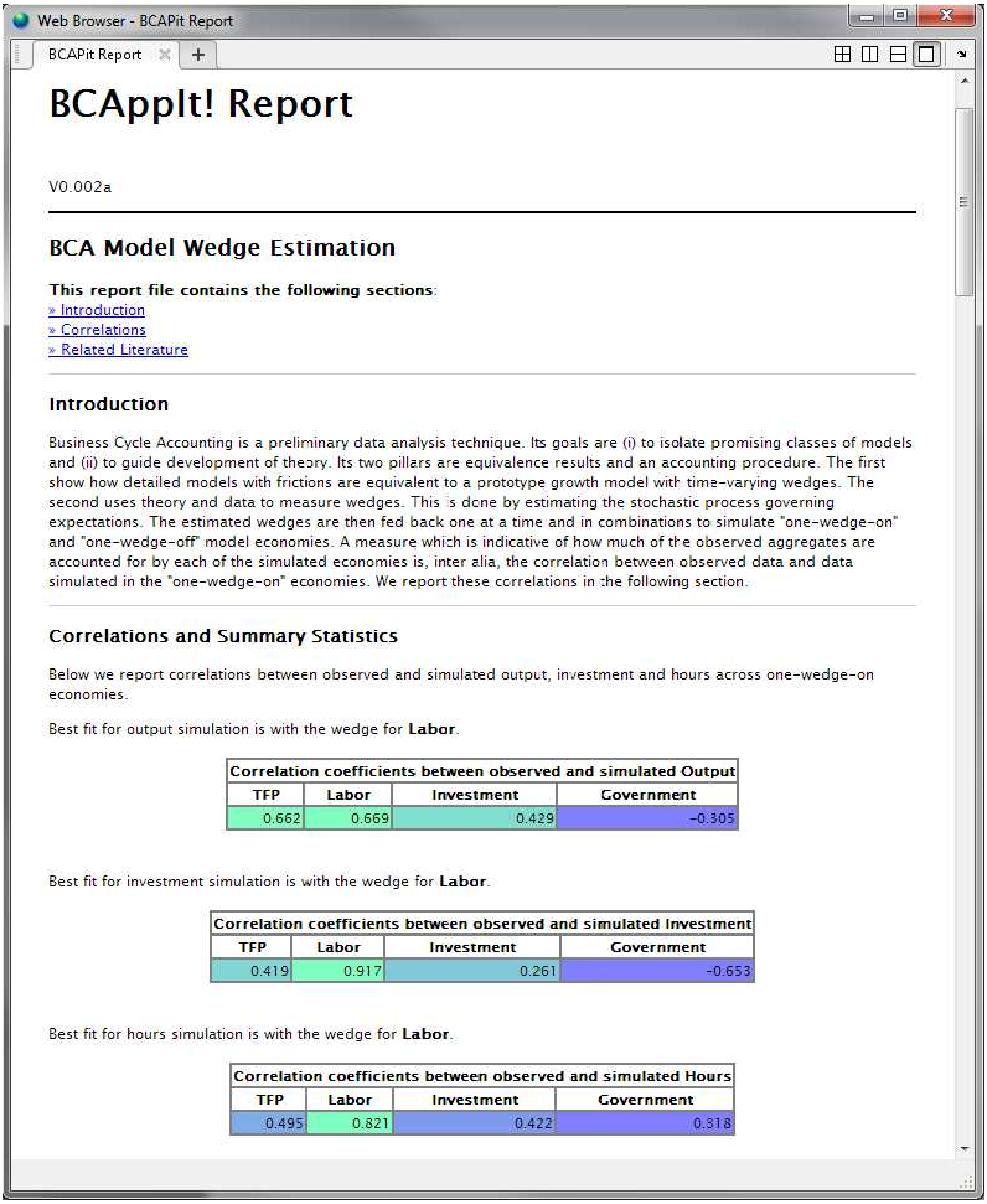


Figure 2.10: Simulation Panel of BCAppIt!

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.



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

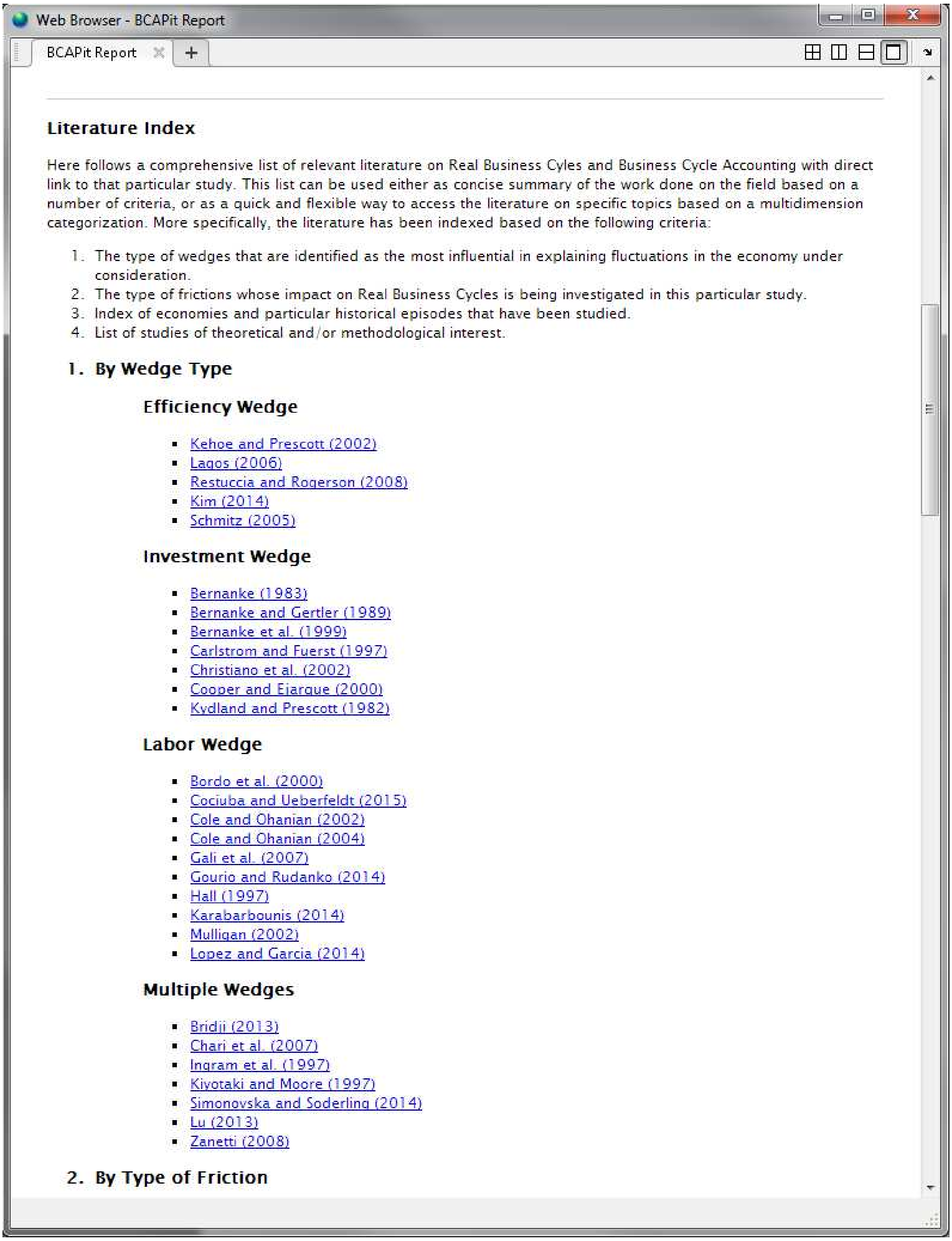
Best fit for investment simulation is with the wedge for **Labor**.

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!



Web Browser - BCAPit Report

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!

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