WHAT DRIVES RECESSIONS AND EXPANSIONS?
Accounting for business cycles in an era of crises

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Success is not final, failure is not fatal: it is the courage to continue that counts.

Winston Churchill

Biographical Note

“It is not personal, but I hate mathematics”. This quote is from a conversation I had with my undergraduate professor of quantitative methods, Gustavo Mirapalheta (before he advised me during the undergraduate thesis, using quantitative methods). Boy, I was wrong! I concluded my undergraduate studies in Business Administration in 2008, from ESPM in São Paulo, Brazil – the city I was born in January 13, 1986. At the time, I also joined the ESPM’s swimming team (and became director of swimming at the students athletic organization). As you can see by the content of this thesis, I changed a lot during that time. The emphasis in finance in the latter years of my undergraduate studies revealed that my future interests were not aligned with marketing (the reason I chose ESPM in the first place) anymore. I wanted to become an economist!

Talking to Frederico Turolla (former professor, current partner/friend) about choosing to change the course of my career, I learned that in Brazil we have two types of masters degree: academic and professional. This information would be precious on the near future. I applied (and was approved) to the MSc in Economics at University of Kent. Over there I aimed to study...game theory! (Not bad for someone who – wrongly – coined the first phrase of this note a couple years before). The greatest financial crisis since the 1930s plus the lack of financial possibilities made impossible for me to study at Kent. I was frustrated, but perhaps this went for the better. I found that the São Paulo School of Economics at Getúlio Vargas Foundation (EESP-FGV) had a new research line in Financial Macroeconomics.

At EESP-FGV I learned a lot. And while I was gathering the knowledge to accomplish my new goal (to become an economist at an important bank) I found passion in a different and very, very unexpected path: teaching. Suddenly, I wanted to become a professor of economics, not a professional economist anymore. Then I realized I should do a PhD. I “anticipated” the defense of my master thesis in six months (because I wrote it before finishing the other credits) and applied to the program at FEP.

Charles Bukowski once wrote “*I want the whole world or nothing*”. That is how I felt when I left my country and crossed the Atlantic. And from a certain point of view, that’s exactly what I got (the former, not the latter). But, instead of stealing it like the bucolic writer, I “conquered” it, by allowing an amazing feeling to grow. Suddenly, I was a citizen of the world. But the conquest was just getting started.

Doing a PhD is a hard task. Doing it “an ocean” away from your home is even harder. In one way or another, I managed it. I arrive in Porto on September 3, 2011. The first short exam was on September 6. The second on September 7 (and this continued like that for two weeks). Difference and differential equations. The game had just got started!

I felt in love with the country, with the city, with the people, with the food! I made great friends at FEP. And also at Hapkido classes (a Korean martial art that I sadly haven't continued to practice after my years in Porto).

At the end of the master in economics and the beginning (to the middle) of the PhD I started a blog about (international) macroeconomics, entitled *Economic Approach*. I actually received a job offer to become an economist in a consultancy firm in Porto because of it. I declined because it was in the first semester of the PhD course and I knew I could not handle to do both (I did it during the master in economics, but working and studying at this level is not an easy task, trust me).

In 2013 I had to go back to Brazil and ended my blog.

At home I invested in starting my academic career. I became a Teaching Assistant at the same master program in Economics I attended to. Then the worst period of my life happened. Let me just say that a negative exogenous shock hit my life and things become very, very complicated. And this exogenous shock arouse from whom I would never expected. The bright side is that it helped to craft some great friendships for life. For instance, when I became an associate consultant at *Pezco Economics and Business Intelligence*, whose senior partner/owner is Frederico Turolla.

Unexpectedly, an invitation came to teach Statistics at the EESP-FGV Professional Master in Economics. I became a professor of economics in the very program I learned economics for real and I was thrilled. And a little bit terrified. Almost at the same time, I became also professor of Economics at Armando Alvarez Pentado Foundation (FAAP). Within a few semesters, I was teaching subjects I really like, such as International Finance, Financial Macroeconomics and Statistics (at EESP) and Introduction to Economics, Brazilian Economy and Game Theory – destiny has its own whims – at FAAP. This is just to name a few.

Other teaching opportunities appeared (also at different institutions) and semester after semester I struggled with myself to decrease a little bit my around-25-hours-per-week teaching load. Add to this the more than 70 op-eds I wrote since 2013 (in Brazilian and international publications) and the difficulties I experienced during a complicated period (2013-2014) and you understand why I took too long to finish the PhD (we do not have the counter-factual, but I think it is safe to affirm that it would be different – and faster – if I could only dedicate my time to the thesis). But to be honest, I have no complaints. Life has been pretty amazing for me.

I think this is it, in a nutshell. Oh, and also another passion have emerged in the past four years: the “samba de gafieira” (a sort of ball room *samba*).

Acknowledgments

I think the acknowledgments section is one of the most important parts of this thesis. There was no way I would accomplish this work without the support of several people along this amazing journey. As Khalil Gibran once wrote, "*in the sweetness of friendship let there be laughter, and sharing of pleasures. For in the dew of little things the heart finds its morning and is refreshed*". This refreshment that I could rely on was essential and, for that matter, my friends, colleagues and professors are, in some sense, also responsible for this thesis (without carrying the burden of the errors I did not find before submitting it).

Not only because it is usual, but specially because I really want to, I would like to initiate this journey of rebuilding the steps of this thesis by thanking Pedro Brinca, my PhD advisor. We met virtually (since he does not work at FEP and I was already back to Brazil) and nine months later I just "had" to fly to Portugal to meet him. I discover that he was not only a top researcher, but also a great person. In each Skype meeting we had I learned a lot. I mean, a lot. Not only how to write a research paper, but he is also a great model of an advisor. I hope I can follow your steps and contribute with my future students in the way you did it for me.

I also thank João Correia-da-Silva, who co-advised my thesis with Pedro. Differently from Pedro, he was my professor during the PhD program. Starting with Mathematical Economics, he helped me to gather an important toolkit for this thesis. Later on, during the subject Advanced Topics, an one-on-one weekly meeting (in which we decided to discuss monetary economics), my admiration only rose. His comments enriched this thesis.

The third professor I would like to thank is Ana Paula Ribeiro. Not for her almost-five-hours-exam on my birthday in 2012, but for other two things. First, she is an amazing professor of macroeconomics and during two subjects, she "prepared me" for what was coming. For a while I was blaming myself for not having asked her to advise me. But as it turned out that, in some sense she did. That is the second reason. She was in the intermediate defense of this thesis. And with a 50-minutes-comment-in-a-row she helped me to see potential improvements and asked provocative and important questions.

I also own professors Elvira Silva and António Brandão a lot. Their empathy made it easier for me to finish this PhD program in another continent.

Still in the old continent, two portuguese showed me that the meaning of "friendship" is the same across the Atlantic. With the stimulant discussions I had with António Neto during my stay at FEP and latter on, when we met in Lisbon, I found a friend and a future ~~partner in crime~~ research partner. He helped me a lot during the whole PhD program. Also, there is João Ribeiro, not only by all the couchsurfing (thanks a lot by the way), but also (and specially) by sharing his views of the world and expand my knowledge on different matters. His "light way of life" made all the difference.

Back to Brazil, I would like to thank Ricardo Rochman, Anapaula Davila, Paulo Dutra and Luiz Alberto Machado. You all believed I could do the one thing I am most passionate about: teaching. The trust you have deposited on me made this thesis possible. Thank you all for that.

Fernanda Magnotta also has an important role in my academic trajectory. Not only for the same reason as those in the previous paragraph, but also for her unconditional support, kindness and friendship.

I also thank Ana Lúcia for making this PhD thesis journey (and life for that matter) easier (well, less difficult).

Special thanks to partners/friends/great human beings Frederico Turolla, Cleveland Prates, Pedro Godeguez. You have helped in the worst years of my life (no relation with the PhD, just a temporal coincidence) and became friends for life.

I thank the friendship of Ana, André, Armenio, Brenda, Diego, Isabela, Rafael and Viviane. Life is not the same without you.

I could not end this section without thanking...Youtube videos!

Last, but not least, I would like to thank the support and love of my brother, Lucas, my mother, Gisele, and my father, João Ricardo.

Abstract

This thesis addresses business cycles modeling along a few dimensions. In Chapter 2, a comprehensive literature review on Business Cycles Accounting, a tool to understand the drivers of business cycles fluctuations and to help in the modeling process, enables a threefold contribution. First, to present an explanation of the method to the non-specialist researcher, along with its extensions (monetary, open-economy and international business cycle accounting) and the "mappings" from detailed economies to prototype models. Second, to analyze the drivers of the 1973, 1990 and 2001 recessions in US (fulfilling the gap in the existing Business Cycles Accounting literature. Third, to draw broad conclusions regarding the relative contribution of each wedge in explaining macroeconomic data movements.

International crises are usually transmitted via either price or quantity shocks on the balance of payments. But what if the integration of intermediate goods markets changes no only how output is produced, but also how crises are transmitted? Using the weak recovery of Mexico during the Great Recession (slower than the one after the "Tequila crisis"), Chapter 3 applies the Business Cycles Accounting and provides two contributions. First, within the "accounting" dimension, the main driver of the Mexican Great Recession is the efficiency wedge. Second, an equivalence is proposed between the neoclassical growth model (both in the closed and open-economy versions) and a small open-economy model augmented with intermediate imported goods in the production function. The model is able to reproduce both the intensity and the velocity of the recoveries from the 1995 and 2008 crises after exchange rate shocks. The results reveal an international transmission mechanism "hidden" in the efficiency wedge.

In Chapter 4 the economic depression Brazil experienced within 2014-2016 is addressed. The synthetic control estimations point towards a domestic source of the crisis, whereas the business cycle accounting method finds that it was driven by the efficiency wedge. The econometric evidence reveals that the development bank outlays have a positive (negative) impact in the short (long) run in the efficiency wedge. A general equilibrium model with financial frictions and a public development bank is able to reproduce the dynamics of output during the crisis.

Keywords: Business Cycle Accounting, Brazil, Mexico, United States, Recessions, Expansions, Business Cycle Modelling, DSGE, Open Economy, Financial Frictions

JEL Classification: E30, E32, E37, E50, E51, E60, E65 F41

Resumo

Esta tese aborda a modelagem de ciclos econômicos em algumas dimensões. No Capítulo 2, a revisão abrangente da literatura sobre *Business Cycles Accounting*, uma ferramenta para entender as flutuações dos ciclos de negócio e para ajudar no processo de modelagem, permite uma contribuição tripla. Primeiro, apresentar o método ao pesquisador não especialista, além das suas extensões (monetária, em economia aberta e dos fluxos internacionais) e os "mapeamentos" de economias detalhadas para protótipo de modelos. Depois, analisa a as recessões de 1973, 1990 e 2001 nos EUA (preenchendo a lacuna existente na literatura de *Business Cycles Accounting*). Terceiro, apresenta conclusões amplas sobre a contribuição relativa de cada distorção aos movimentos de dados macroeconômicos.

As crises internacionais geralmente são transmitidas através de choques de preço ou quantidade na balança de pagamentos. Mas e se a integração dos mercados de bens intermediários mudar não só a forma como o produto é produzido, mas também como as crises são transmitidas? Usando a fraca recuperação do México durante a Grande Recessão, o Captulo 3 aplica o *Business Cycles Accounting* e conclui que o principal motor da Grande Recessão mexicana é a distorção de eficiência. Depois, apresenta equivalências entre o modelo de crescimento neoclássico (tanto nas versões de economia aberta como fechada) e um pequeno modelo de economia aberta com bens intermediários importados na função de produção O modelo é capaz de reproduzir a intensidade e a velocidade das recuperaçesõ das crises de 1995 e 2008 após choques cambiais. Os resultados revelam um mecanismo de transmissão internacional "escondido" na distorção de eficiência.

No Captulo 4, a depressão econômica que o Brasil experimentou no perodo 2014-2016 é abordada. As estimativas de controle sintético apontam para uma fonte doméstica da crise, enquanto que o *Business Cycles Accounting* indica que o episódio foi resultado do comportamento da distorção de eficiência. A evidência econométrica revela que os desembolsos do banco de desenvolvimento público têm um impacto inicial positivo na distorção de eficiência, mas depois de alguns trimestres afeta negativamente a mesma, mais do que compensando o efeito inicial. Um modelo de equilíbrio geral com fricções financeiras e um banco de desenvolvimento público é capaz de reproduzir a dinâmica de produção durante a crise.

Palavras-chave: Contabilidade de Ciclos de Negócio, Brasil, México, Estados Unidos, Recessões, Expansões, Modelagem de Ciclos de Negócio, DSGE, Economia Aberta, Fricções Financeiras

Classificação JEL: E30, E32, E37, E50, E51, E60, E65 F41

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Chapter 1

Introduction

What drives recessions and expansions? This question motivated a whole research agenda may be answered with two words that seem to be real friends of researchers in economics: it depends. Which recession? Which expansion? After the rational expectations revolution in the 1970s we do not have an unique framework for answering that question. Each episode seems to be driven by different reasons. In the 1980s the Real Business Cycles (RBC) models lead the way to DSGE modeling. When the perfectly competitive framework was not enough, imperfections were introduced. The New Keynesian models became the mainstream DSGE modeling practices and the set of theoretical models keep expanding.

The rise of DSGE modeling called for proper guidance. Which is the best model to explain a particular episode? One way is to use theory to narrow the search and test the candidates. This procedure alone seems to be inefficient and Business Cycle Accounting (henceforth BCA) emerged to complement the theory-driven search, fulfilling the gap of proper guidance.

This thesis was written under the two presented pillars (DSGE modeling and BCA) and it aims to contribute to business cycles analysis literature in three dimensions: a survey on BCA literature (the broad-conclusion-on-existing-literature dimensions), the identification of an transmission channel of international crises (the equivalence dimension) and the analysis of a particular episode (the Brazilian 2014-2016 depression), which represents the "accounting dimension". In order to do that, this thesis is composed by three essays, besides this introduction.

Chapter 2, entitled "Business Cycle Accounting: from theorems to findings" has a comprehensive analysis of BCA literature findings. It presents an explanation of the method to the non-specialist researcher, along with its extensions (monetary, open-economy and international BCA). Also, it applies BCA to three US recessions: 1973, 1990 and 2001 (fulfilling the gap in the existing BCA literature). The results show the efficiency wedge as the main driver, whereas the wedge playing the secondary role changed according the episode.

BCA also relies on mappings from detailed economies to prototype models with wedges. Therefore, the chapter surveys the already known mappings and by combining them with the literature findings, not only we can draw some broader conclusions on the relative importance of the wedges, but also by gathering, synthesizing and systematizing enough results, it provides a useful starting point for future research.

Among the main results of the chapter is the fact that the efficiency wedge seems to be the lead driver of business cycles in general, whereas for some episodes such as the Great Recession in US, the labor wedge has the most important role. The investment wedge may help to explain country risk spreads in international bonds, while the government consumption wedge appears to have a less important role, even during international crises.

International crises are typically perceived as either price or quantity shocks on the balance of payments. But what if the integration of goods markets changes how output is produced and also how crises are transmitted? Chapter 3, entitled "Output falls and the international transmission of crises", uses the weak recovery of Mexico during the Great Recession (slower than after the "Tequila crisis"), applies BCA and provides two contributions.

First, within the "accounting" dimension of BCA, the main driver of the Mexican Great Recession is the distortion in the production decision (the efficiency wedge). Second, an equivalence is proposed between the neoclassical growth model and a small open-economy model augmented with intermediate imported goods in the production function. The model is able to reproduce both the intensity and the velocity of the recoveries from the 1995 and 2008 crises after exchange rate shocks. The results reveal an international transmission mechanism "hidden" in the efficiency wedge.

In Chapter 4, "Economic depression in Brazil: the 2014-2016 fall", the essay tackles the fact that, during the Great Recession, Brazil experienced a fast recovery. However, since then, it seems to have lost the ability to grow. Moreover, the country entered in a depression for eleven quarters, registering two years of contraction in GDP for the first time in history. The synthetic control estimations point towards a domestic source of the crisis, whereas the BCA indicates that it has been driven by an efficiency wedge.

What is behind the protagonism of the efficiency wedge during the Brazilian depression? Due to the rapid public credit growth, the hypothesis that the development bank and the efficiency wedge were associated was investigated. The estimation reveals that while an increase in the outlays has a positive impact on the wedge in the short run, after a few quarters the effect is negative and offsets the previous positive contribution. Furthermore, a general equilibrium model with credit market frictions and a public development bank is able to reproduce the dynamics of output during the crisis.

Finally, Chapter 5 present the main conclusions of the three essays, along with some proposals for future research based on this work.

Chapter 2

Business Cycle Accounting: from theorems to findings

All people know the same truth. Our lives consist of how we choose to ***distort*** *it.*
Woody Allen (bold is mine).[1]

2.1 Introduction

Business cycles fluctuations have been analyzed under several 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. Sometimes, however, the models needed some changes to fit data. Why? One hypothesis is that "data is wrong". It is possible that mismeasurement of aggregate data leads researchers to wrong conclusions. However, it also possible that in order to have a better representativeness of real world DSGE models need to be extended to encompass, for instance, nominal price rigidity, frictions in the labor markets and financial frictions.

But what 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. In the model we have 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

[1] Woody Allen as Harry Block in the movie *Deconstructing Harry.*

wedge (the four wedges are: the efficiency wedge, the labor wedge, the investment wedge and the government consumption wedge, respectively).

By construction, the four wedges together account for the whole data. After estimating the four wedges, a decomposition is done to assess which wedge(s) is(are) more important. In order to do that, the path of the variables of interest (e.g. output) is simulated allowing one wedge to vary at a time, holding the remaining wedges constant. The comparison of simulations with different wedges helps us identify 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 the equivalences. The prototype economy can be mapped into different detailed economies, given the wedge that is introduced. For instance, an efficiency wedge may arise from input-financing frictions (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 approach other dimensions, extending the basic framework: monetary BCA, open-economy BCA and international BCA. The reasoning remains the same: the outcomes of a benchmark model with distortions are compared with data, though the prototype economies are different. The first incorporates price rigidity and deals with deviations from monetary policy rules and inflation. In the second, the set up for the prototype model is a small open economy. Finally, the third one analyses the economic relationship between economies, 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: the first is to present the method (its extensions and limitations) to the non-specialist. The second is to fulfill the BCA literature by applying it to three US recessions: 1973, 1990 and 2001. Moreover, there is a discussion on the relative importance of each wedge during expansions and recessions. The third is to survey the vast literature on BCA and gather it in a systematic way. 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 on the relative importance of each wedge.

The results from BCA for the US in the three episodes provide different roles for each wedge. The efficiency wedge is the most important, accounting for at least

50% of output movements. However, the secondary role changes from one episode to another. For instance, for the 1973 and 1990 recessions it is the labor wedge, whereas for the 2001 it is the government consumption wedge, an unusual result (see).

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 either by explaining output movements and/or the aggregate investment dynamics. The labor wedge, on the other hand, is closely related to hours of work. Investment wedges, in an open-economy set up, may help to explain country risk spreads on international bonds. Moreover, larger changes in interest rates and currency crises are usually associated with investment and/or the labor wedges (the former usually for emerging markets whereas the latter may be important for both developed and emerging economies). The government consumption usually is not as important as the other wedges. Its capability of explaining economic fluctuations is very often either very small or nil.

This chapter is organized as follows. The next section introduces BCA, presenting the prototype economy and how to implement the procedure (applying it to US data) and its limitations. In Section 2.3 the mappings from different classes of detailed models into the prototype economy with wedges are addressed. Section 2.4 presents the extensions of the method: monetary business BCA, open-economy BCA and international BCA. Section 2.5 discusses the literature findings for the applications of business cycle accounting and its extensions for developed and emerging market economies. Finally, in Section 2.6 some conclusions are drawn.

2.2 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[2]. Then, when building quantitative models, researchers should 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 help researchers. 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 func-

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

tion of change in factors and four residuals[3].

The starting point is the so-called neoclassical growth model[4]. An extensive body of research has devoted its efforts in creating models departing from the neoclassical framework. For instance, some models introduce nominal price rigidity, wage rigidity and labor unions[5]. But which distortion is better? Does the answer change from one episode to another? The BCA literature helps to respond these questions, and shed some light on how to proceed further.

BCA was introduced by Chari et al. (2002) and consolidated in Chari et al. (2007a) (henceforth CKM)[6]. 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 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 production factors utilization. It is represented by a (residual that looks like a) technology parameter in the production function. The labor wedge creates a departure from the optimum condition relating labor decisions. 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 marginal product of labor.

The investment wedge is related to the intertemporal choice between present and future consumption (the combination of 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.

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

[4]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.

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

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

2.2.1 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 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:

$$y_t(s^t) = A_t(s^t)F(k_t(s^{t-1}), (1 + \gamma)^t l_t(s^t)), \tag{2.1}$$

$$-\frac{U_{l,t}(s^t)}{U_{c,t}(s^t)} = (1 - \tau_{l,t}(s^t))A_t(s^t)(1 + \gamma)F_{l,t}, \tag{2.2}$$

$$U_{c,t}(s^t)(1+\tau_{x,t}(s^t)) =$$
$$\beta \sum_{s^{t+1}} \pi_t(s^{t+1}|s^t)[U_{c,t+1}(s^{t+1})(A_{t+1}(s^{t+1})F_{k,t} + (1-\delta)(1+\tau_{x,t+1}(s^{t+1})) + \phi_{k_{t+1}}], \tag{2.3}$$

$$c_t(s^t) + x_t(s^t) + g_t(s^t) = y_t(s^t), \tag{2.4}$$

where $U_{c,t}$, $U_{l,t}$, $F_{l,t}$, $F_{k,t}$ and $\phi_{k_{t+1}}$ are derivatives of the utility function, the production function and adjustment costs with respect to its 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.

2.2.2 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

$$A_t(s^t) = \frac{y_t(s^t)}{F(k_t(s^{t-1}), (1+\gamma)^t l_t(s^t))}, \tag{2.5}$$

whereas the labor wedge is defined as

$$(1-\tau_{l,t}(s^t)) = -\frac{U_{l,t}(s^t)}{U_{ct}(s^t)}(A_t(s^t)(1+\gamma)F_{l,t})^{-1}, \tag{2.6}$$

the investment wedge is defined by

$$\frac{1}{(1+\tau_{x,t}(s^t))} =$$
$$U_{c,t}(s^t)(\beta \sum_{s^{t+1}} \pi_t(s^{t+1}|s^t)[U_{c,t+1}(s^{t+1})(A_{t+1}(s^{t+1})F_{kt} + (1-\delta)(1+\tau_{x,t+1}s^{t+1}) + \phi_{k_{t+1}}])^{-1}, \tag{2.7}$$

and finally we have the government consumption wedge

$$g_t(s^t) = y_t(s^t) - c_t(s^t) - x_t(s^t). \tag{2.8}$$

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 that the rate of time preference is 2.8%. Moreover, $\gamma = 0.004$ and $\gamma_N = 0.0039$ are calculated from data and the parameter in the adjustment costs funcition, $a = 12.574$, from Brinca et al. (2016).

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 $\pi_t(s_t|s^{\tau-1}) = \pi_t(s_t|s_{t-1})$, i.e. 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}, therefore, it follows a first order Markov process. Moreover, we also assume that ii) agents rely only on previous realization of wedges to forecast future wedges and iii) the wedges are sufficient statistics for the event at 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[7]:

$$s_{t+1} = P_0 + Ps_t + \epsilon_{t+1}, \tag{2.9}$$

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. 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

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

[8]Brinca et al. (2017) 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, there is no problem. The same is not true for deep parameters.

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

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. 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 wedges, the accounting exercise is done by simulating the economy to see the relative contribution of each wedge to data movements. This allows us to understand the drivers of each episode[10].

A tale of three recessions

The BCA literature on US recessions has covered the Great Depression, the 1981 recession and the Great Recession[11]. This paper aims to fill the gap with other three recessions[12]: 1973, 1990 and 2001. With that in mind, the BCA exercises uses OECD data for the US from 1960 to 2014. All variables are at quarterly frequency, except the population, which is taken annually and the quarterly figures are obtained 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;
- Working age population.

[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.

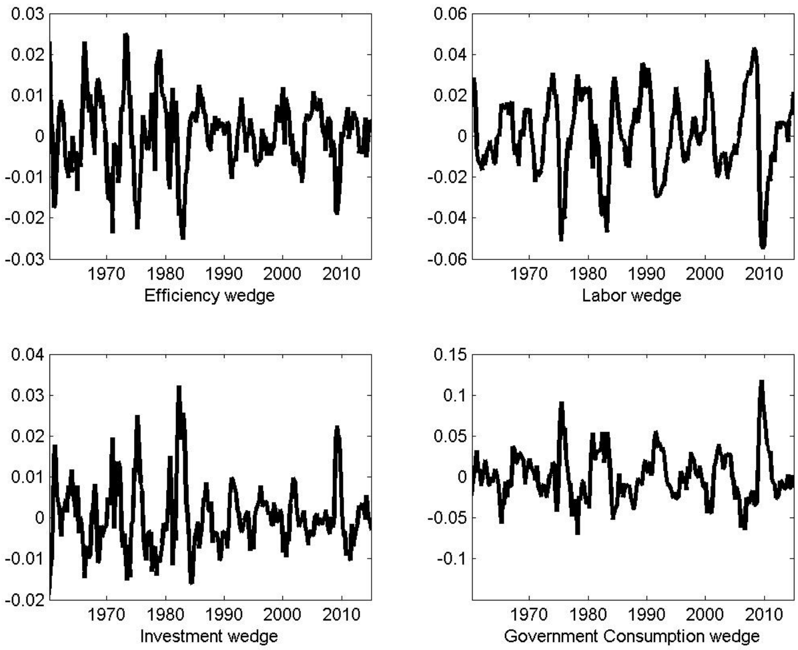
[11] Chari et al. (2007a), Brinca et al. (2016)

[12] See Federal Reserve Bank (2017) for the US recessions.

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 (Hodrick & Prescott, 1997) and are presented in Figure 2.1[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 US.

Figure 2.1: Estimated HP-filtered wedges for the US economy



Data from OECD; Author's calculations and elaboration.

The efficiency wedge volatility 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. From the prototype model, all the result decisions of economic agents rely on the realization of the wedges. But which distortion is more important? Following Chari et al. (2007a), the marginal effect of each wedge is obtained as follows. All other wedges are held fixed, but the one we are interested in, e.g. if we want to

[13]The smoothing parameter is 1600.

see the contribution of the efficiency wedge, we let it to fluctuate, while the others (labor, investment and government) are held fixed[14]. Then we can see how much of the data behavior the model with only one distortion can account for. The procedure also works by letting two or three wedges varying throughout time as well.

The 1973 Recession

The US 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 aforesaid recessions will be evaluated in a 10 quarters window from its pre-recession peak. Figure 2.2 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 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.

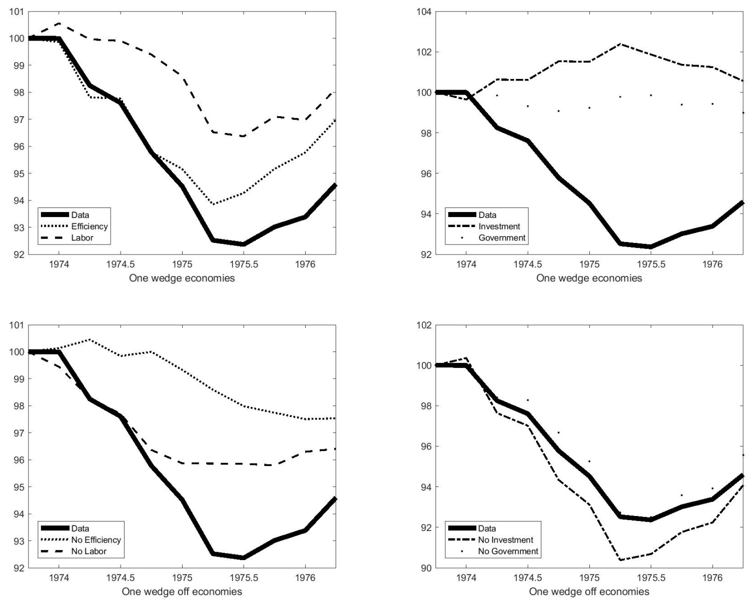
The literature has worked with a few statistics in order to make the choice of the better model more rigorous, for instance, the success ratio, the root mean square error (RMSE), Theil's U and the linear correlation coefficient. Output is normalized to a given initial value and the statistics are calculated. 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:

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

[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.

where i is the subscript for output from 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 2.1, the efficiency wedge alone is responsible for 62% of output movements, with a secondary role for the labor wedge (28%). The investment wedge explains only 4%) and the government consumption wedge accounts for 6%. When considering all but one wedge, the simulated economy without the investment wedge has the highest statistics and accounts for 96% of output movements.

Figure 2.2: Model vs Data: output during the 1973 recession

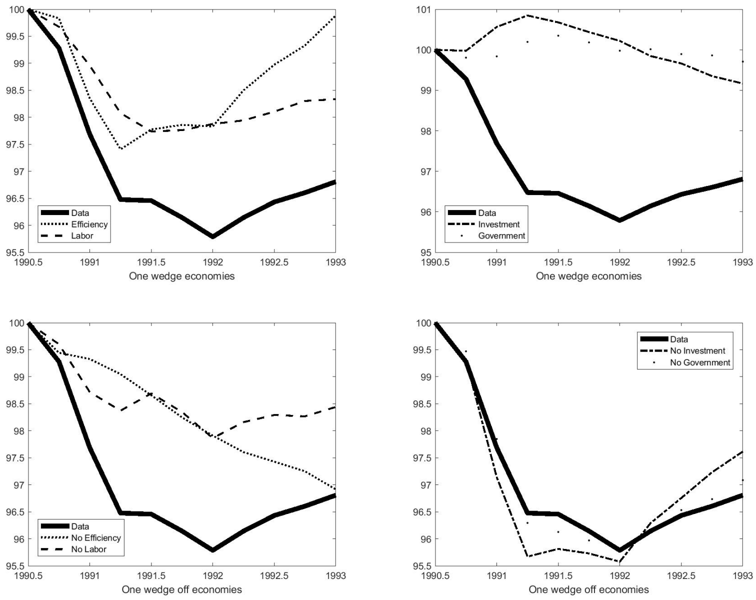


Note: 1973Q1=100; Author's elaboration.

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 2.3 presents simulations for both “one wedge economies” and “one wedge off economies” and the statistics are available in Table 2.1.

Figure 2.3: Model vs Data: output during the 1990 recession



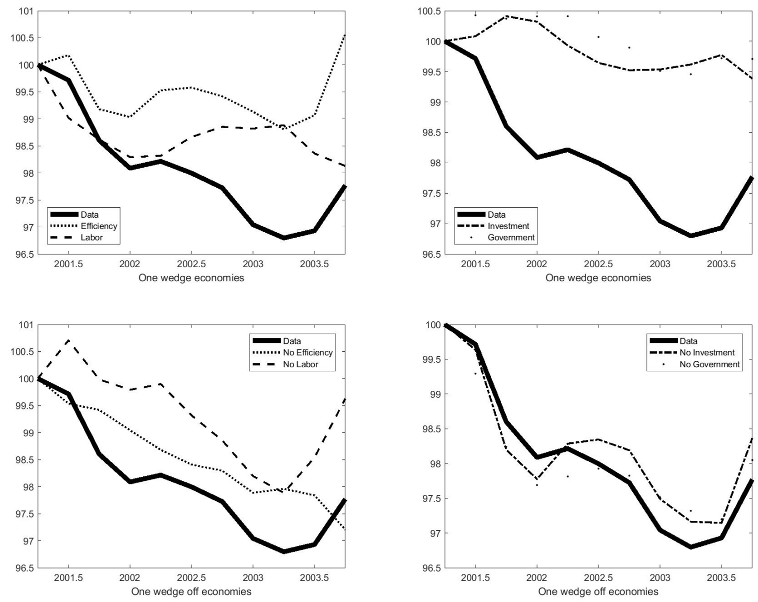
Note: 1990Q2=100; Author’s elaboration.

The 2001 Recession

The 2001 recession has two characteristics that are similar with the 1990 recession: they both were eight-months episodes with the efficiency wedge explaining around half of it. Within the BCA analysis, the difference relies on the role of the other wedges. In this case, the secondary contribution is due to the government consumption wedge, explaining 21% of output dynamics, whereas the labor wedge accounted for 16% and the investment wedge for 12%, as can be seen in Table 2.1.

Figure 2.4 presents simulations for both “one wedge economies” and “one wedge off economies”. Output would recover faster than observed data did with only the efficiency wedge and even faster with only the labor wedge wedge. For the model with only the investment, output would initially rise and only at the end of the sample period it would achieve a value under the initial condition. The trajectory for the model with only the government consumption wedge is similar to the investment wedge, though smoother.

Figure 2.4: Model vs Data: output during the 2001 recession



Note: 2001Q1=100; Author's elaboration.

Table 2.1: 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
2001 recession				
One wedge economies	50.49	16.02	12.46	21.04
One wedge off economies	49.51	83.98	87.54	78.96

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) .

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 2.2, 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 US. 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 2.2: The contribution of each wedge in recessions and expansions

Statistic	ω_e	ω_l	ω_x	ω_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: Economies with (without) the efficiency wedge (ω_e), the labor wedge (ω_l), the investment wedge (ω_x) and the government consumption wedge (ω_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 worth to be highlighted, regarding the limitations of the method.

[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.

2.2.3 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. Two main caveats could be risen regarding the technique: one about the model and 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. The other reason is due 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.

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.

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 its components used in BCA, with its own deflator). 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.

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

2.3 From accounting to modeling

One of the main contributions of BCA is helping the researcher 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.

2.3.1 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' optimal decisions geneate 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.

2.3.2 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..

2.3.3 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.

2.3.4 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 2.3 and 2.4.

2.4 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.

2.4.1 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:

$$c_t(s^t) + (1+\tau_{xt}(s^t))x_t(s^t) + (1+\tau_{bt}(s^t))[\frac{b_t}{(1+R_t)p_t} - \frac{b_{t-1}}{p_t}] =$$
$$(1-\tau_{lt}(s^t))w_t(s^t)l_t(s^t) + r_t(s^t)k_t(s^t) + T_t(s^t),$$

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:

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

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:

$$\sum_{s^{t+1}} \beta \frac{U_{c,t+1}(s^{t+1})}{U_{c,t}(s^t)} \frac{1+\tau_{b,t+1}(s^{t+1})}{1+\tau_{b,t}(s^t)} \frac{p_t(s^t)}{p_{t+1}(s^{t+1})}[1+R_t(s^t)] = 1, \tag{2.10}$$

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

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

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 US 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. 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].

2.4.2 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.

[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).

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

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

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

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

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

$$c_t(s^t) + x_t(s^t) + g_t(s^t) + tb_t(s^t) + \Theta(\frac{x_t}{k_t})k_t(s^t) = y_t(s^t). \tag{2.11}$$

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:

$$\sum_{s^{t+1}} \beta U_{c,t+1}(s^{t+1}) = U_{c,t}(s^t)(\frac{\Gamma}{R(1 + \tau_{d,t}(s^t))} - \Phi_d(d_{t+1})). \tag{2.12}$$

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, 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

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

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).

2.4.3 International Business Cycle Accounting

BCA was also extended to embody economic relationship 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 $i \in \{A, B\}$:

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

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:

$$\begin{aligned}&[q_t(s_t^{t+1}|s^t)d_{t+1}^A(s_t^{t+1}|s^t) - d_t^A(s^t)]+ \\ &[q_t(s_t^{t+1}|s^t)d_{t+1}^B(s_t^{t+1}|s^t) - d_t^B(s^t)] = \tau_{tb,t}(s^t),\end{aligned} \tag{2.13}$$

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

$$tb_t^A(s^t) + tb_t^B(s^t)/p_t(s^t) = \tau_{tb,t}, \tag{2.14}$$

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

$$p_t(s^t) = \frac{p_t^B(s^t)}{p_t^A(s^t)}. \tag{2.15}$$

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:

$$c_t^i(s^t) + x_t^i(s^t) + g_t^i(s^t) + tb_t^i(s^t) + \Theta(\frac{x_t^i(s^t)}{k_t^i(s^t)})k_t^i(s^t) = y_t^i(s^t). \tag{2.16}$$

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 2.3 and 2.4 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 2.3: 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 2.4: 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)

2.5 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 2.5 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 2.5: 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 (2016)
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 & Çiçek (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)

2.5.1 Developed economies

The initial efforts on BCA were to explain two major episodes for the US 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 US was also focus of analysis with BCA. Ohanian (2010) investigates what are the causes of the US 2007-2009 recession that make it not only different from other postwar US 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 US 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 (US, Spain, Ireland and Iceland) the labor wedge was the most important distortion.

[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.

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 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 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 consump-

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

tion 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 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

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

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 US.

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.

2.5.2 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 2.6 and 2.7), 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 & Çiçek (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 (2016) 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 US, 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 US (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 2.6 and 2.7. The next section is dedicated to final remarks.

Table 2.6: 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	US	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 2.7: 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 US	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	US	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 & Çiçek (2011)	BCA	Turkey	1968-2009	Important	Medium	Very small/nil	Very small/nil	-	-	-	-	-
Vasilev (2016)	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).

2.6 Final remarks

What are the drivers of business cycles? A whole research area has devoted much effort for providing a set of evidence for this question. Each episode, for each country has its own characteristics, so there is no general model to account for short run fluctuation. 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 relies on two dimensions. First, the accounting dimension. By defining a perfectly competitive prototype model with wedges, the relative contribution of each wedge can be assessed. After identifying the drivers of macroeconomic movements, the second dimension, the equivalence theorems – mappings of frictions into classes of detailed economies – helps to guide further research on business cycle fluctuations.

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 the relationship between countries (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 account of wedges and the 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?

In this paper, the application of BCA focused on three US recessions (1973, 1990 and 2001). Even though the efficiency wedge was the main driver of all of them, it was more important during the first oil shock than in the other crises. An interesting result is that the government consumption wedge played a secondary role for explaining the recession after the technology bubble burst in the US stock exchange.

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 provides a reasonable sample for the next step: broader conclusions and pattern identification. 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, episodes of contagion may be one motivation for other wedges driving business cycles. Second, economic policy, specially in emerging markets. Finally, major events, such as the Great Depression and the 2008 financial crisis.

The business cycle theory has evolved and created reasonable criteria for helping researchers to develop detailed DSGE models. Further work may be done either by expanding BCA in other dimensions rather than the three presented in this paper. In this paper, some patterns were found, specially during financial crises. Data availability and new papers will eventually provide new findings and broader conclusions may be drawn. Nevertheless, it is already a good starting point for short-run economic modeling.

Chapter 3

Output falls and the international transmission of crises

One knows a financial crisis when it happens.
Charles Kndleberger.[1]

3.1 Introduction

In the past 800 years we have been dealing with several financial crises[2]. The problem has grown and the frequency of financial crises has increased since the end of Bretton Woods, specially since the 1990s[3]. Economic recessions usually take four quarters, but recoveries from crises associated with a credit boom and bust are worse (Claessens et al., 2009). The unemployment rate may stay above its pre-crisis level for over a decade (Reinhart et al., 2010).

The so-called Great Recession emerged from the collapse in the US housing markets and hit not only the US economy, but several economies around the world (Claessens et al., 2009; Rose & Spiegel, 2012). The largest financial crisis since the 1930s destabilized important macroeconomic variables both for the short and the long-run (Reinhart & Reinhart, 2010).

How was the crisis transmitted? Integration in goods and services markets as well as financial markets may provide the answer. Furthermore, does the growing integration affects not only production decisions, but also how crisis are transmitted? In order to address this issue quantitatively, we approach Mexican data. From Figure 3.1 in Section 3.2 we have some evidence of two major downturns in the country:

[1]Kindleberger & O'Keefe (2001).

[2]See Reinhart & Rogoff (2009) and Kindleberger & O'Keefe (2001) for a vast documentation of financial crises.

[3]See Bordo et al. (2001) and Eichengreen (2002)

the so-called "Tequila crisis" in 1995 (top graph) and the Great Recession (bottom graph). The recovery in Mexico after the 2008 crisis was weak, with GDP and industrial production achieving pre-crisis levels only in 2011 (Ibarra, 2015).

Both episodes differ in severity and duration, but may provide a rich sample for answering the question about the transmission. First, what are the drivers of both crises? An useful way is to use the business cycle accounting (henceforth BCA). Following Chari et al. (2007a) and Brinca et al. (2016), the relevant distortions in the neoclassical growth model are estimated and analyzed (the accounting procedure). The method relies on two pillars: accounting and equivalences (Brinca et al., 2016). This paper provides contributions on both.

First, the BCA decomposition favors the efficiency wedge (i.e., distortion in the production decisions) as the most relevant wedge for explaining per worker output movements in Mexico in both crises. The secondary and tertiary roles are different, though. For the 1995 episode, the investment wedge (the distortion in the intertemporal decision) plays the secondary part, whereas in the Great recession, it was the labor wedge (the distortion in the labor decision), but with both the investment and the government consumption wedge (the distortion on the resource constraint) playing close tertiary roles.

What lies behind the relative importance of each wedge? Furthermore, what lies behind the international transmission of the crisis to domestic production in Mexico? After finding that the efficiency wedge is the main driver of GDP, a DSGE model is build to understand the crisis (the equivalence procedure). Given that Mexico is an open-economy and the fact that the government consumption wedge is not as important as the other wedges to understand the crisis, there may be an international channel "hidden" in the efficiency wedge, since imported intermediate goods play an important role in final goods production in Mexico. A small-open economy model augmented with imports in the production function was estimated to analyze the Great Recession. The model seems to capture the essence of the international link of the crisis, the directly link to production decisions, rather than via the balance-of-payments dynamics. The model is able to replicate observed movements in data for both crises (1995 and 2008).

This chapter is organized as follows. Besides this introduction, the next section presents a literature review of BCA and the prototype model used for identifying relevant wedges driving Mexican business cycles. Section 3.3 presents the business cycle accounting and the detailed economy used to understand the Mexican Great Recession. The last section is dedicated to final remarks and conclusions.

3.2 International crises and business cycles: accounting and modeling

From the prototype economy presented in Chapter 2 we can estimate each of the four wedges using per worker data on output, investment, hours of work, government consumption and net exports. Following Brinca et al. (2016), original variables were adjusted. For instance, since decisions on the consumption of durable goods look like investment decisions, they were subtracted from aggregate consumption and added to aggregate investment[4].

The Mexican case is also addressed by Sarabia (2008) and Meza (2008). In both papers the efficiency is the most important, whereas in the latter it divides the protagonism with the labor wedge. In Sarabia (2008), even though for the 1995 episode the role of the investment wedge is higher than for the 2001 recession, it still plays a minor role. The labor wedge is more important for explaining the 1995 crisis than the 2001 recession. For Meza (2008), the main goal is to understand to role of fiscal policy. Using an adjusted version of BCA (adding net exports to investment, rather than to government consumption), he finds that policy changes, specially via tax increases are important quantitatively. This paper complements the existing business cycle accounting literature for Mexico by i) adjusting consumption and investment quarterly data, ii) extending the sample period and iii) focusing on the 2008 financial crisis recovery.

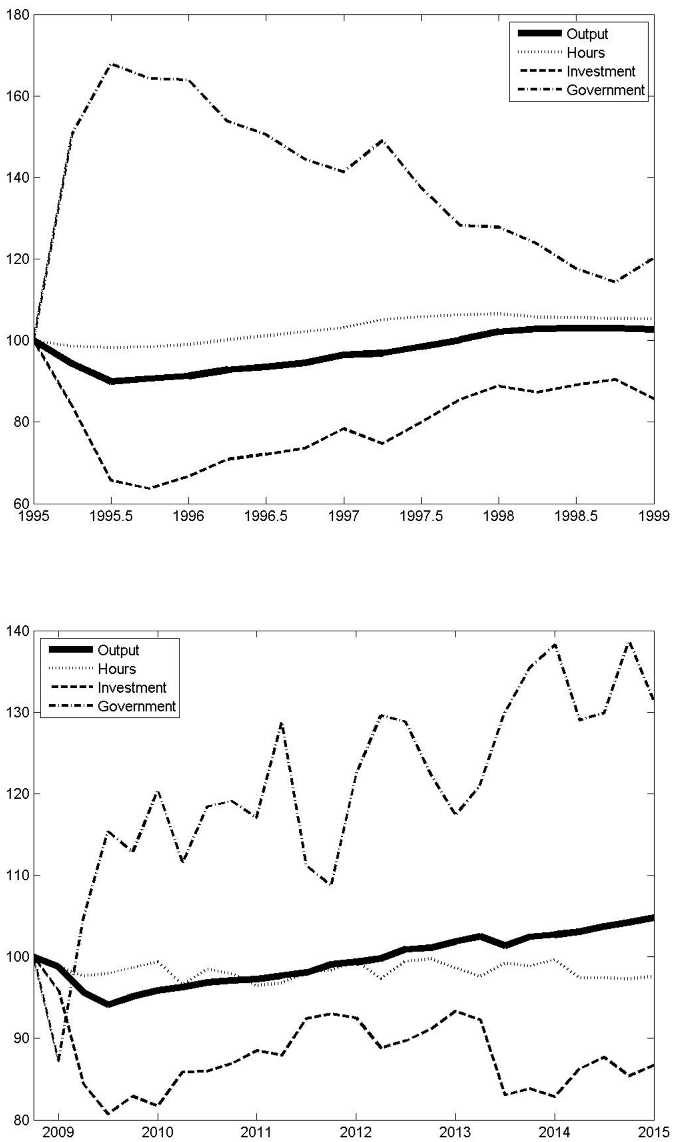
Figure 3.1 presents data for two periods: the 1995 crisis and the Great Recession in Mexico. In the so called "Tequila Crisis" output fell more than in the Great Recession, achieving a 10.1% accumulated fall in the third quarter of 1995 when compared with the pre-crisis peak (1995Q1), whereas in the latter episode the bottom was a 5.9% accumulated fall in the first quarter of 2009, relative to the pre-crisis peak in the second quarter of 2008. The velocity of the recovery also differed. In the 1995 episode, pre-crisis peak level was restored after 11 quarters, whereas after the fall in 2008, output took 15 quarters to achieve its pre-crisis level.

It is not only the dynamics of output that differed from one episode to another. In the 1995 episode, investment contracted more than 36% in the third quarter of 1995, while in the Great Recession the bottom was achieved with a 19.3% fall.

The dynamics of government consumption plus net exports also differed between episodes. In the "Tequila crisis", it rose after the shock, accumulating an almost

[4]Data from OECD used in Brinca et al. (2016). Quarterly tax data and population data was obtained by linear interpolation from annual data. To extend durables goods time series to match other macro variables, a linear regression of durables goods on both output and investment was used and its intersection changed to smooth the "transition" from observed to estimated data

Figure 3.1: Macroeconomic variables in the 1995 and 2008 crises



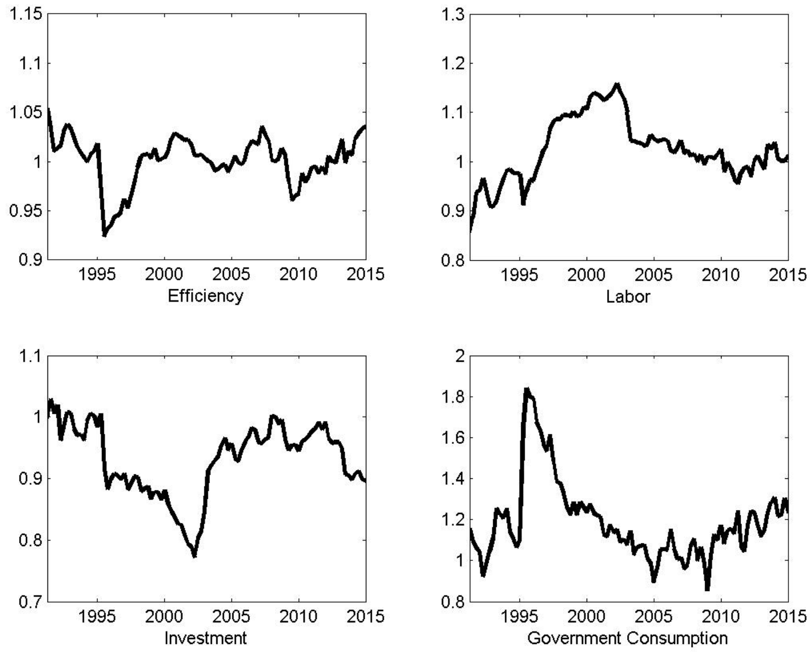
Notes: For the 1995 crisis (top graph), 1991Q1=100. For the 2008 crisis (bottom graph), 2008Q2=100.

68% increase in the third quarter of 1995. During the Great Recession, however, the behavior was different. The initial response was a fall, rather than an increase. After the fall, it started to augment, but its movements were more erratic than in the 1995 crisis.

Finally, in both crises hours of work presented lower volatility when compared with other variables. But as the previous cases, the dynamics differed between episodes. For the 1995 crisis, it felt 1.7% but it as recevored after four quarters. In the 2008 crisis, 25 quarters after the fall and it was still below pre-crisis level.

The prescriptions of the neoclassical growth were confronted with the presented data and the path of the estimated wedges is shown in Figure 3.2. The efficiency wedge felt more during the “Tequila crisis” than in the Great Recession, but after the fall it took more time to achieve its pre-crisis level in the latter episode. For the investment wedge, the relative recovery is inverse, i.e., it took more time after the “Tequila Crisis” to increase than after the Great Recession. The labor wedge felt in an equivalent way in both episodes. The behavior of the government consumption wedge follows the slower-recovery characteristic of the Great Recession seen in both output data and efficiency wedge.

Figure 3.2: Estimated HP-filtered wedges for the Mexican economy



After measuring/estimating the distortions, it is possible to simulate variables paths to see which wedge helps to explain data movements. Following Chari et al. (2007a), the marginal effect of each wedge is obtained by keeping all other wedges fixed, but the one we are interested in, e.g. if we want to see the contribution of the efficiency wedge, we let it to fluctuate, while the others (labor, investment and government) are held fixed. Then we can see how much of the data behavior the model with only one distortion can account for. The procedure works letting two or three wedges varying throughout time as well.

The prototype economy was simulated with only one wedge (all other remained constant) and with only one wedge off (only one wedge remaining constant) and the output path for each simulation for both crises (1995 and 2008) are presented in figures 3.3 and 3.4. Table 3.1 presents four statistics for the BCA simulations: success ratio, linear correlation, root mean-square error (RMSE) and a ϕ statistic following Brinca et al. (2016), defined in Chapter 2.

The efficiency wedge alone has the best performance amongst one wedge economies for both episodes. However, this is not true for the full sample. For instance, it accounts for only 18% of whole output movements, whereas it explains 85% of output movements in the 1995 crisis and 44.6% during the Great Recession. After the "Tequila crisis", the distortion in the production decisions would imply a lower output level (see Figure 3.3) and a faster recovery in the Great Recession compared to actual data, calling for a (secondary) role of other wedges (see Figure 3.4).

The investment wedge plays a secondary for explaining output variations. It accounts for 22% in the whole sample, 10% in the 1995 crisis and 17% during the Great Recession. Figure 3.3 shows that the model without the investment wedge implies a lower fall and a higher output after the 1995 crisis. The labor wedge explains less than 4% of output fluctuations in the whole sample, 2% in the "Tequila crisis" and 21.7% in the 2008 crisis.

Figure 3.3: Simulated economies during the 1995 crisis

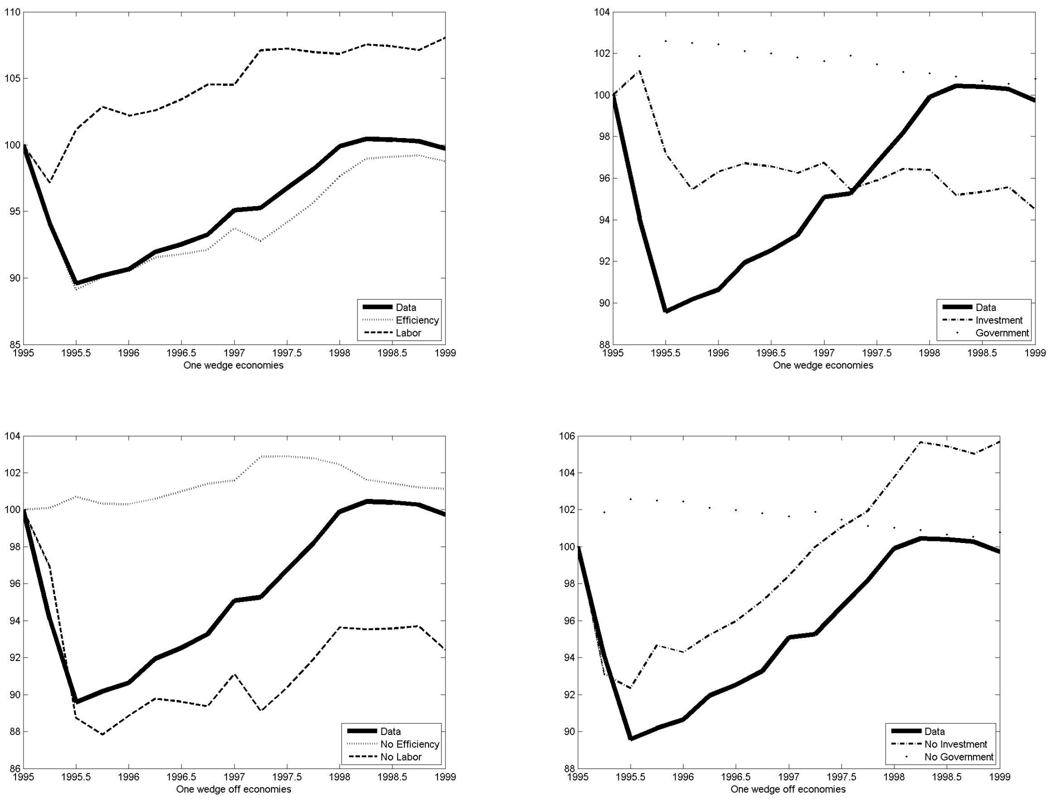


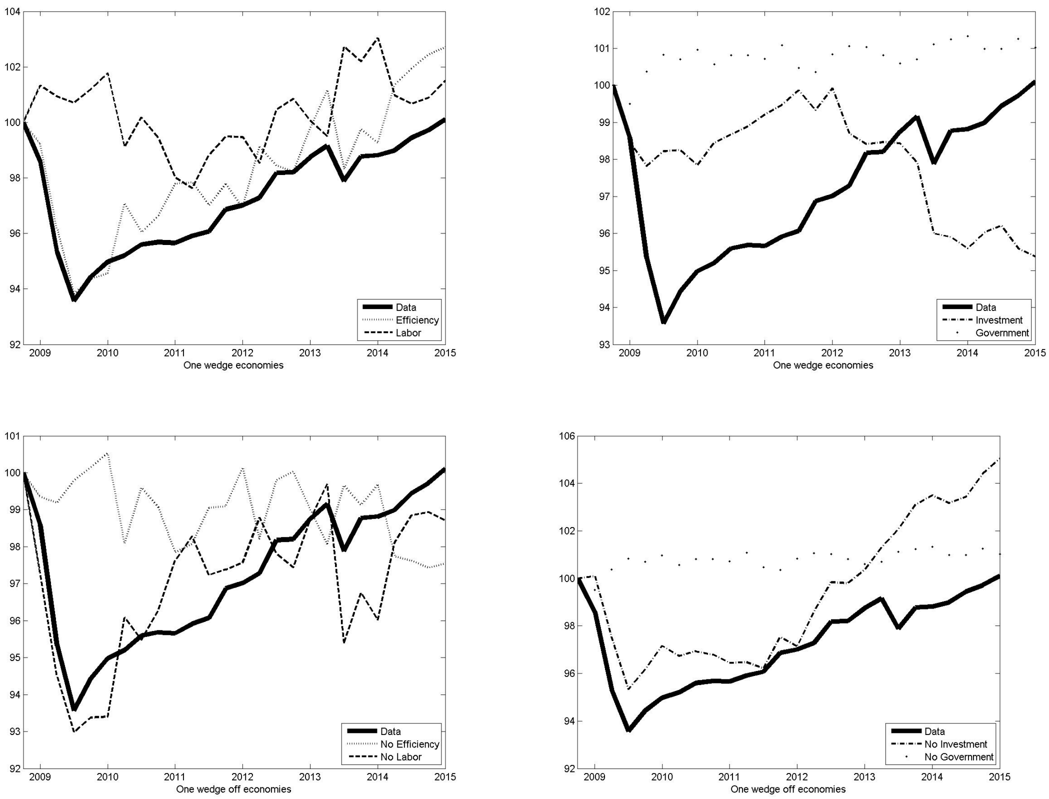
Table 3.1: BCA decomposition statistics

Statistic	**Efficiency**	**Labor**	**Investment**	**Government**
One wedge economies - full sample				
Success Ratio	0.779	0.474	0.579	0.337
Correlation	0.839	0.295	-0.180	-0.480
RMSE	0.016	0.046	0.052	0.032
ϕ_i^y	0.179	0.036	0.222	0.564
One wedge off economies - full sample				
Success Ratio	0.558	0.726	0.653	0.916
Correlation	0.114	0.383	0.158	0.983
RMSE	0.030	0.042	0.198	0.009
$1-\phi_i^y$	0.821	0.964	0.778	0.436
One wedge economies - 1995 crisis				
Success Ratio	0.923	0.615	0.538	0.154
Correlation	0.960	0.359	0.234	-0.934
RMSE	0.015	0.099	0.042	0.083
ϕ_i^y	0.852	0.019	0.103	0.027
One wedge off economies - 1995 crisis				
Success Ratio	0.538	0.692	0.692	0.923
Correlation	0.498	0.686	0.650	0.998
RMSE	0.075	0.041	0.219	0.015
$1-\phi_i^y$	0.148	0.981	0.897	0.973
One wedge economies - Great Recession				
Success Ratio	0.750	0.536	0.536	0.464
Correlation	0.899	0.308	-0.332	-0.022
RMSE	0.017	0.025	0.028	0.028
ϕ_i^y	0.446	0.217	0.170	0.167
One wedge off economies - Great Recession				
Success Ratio	0.571	0.750	0.571	0.857
Correlation	-0.159	0.784	0.179	0.981
RMSE	0.023	0.012	0.112	0.007
$1-\phi_i^y$	0.554	0.783	0.830	0.833

Success ratio: relative frequency when simulated and observed data had the same sign; Linear correlations between simulated and observed data; RMSE: root of the mean-square error; ϕ-statistic following Brinca et al. (2016).

Finally, the government consumption wedge has some contradictory results. Even tough it is the main driver of output movements in the full sample, accounting for 56.4% of output movements, its contribution falls to less than 3% in the 1995 and to 16.7% in the Great Recession. The simulated output paths presented in Figure 3.4 for the economies with only the government consumption wedge are in line with the simulation from a sudden stop in Chari et al. (2005). In both cases, output would rise if the driver was only that wedge, whereas observed data follows a different path. Furthermore, output from the models with only this wedge have negative correlations with data.

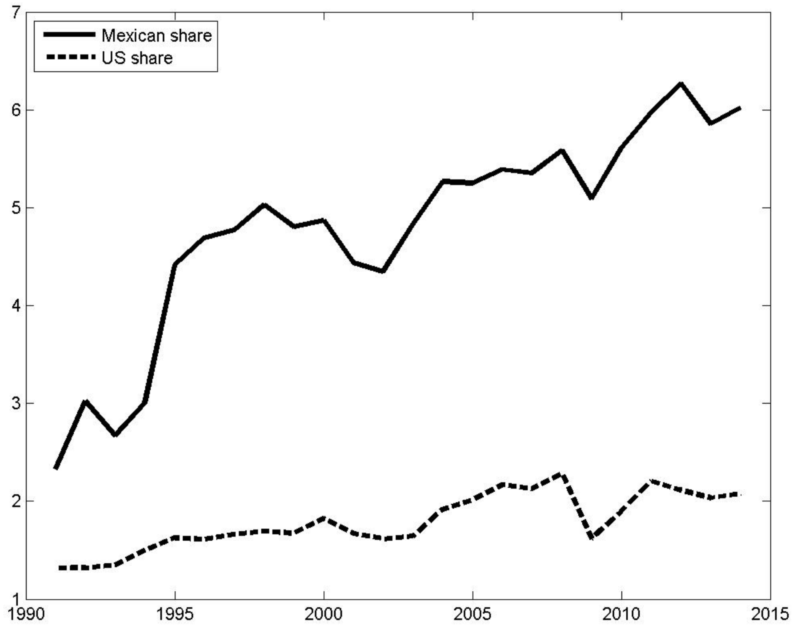
Figure 3.4: Simulated economies during the 2008 crisis



The poor performance for the models with only a government consumption raises a question. Given the fact the 1995 is an exchange rate crisis and the 2008 is an international crisis, should not they be transmitted via the balance of payments, assigning a greater role for the government consumption wedge due to an increase in net exports after exchange rate depreciations?

In order to answer that one should be able to match the importance of the efficiency wedge with a hidden international transmission link. Let us begin by accounting for the importance of intermediate goods in Mexican GDP. Using intermediate goods data from WITS-World Bank and GDP data from the World Economic Outlook Database (April 2016), we can see in Figure 3.5 the share for Mexico. For a matter of comparison, the same proportion for the US is shown.

Figure 3.5: Intermediate goods imports - share of GDP



Total imports of intermediate goods not only rose since the 1990s (as one could expect since output trend growth is positive since then), but it has increased faster than GDP. The share of GDP destined to foreign intermediate goods is almost twice the level it was in 1995. Moreover, the Mexican economy was hit by at least two shocks during the Great Recession: exports falling due to a lower demand from the US and a risk aversion movement depreciating the exchange rate (Sidaoui et al., 2010).

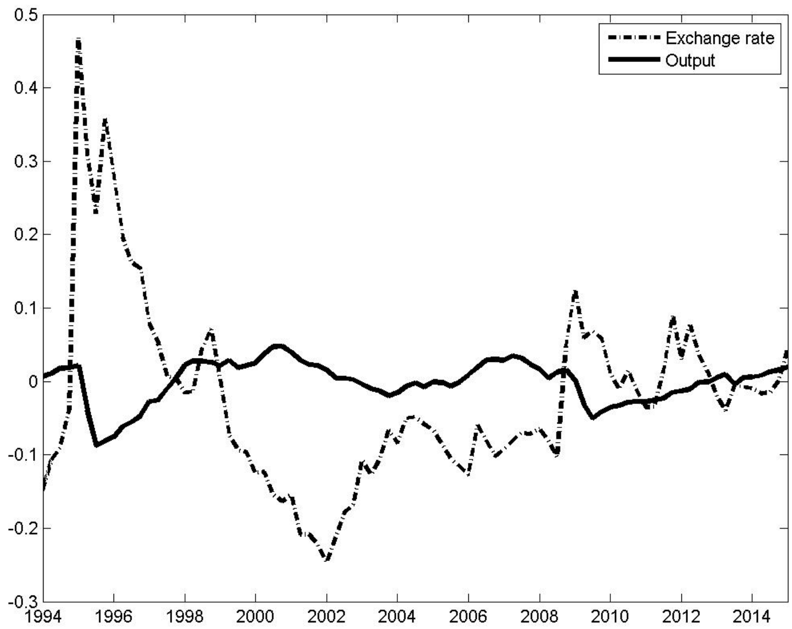
Figure 3.6 presents two series: log-detrended per capita output (using the HP-filter in Hodrick & Prescott (1997)) and deviations from the purchase power parity equilibrium for the real exchange rate[5]. The coefficient of linear correlation for both series is negative -0.61. Usually, output deviations and real exchange rate deviations move to opposite directions, simultaneously.

With all that in mind, the next section presents a model using imported-goods in the production function to understand the crisis in Mexico[6].

[5]In the long run the real exchange rate should be equals to 1 according to the purchase power parity theory. The sample mean is 0.99.

[6]Kim (2014) also introduces imported intermediate goods in the production function. However, his paper focuses on the impact of tariff changes during the Korean crisis, rather than the influence of the real exchange rate.

Figure 3.6: HP-filtered per capita output vs Real exchange rate changes



Note: a rise in the exchange rate means a depreciation.

3.2.1 Detailed economy

We introduce imported intermediate inputs in the final goods production in Schmitt-Grohé & Uribe (2003) small open-economy debt-elastic interest rate model. Households behave in a rational way, maximizing its present-valued expected lifetime utility:

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

where c_t stands for consumption, l_t for hours of work and $U(c_t, l_t)$ is the instantaneous utility. As is usual in this kind of model, households have a positive but decreasing marginal utility of consumption and an increasing marginal disutility of labor. The domestic agents can use their own resources as well as foreign capital. The foreign debt (d_t) dynamics is given by:

$$d_t = (1 + r_{t-1})d_{t-1} - y_t + c_t + x_t + \Lambda(k_{t+1}) + e_t m_t$$

where $\Lambda(k_{t+1}) = \frac{\phi}{2}(k_{t+1} - k_t)^2$ represents capital adjustment costs. Current foreign debt (d_t) is a function of the last period's stock of debt and the one-period interest rate (r_t), net from savings made for paying part of the debt (i.e., aggregate income – y_t – less the amount spent in consumption – c_t – and investment – x_t – and the last contemplating capital accumulation costs), m_t stands for net imported intermediate goods and e_t is the real exchange rate.

The interest rate is a function of the equilibrium interest rate and the country's foreign indebtedness level, as follows:

$$r_t = r + \psi(e^{d_t - d} - 1).$$

The production technology has the standard Cobb-Douglas formulation[7]:

$$y_t = m_t^{\mu}(k_t^{\alpha} l_t^{1-\alpha})^{1-\mu}.$$

The real exchange rate is assumed to be exogenous, following an AR(1) process:

$$\ln e_t = \rho_e \ln e_{t-1} + \epsilon_t^e.$$

The capital accumulation is given by the current stock of capital net of depreciation plus the flow of investments:

$$k_{t+1} = (1-\delta)k_t + x_t.$$

Under the presented assumptions, the optimization problem is given by:

$$\max_{c_t, l_t, d_t, k_{t+1}} E_t \sum_{t=0}^{\infty} \beta^t U(c_t, l_t)$$

subject to the debt dynamics, the production function and the capital accumulation law of motion, given the exogenous movements of TFP.

One more restriction should be imposed to assure a Non-Ponzi dynamics of the system. The transversality condition is given by:

$$\lim_{j \to \infty} E_t \frac{d_{t+j}}{\prod_s^j (1 + r_s)} \leq 0$$

which implies that the present value of the debt should be less or equal to zero, i.e., no remaining debt in the limit.

The first order conditions are:

$$\lambda_t = \beta E_t \lambda_{t+1}(1 + r_t), \tag{3.1}$$

[7]Which respects the Inada conditions. See Kim (2014).

$$\lambda_t = U_{c_t}, \tag{3.2}$$

$$-\frac{U_{l_t}}{U_{c_t}} = (1-\alpha)(1-\mu)\frac{y_t}{l_t}, \tag{3.3}$$

$$\lambda_t(1+\phi(k_{t+1}-k_t)) = \beta E_t \lambda_{t+1}(\phi(k_{t+2}-k_{t+1}) + 1 - \delta + (1-\mu)\alpha\frac{y_{t+1}}{k_{t+1}}), \tag{3.4}$$

$$\frac{\partial \mathcal{L}}{\partial m_t} = 0 \Leftrightarrow \frac{\mu y_t}{m_t} = e_t, \tag{3.5}$$

where $\partial U(c_t, l_t)/\partial c_t = U_{c_t}$ and $\partial U(c_t, l_t)/\partial l_t = U_{l_t}$ and λ_t represents the Lagrange muliplier. The definition of trade balance over GDP (tby_t) closes the model:

$$\begin{aligned}
&y_t - c_t - x_t - g(k_{t+1}) - e_t m_t = (1+r_{t-1})d_{t-1} - d_t, \\
&y_t - c_t - x_t - g(k_{t+1}) - e_t m_t = tb_t, \\
&1 - \frac{c_t}{y_t} - \frac{x_t}{y_t} - \frac{g(k_{t+1})}{y_t} - e_t\frac{m_t}{y_t} = tby_t.
\end{aligned} \tag{3.6}$$

3.2.2 Equivalences and quantitative analysis

In order to work with the DSGE model, the preferences regarding consumption and leisure should be defined. Two natural candidates arise: the utility function used in BCA exercises (BCA preferences) and the one used in Schmitt-Grohé & Uribe (2003) (SGU preferences).

BCA preferences

Let us assume that households combine consumption and leisure in an additive log-form. If this is the case, one could express household's preferences as follows:

$$U(c_t, l_t) = \ln c_t + \omega \ln(1 - l_t)$$

Thus equations (6) and (7) become, respectively:

$$\lambda_t = \frac{1}{c_t} \quad \text{and} \quad \frac{\omega c_t}{1 - l_t} = (1-\alpha)(1-\mu)\frac{y_t}{l_t}$$

Under these preferences an equivalence is proposed.

Proposition 1. *Considerer the prototype economy previously described, with* $U(c_t, l_t) = \ln c_t + \omega \ln(1 - l_t)$, $A_t = m_t^{\mu}(k_t^{\alpha} l_t^{1-\alpha})^{-\mu}$, $(1 + \tau_{x,t}) = (1 + \phi(k_{t+1} - k_t))$, $(1 + \tau_{x,t+1}) = 1 + (1 + \phi(k_{t+2} - k_{t+1}))/(1 - \delta)$, $(1 - \tau_{l,t}) = 0$ *and* $g_t = (1 + r_{t-1})d_{t-1} - d_t + \frac{\phi}{2}(k_{t+1} - k_t)^2 + e_t m_t - \frac{a}{2}(\frac{x_t(s^t)}{k_t(s^{t-1})} - b)^2$. *The equilibrium allocations in the detailed economy match equilibrium allocations in the prototype economy.*

Proof. The efficiency wedge mapping comes from equating both production functions: $A_t k_t^{\alpha} l_t^{1-\alpha} = m_t^{\mu}(k_t^{\alpha} l_t^{1-\alpha})^{1-\mu} \iff A_t = m_t^{\mu}(k_t^{\alpha} l_t^{1-\alpha})^{-\mu}$. The labor wedge distorts the intratemporal decision. In the detailed economy, there is no such distortion in equation (3.7), thus $(1 - \tau_{l,t}) = 0$. From equation (3.6) we have the marginal utility of consumption. The right hand side of equation (3.4) – in the prototype economy – presents the marginal utility of consumption, which is equal to the Langrange multiplier, times the investment wedge. By equating the left hand side of equation (3.8) to the left hand side of equation (3.3) we have see that $(1 + \tau_{x,t}) = (1 + \phi(k_{t+1} - k_t))$. Moreover, making both right hand sides equal yields $\beta E_t[u_{c,t+1}(A_{t+1}F_{kt} + (1 - \delta)(1 + \tau_{x,t+1}))] = \beta E_t \lambda_{t+1}(\phi(k_{t+2} - k_{t+1}) + 1 - \delta + (1 - \mu)\alpha \frac{y_{t+1}}{k_{t+1}}) \iff (1 + \tau_{x,t+1}) = 1 + (1 + \phi(k_{t+2} - k_{t+1}))/(1 - \delta)$. The government consumption wedge arises from the resource constrain, by isolating output, investment and consumption (and the different functional form for adjustment costs): $g_t = (1 + r_{t-1})d_{t-1} - d_t + \frac{\phi}{2}(k_{t+1} - k_t)^2 + e_t m_t - \frac{a}{2}(\frac{x_t(s^t)}{k_t(s^{t-1})} - b)^2$. □

Proposition 1 states that the efficiency wedge (the distortion in production decisions) depend, among other things, on net imports. Due to the participation of imports in Mexican production, an increase in imports would soar GDP. On the other hand, if imports decrease, one should expect GDP to fall. Furthermore, net imports would decrease if real exchange rate depreciates under Marshall-Lerner conditions. If imports are that important to Mexico, one should see a negative correlation between real exchange rate depreciation and short-run output growth.

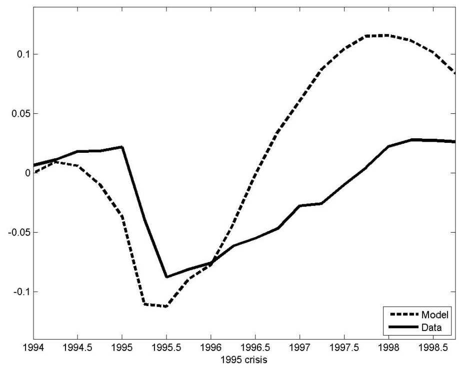
It is opportune to do also the equivalence with an extension of business cycle accounting that departs from an open-economy version of the prototype model.

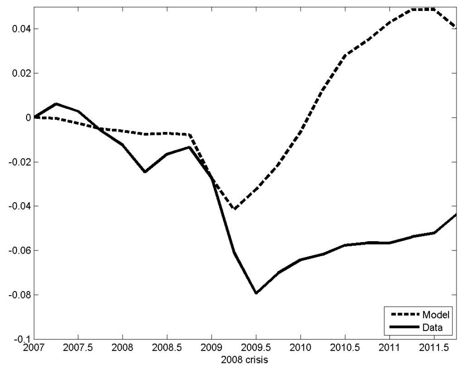
Proposition 2. *Considerer the open-economy prototype model of Otsu (2010b), with* $U(c_t, l_t) = \ln c_t + \omega \ln(1 - l_t)$, $g(k_{t+1}) = \Theta(\frac{x_t}{k_t})$, $\Phi(.) = 0$, $A_t = m_t^{\mu}(k_t^{\alpha} l_t^{1-\alpha})^{-\mu}$, $(1 + \tau_{x,t}) = ((1 + \gamma_n)(1 + \gamma))^{-1}$, $(1 + \tau_{x,t+1}) = 1 + g(k_{t+1}) - \frac{y_{t+1}}{k_{t+1}}\alpha\mu$, $(1 - \tau_{l,t}) = 0$, $g_t = e_t m_t$ *and* $(1 + \tau_t^D) = \frac{1 + r_{t-1}}{R}$. *The equilibrium allocations in the detailed economy match equilibrium allocations in the prototype economy.*

Proof. The proof of the mappings for the efficiency wedge, the labor wedge and the marginal marginal utility of consumption are the same as in the proposition 1. The investment wedge at t and $t + 1$ comes from comparing both Euler equations. Let us assume that capital adjustment costs are the same in both models, i.e. $\Theta_t(\frac{x_t}{k_t}) = \frac{\phi}{2}(k_{t+1} - k_t)^2$ and that there is no cost of adjusting debt. Thus the government consumption wedge arises from the resource constrain: $g_t = e_t m_t$ and the foreign debt wedge comes from comparing households' budget constraint in Otsu (2010b) with the resource constraint in the model of this paper. □

Under BCA preferences the model has different performances when comparing the outcomes with data for both the 1995 and the 2008 crises. For the former the initial fall is accounted for the model, whereas the recovery prescribed by would be faster and stronger than the one observed in data. The same pattern happens when considering only the 2008 crisis. However, the performance is even poorer, since the model would prescribe a lesser fall and a stronger recovery. Figure 3.7 presents the comparisons.

Figure 3.7: Output: data vs model with BCA preferences





Notes: The outcome of a log-linearized model and the HP-filtered output data.

Even though the main driver of the two episodes is the efficiency wedge, the decomposition also favored the investment wedge, with a less important role in both fluctuations. The wedge may arise from difference preferences and the natural candidate is the utility function from Schmitt-Grohé & Uribe (2003)[8].

SGU preferences

Schmitt-Grohé & Uribe (2003) use a different functional form:

$$U(c_t, l_t) = \frac{[c_t - \omega^{-1} l_t^{\omega}]^{1-\gamma} - 1}{1-\gamma}$$

Thus equations (3.6) and (3.7) become, respectively:

[8]See appendix B for the issue of different preferences resulting in a investment wedge.

$$\lambda_t = [c_t - \omega^{-1} l_t^{\omega}]^{-\gamma}$$

and

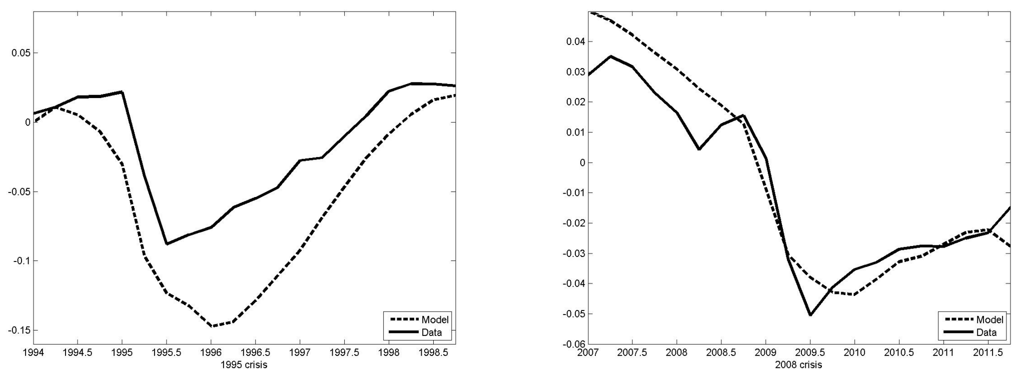
$$(1-\alpha)(1-\mu) y_t = l_t^{\omega}$$

In order to understand the transmission of the Mexican Great Recession, the model was simulated using Dynare with both BCA and SGU preferences. The model under SGU preferences performs better than the one with BCA preferences.

From the business cycle accounting we already knew that, even favoring the efficiency wedge as the main driver of the slow recovery after the Tequila crisis and Great Recession, in both episodes the investment wedge plays a greater role than in the whole sample. In the small open-economy model used in this paper, both the labor and investment wedge arise from different preferences.

To assess the effects of the real exchange rate shocks on the output dynamics for the "Tequila crisis", the outcomes of the DSGE model (log-linearized) were confronted with observed data and presented in Figure 3.8[9].

Figure 3.8: Output: data vs model with SGU preferences



Notes: The outcome of a log-linearized model and the HP-filtered output data.

[9] See Table 5.1 in Appendix B for the parameterization

We can see from Figure 3.8 that the model with SGU preferences has a good performance, in both crises. The statistics are presented in Table 3.2.

Table 3.2: Model evaluation: BCA vs SGU preferences

Statistic	**BCA preferences**	**SG preferences**
1995 crisis		
Success Ratio	0.600	0.150
Correlation	0.407	0.891
RMSE	0.080	0.049
2008 crisis		
Success Ratio	0.485	0.150
Correlation	-0.02	0.793
RMSE	0.042	0.019

Success ratio: relative frequency when simulated and observed data had the same sign; Linear correlations between simulated and observed data; RMSE: root of the mean-square error.

The model is able to capture both the intensity of output fall in the episode and the recovery afterwards. This finds complement the existing literature on the 1995 crisis that attribute to banking fragilities, changes in world capital movements, economic policy and foreign interest rates to the roots of the crisis (Kaminsky et al., 2003; Calvo & Mendoza, 1996) by adding in another driver of output fall and recovery, the imports.

The model also accounts for the output dynamics during the Great Recession. After a initial shock output fell, and differently from the experience of the 1990s, the recovery was slow. Despite for a brief decoupling period, the model mimics these features of data. The exchange rate depreciation following the crisis decrease imports, what in the aforesaid model diminishes production. The real exchange rate path after 2008 may help to explain the Great Recession in Mexico.

3.3 Final remarks

The largest financial crisis since the Great Depression imposed a hard reality on both developed and emerging market economies. Arising from problems within the US housing market and transmitted via complex financial instruments networks throughout financial markets around the world, its recovery was anything but fast. Mexico is one example of it.

When comparing with the "Tequila" crisis, some variables felt more after 2008 than after 1995 and the post-crisis recovery was slower. The business cycle accounting method helps us to understand the mechanisms of the observed dynamics. By confronting real data with the outcomes from a neoclassical growth model, one could estimate distortions in agents' optimal decisions driving business cycles. In the case of the Mexican Great Recession, the efficiency wedge explains most of the output variation. However, the model with only the efficiency wedge prescribes a faster recovery than the one observed in data. Therefore, other distortions are also important.

Due to a rising importance of foreign intermediate goods in final goods production in Mexico, a small-open economy model was extended to encompass this feature. It is possible to map the detailed economy into the prototype economy with wedges for both traditional and open-economy BCA.

Using BCA preferences the open-economy model has a poor performance. The models with SGU preferences was able to account for output fall and recovery in the 1995 and 2008 crisis. This reveals a "hidden" international link that can be mapped into an efficiency, rather than via the government consumption wedge.

Chapter 4

Economic depression in Brazil: the 2014-2016 fall

There are repeated periods during which real GDP falls, the most dramatic instance being the early 1930s. Such periods are called recessions if they are mild and depressions if they are more severe.

Gregory N. Mankiw.[1]

4.1 Introduction

Dealing with financial crises is not a new feature of capitalist economies. Actually, this is a problem of more than eight centuries[2]. Nevertheless, since the Great Depression, no other episode was as strong as the 2008 financial crisis[3]. The crisis hit the world economy emerging from problems in the US housing market, spreading to the rest of the world throughout a complex derivatives network and the economic policies responding to the fall (Brunnermeier, 2009). In Brazil, differently from the experience of the developed countries, it was just a contraction of two quarters, in 2009.

After the fall, the economy bounced back and 2010 was prosperous. However, since 2011, growth rates trended downwards. Specially after 2014, when its close-to-zero growth marked a period of a severe recession or, as it is called in this paper, a depression.

The aim of this paper is to understand the drivers of the Brazilian 2014-2016 depression. To this end, this paper is organized as follows. The next section addresses

[1] Mankiw (2010).
[2] Reinhart et al. (2010).
[3] Claessens et al. (2009).

Brazilian business cycles. Since the 1980s the country seems to have lost the ability to have sustainable growth rate that suits its emerging market status. One reason is the dynamics of total factor productivity, also explored in next section. Having experienced nine recessions since the 1980s, the country faces a complicated long run dilemma. The short run is no less challenging.

The eighth period of expansion since 1981 was ended by the 2014-2016 depression. At the same time, the world registered more or less steady growth rates and one could wonder whether the deceleration was a byproduct of a global fall or if it was the consequence of domestic policies. Section 4.3 deals with that issue. The evidence points towards a domestic cause after all.

Section 4.4 analyzes the drivers of the depression using BCA. The decomposition exercises indicate a prominent role for the efficiency wedge during the depression.

The importance of earmarked credit in Brazil leads us to look further on credit markets and the relationship between the efficiency wedge and the loans of the federal public development bank. As a result, an increase in the development bank outlays has a positive impact on the efficiency wedge in the short run. However, this is offsetted by a negative impact a few quarters after the shock.

The intuition is the following. At first, by accumulating capital in a publicly-financed sector, total production may rise even more than accumulation of factors would prescribed (generating an efficiency wedge). However, in the second period, if the credit was allocated to projects with low returns, aggregate productivity decreases.

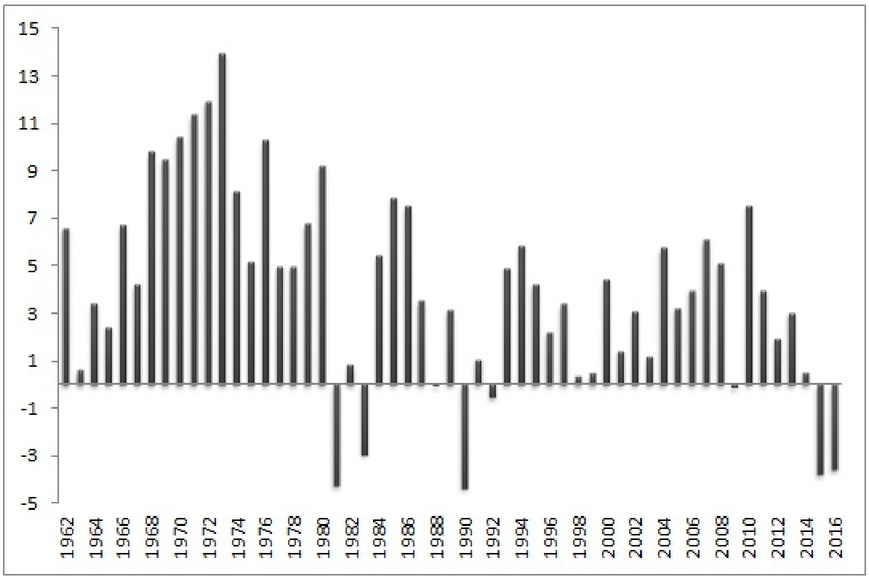
A dynamic general equilibrium model with credit market frictions and a public bank is able to mimic output dynamics and help us to understand the episode. By combining the results, we conclude that the depression is a combination of lagged negative impacts of public lending, which were cut and generated a negative short-run impact. Furthermore, household and firms' debt made the recovery slower than past episodes.

Finally, the last section is destined to further remarks and conclusions.

4.2 Brazil in the long and the short run

The Brazilian economy has experienced different growth patterns, especially since the 1980s. After two-digit growth rates of GDP in the seventies, not only the economy was hit by the second oil shock and the increase of interest rates in the US, but also it seems to have lost its capability to sustain high growth for more than a few periods.

Figure 4.1: GDP Growth Rate (%)



Note: data from IBGE.

After the second oil, interest rates in US rose, leading to a capital outflow. The deterioration of the balance of payments (which showed a large current account deficit) led to a recession and marked the beginning of a new period of economic growth, at lower rates (see Figure 4.1).

The 1980s Brazil's "lost decade" was a combination of high (leading to hyper) inflation, low development and lower growth. The Latin America debt crisis triggered by the 1982 Mexican default managed to make the situation even worse. Several attempts to stabilize the economy were made, but only in 1994, with "The Real Plan", Brazil overcome hyperinflation. However, stabilization alone was not enough to bring back the 1970s growth rates.

According to the business cycle dating committee (CODACE in the Portuguese acronym), Brazil has experienced nine recessions since the 1980s[4]. The duration of each recession has varied from 2 to 11 quarters. The longest recessions were experience within i) a problematic period combining the first direct elections after the dictatorship with unsuccessful stabilizing plans and a presidential impeachment (1989Q3-1992Q1) and ii) a combination of GDP deceleration and also a presidential impeachment (2014Q2-2016Q4). This latter recession was also the most severe (GDP felt from the peak to the through 8.6%), whereas the second stronger fall of real GDP (-7.7% from the peak to the through) occurred after the second oil shock (1981Q1-1983Q1). Table 4.1 presents CODACE dated recessions.

[4]CODACE (2017).

Table 4.1: Brazilian Recessions

Period	Duration (in quarters)	Accumulated growth*	Annualized average quarterly growth
1981Q1-1983Q1	9	-8.5%	-3.9%
1987Q1-1988Q4	6	-4.2%	-2.8%
1989Q3-1992Q1	11	-7.7%	-2.9%
1995Q2-1995Q3	2	-2.8%	-5.6%
1998Q1-1999Q1	5	-1.5%	-1.2%
2001Q2-2001Q4	3	-0.9%	-1.2%
2003Q1-2003Q2	2	-1.6%	-3.1%
2008Q4-2009Q1	2	-5.5%	-10.8%
2014Q2-2016Q4	11	-8.6%	-3.2%

Notes: *Peak to through; Source: CODACE; Author's elaboration.

In the same period (1980-2017), there were eight periods of expansions, each varying from 2 to 20 quarters. The 1983Q2-1987Q2 registered the higher accumulated growth, 30%, from through to peak. After a brief 2003Q1-2003Q2 recession (due to the tight monetary and fiscal policy to contain inflation increase and exchange rate depreciation after the 2002 election), Brazil grew for 21 consecutively quarters. The recession after the 2008 financial crisis was brief. However, the Brazilian depression after 2014 is the only episode of two years of consecutive fall in GDP, interrupting a twenty-quarters, 22.8 % accumulated growth period (see Table 4.2).

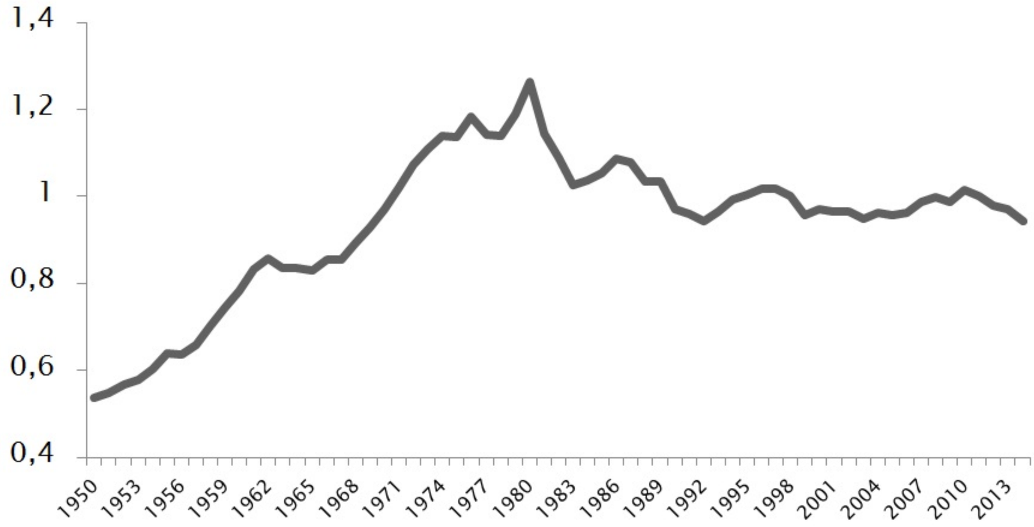
Table 4.2: Brazilian Expansions

Period	Duration (in quarters)	Accumulated growth*	Annualized average quarterly growth
1983Q2-1987Q2	17	30.0%	6.4%
1989Q1-1989Q2	2	8.5%	17.7%
1992Q2-1995Q1	12	19.2%	6.0%
1995Q4-1997Q4	9	8.0%	3.5%
1999Q2-2001Q1	8	7.3 %	3.7%
2002Q1-2002Q4	4	5.3%	5.3%
2003Q3-2008Q3	21	30.5%	5.2%
2009Q2-2014Q1	20	23.0%	4.2%

*Through to peak; Source: CODACE; Author's elaboration.

What is behind the 2014 Brazilian depression? The episode may have its roots in both long and short run choices. The data from Penn World Table 9.0 in Feenstra et al. (2015) may shed some light on the long term trajectory. Using growth accounting, the authors estimated how total factor productivity (TFP) evolved in Brazil from 1950 to 2014. In Figure 4.2 we can see two major periods of TFP growth: from 1950 to 1962 and from 1965 to 1980[5].

Figure 4.2: Total Factor Productivity (2011=1)



Source: Penn World Table 9.0; Author's elaboration.

TFP was the main driver of economic cycles from 1970 to 1974 and from 1980 to 1998, whereas capital accumulation was the key factor within 1974 and 1979. Controlling for the differences between private and public investment in the 1970s and relative price dynamics (between investment and consumption goods) from the 1980s, the neoclassical growth model is able to explain the Brazilian cycles (Bugarin et al., 2010). However, the volatility in consumption, hours and productivity is not explained by a Real Business Cycle model (Ellery Jr et al., 2002), opening room for extensions of the basic framework.

What about the short-run forces that explain the fall after 2014? Is it the consequence of global events or rather of domestic choices. With that in mind the next section addresses the source of the depression.

[5]The first period was interrupted due the political conditions at the time. After killing himself, the former President Getúlio Vargas left a weak economy to a distrusted-by-the-army vice-president to govern. It was a time of a Parliamentarian trial, followed by military coup and a dictatorship.

4.3 The source of the depression

The Brazilian depression emerged within a period where global GDP growth remained relatively constant. Advanced economy marginally increased its performance from 2014 to 2016, whereas Emerging Market Economies registered different records according to the region. Table 4.3 presents IMF data from its World Economic Outlook report released in April.

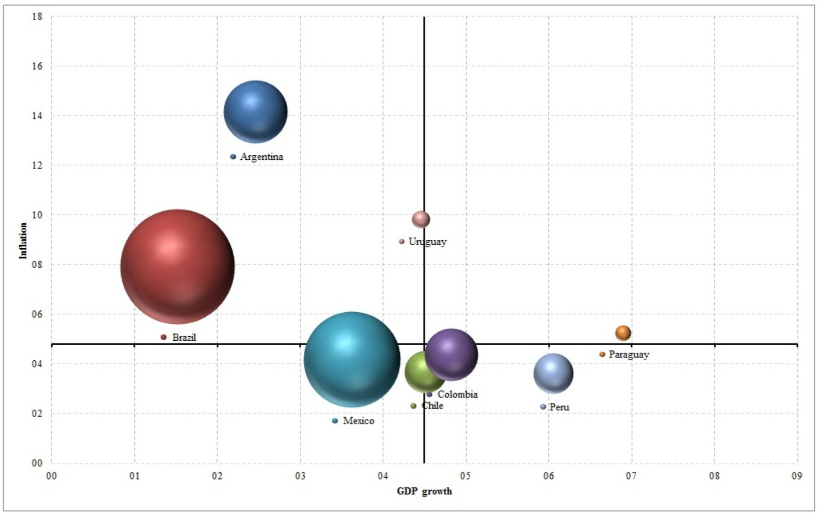
Table 4.3: World GDP Growth (%)

Country Group	**2014**	**2015**	**2016**
World	3.5	3.4	3.1
Advanced economies	2.0	2.1	1.7
Emerging and developing Asia	6.8	6.7	6.4
Emerging and developing Europe	3.9	4.7	3.0
Latin America and the Caribbean	1.2	0.1	-1.0
Argentina	-2.5	2.6	-2.3
Chile	2.0	2.3	1.6
Colombia	4.4	3.1	2.0
Venezuela	-3.9	-6.2	-18.0*
Brazil	0.5	-3.5	-3.5

Notes: Data from International Monetary Fund, World Economic Outlook Database, April 2017.

While Emerging Asia had a small decrease in growth rates, Latin America and the Caribbean countries felt from 1.2% to Latin America to minus 1%. This could raise doubts regarding whether the roots of the depression are domestic or International (regional, at least). Within Latin America, we have Chile and Colombia that, even though with decreasing growth rates, they still grew and had a better performance than its neighbors, Argentina and Venezuela. Figure 4.3 shows the growth-inflation average performance for selected Latin America countries, where sphere sizes are due to PPP adjusted per capita GDP.

Figure 4.3: Growth and inflation after the 2008 crisis



Notes: Data from International Monetary Fund, World Economic Outlook Database, April 2016; authors elaboration. Real GDP average growth from 2010 to 2016, average CPI inflation from 2010 to 2016. Spheres size is given by PPP adjusted per capita GDP.

If it was a global force what is holding Latin America back, one could expect all countries falling in the left side and, if the Phillips curve holds, in the same quadrant (or as close as it is possible). However, they have a very distinct track records, perhaps a consequence of domestic choices, calling for a more rigorous approach.

4.3.1 A synthetic Brazil

The synthetic control method may help answer the following question: is the depression a result of a domestic or an international dynamics? One might wonder whether there may be a combination of economic policies (domestic source) causing the depression. If this is the case, a “treatment-control group” approach could be used to investigate the issue. The difficulty is that we cannot use a proper “control” group, since there are no “two Brazils” to work with. One approach could be to select a group of countries and use them as the control group. But which countries? Are their weight in the group the same? Instead of choosing arbitrarily the “control” group, a data-driven procedure is applied following Abadie et al. (2010) and Abadie et al. (2015).

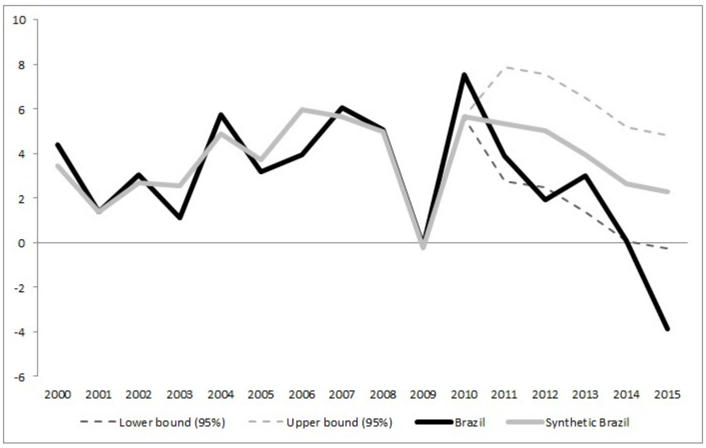
Let us work with $j = 1, ..., J+1$ units (countries), where $j = 1$ is the country we are studying (i.e., Brazil) and the other $j = 2$ to $j = J+1$ are the “candidates” for comparison. In a balanced panel, data for Latin America and Caribbean countries are gathered at t periods. Define T_0 as the pre-intervention period and T_1 as the post-intervention periods, with $T = T_0 + T_1$. The pre-intervention period is defined from 2000 to 2010, whereas the post-intervention period is from 2011 to 2015, since in 2011 there was an economic policy regime change with the new government.

A "synthetic Brazil" is built by averaging countries within the sample, with the vector $W = (w_2, ..., w_{J+1})'$, with $0 \leq w_j \leq 1$ representing the weight of each country[6]. Define Y_1 as the $(k \times 1)$ vector with the pre-intervention values for Brazilian characteristics (in this case: inflation, GDP growth from 2000 to 2010, government net borrowing and current account balance) and let Y_0 be the $(k \times j)$ matrix of pre-intervention values for the characteristics of the other countries in the sample. The contribution of each country (the vector W) is obtained by minimizing the difference between observed Brazilian annual GDP growth in the pre-intervention period (2000 to 2010) and the synthetic Brazilian annual GDP growth:

$$\min_{W} \sum_{m=1}^{k} v_m (Y_{1m} - Y_{0m})^2$$

where v_m is the relative importance of the $m - th$ variable, which is choosen as a cross-validation method following Abadie et al. (2015). Using IMF's data, the synthetic Brazil is composed by the weighted average of Belize (0.089), Ecuador (0.091), Guyana (0.178) Mexico (0.254), Peru (0.355) and Venezuela (0.033). Figure 4.4 Presents the pre/post 2011 behavior of observed GDP growth for actual and synthetic Brazil.

Figure 4.4: Brazilian GDP growth: actual and synthetic



Note: Data from IMF.

The black line represents the actual Brazilian GDP annual growth. The gray line is the synthetic Brazil (the "control group"). The upper and lower bounds

[6]See Table 5.2 for the list of the 32 countries and appendix C for data details.

(point estimations +/- 1.96 standard deviation) for the synthetic estimation are the dashed lines. Not only the "treated" series has followed the lower bound, but also it overpasses it.

The results corroborate with the hypothesis that a deceleration would happen, but not as strong and recessive as the observed figures. It seems a domestic issue after all. The next section aims to understand the drivers of the depression.

4.4 The transmission of the depression

The 2014-2016 Brazilian depression is one of the two longest episodes since 1981 and is the deepest with respect to GDP fall (closely followed by the 1981Q-1983Q recession). This sections addresses the issue of what has been driving output since 2011. The investigation of the dynamics of the depression imposes some challenges, since there are several possible mechanisms available to explain the episode. Therefore, the BCA method may help us to understand the depression.

This work complements BCA analysis of Chakraborty & Otsu (2013), Graminho (2006) and Lama (2011) by not only extending the sample period, but also using i) quartely data and ii) adjusting consumption and investment data by removing durables goods from the former and adding it to the latter. Next we present the neoclassical growth and the BCA results.

4.4.1 Accounting for business cycles in Brazil

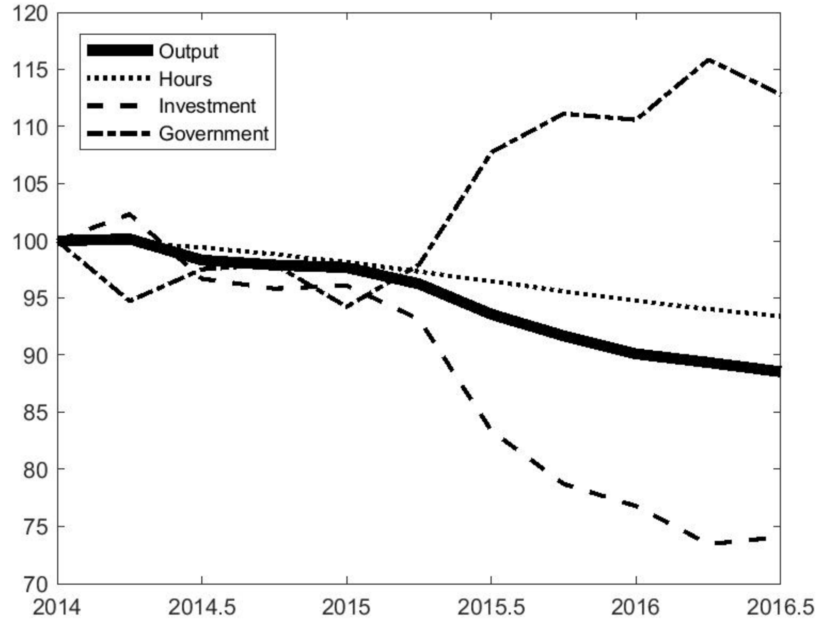
The BCA exercises used data from the first quarter of 1996 to the second quarter of 2016[7]. Figure 4.5 presents per worker output, investment, government consumption plus net exports and hours of work for the depression period. There seems to be two different moments: in the first (2014-2015), the behavior of macroeconomic variables are similar. Output falls as well as hours of work, investment and government consumption plus net exports. This seems to corroborate with the synthetic estimation in which for the aforesaid period there was a more generalized deceleration, i.e. domestic and international drivers for the GDP fall in Brazil and other Latin America countries (materialized in the prescribed GDP fall for the synthetic Brazil).

In the second moment (2015-2016), however, even though hours of work kept declining at the same rhythm, the output trajectory became steeper, investment more depressed and even the strong increase in government consumption plus net exports was not enough to sustain aggregate production[8].

[7]See Appendix C for more details.

[8]Net exports tend to be counter-cyclical and follow exchange rate depreciation, whereas in some

Figure 4.5: Macroeconomic variables (2014Q1=100)



Source: See appendix for BCA data; Author's elaboration

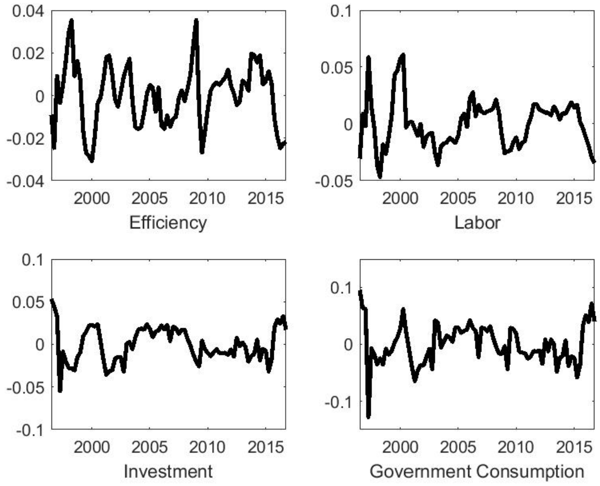
Using the prototype economy and the presented data, one could estimate the deviations from optimal behavior used in the Business Cycle Accounting. Figure 4.6 presents all wedges. It is interesting that while investment felt strongly during the depression, the investment wedge actually rose at the same time, along with the government consumption wedge. On the other hand, both the efficiency and the labor wedges felt during the episode.

After estimating the wedges, the trajectory of output is simulated. Figure 4.7 presents two sets of simulations. In the top graphs there are the "one wedge economies", in which economies are simulated by allowing one wedge to fluctuate, while the others remain constant. In the bottom graphs there are the "one wedge off economies", in which economies are simulated by holding one wedge constant and allowing the other to fluctuate.

As we can see the simulated output path with the efficiency wedge accounts for almost the whole production dynamics during the 2014-2016 depression. The model with only a labor wedge prescribes a delayed (and softer) recession and the model with only an investment wedge, even though accounts for the initial fall, presents a faster output recovery. Finally, output does not fall with the model with only the

cases fiscal policy may also be counter-cyclical. See Frankel et al. (2013) for a discussion of fiscal policy in emerging markets.

Figure 4.6: Estimated HP-filtered wedges for the Brazilian economy



Source: Author's elaboration

government consumption wedge.

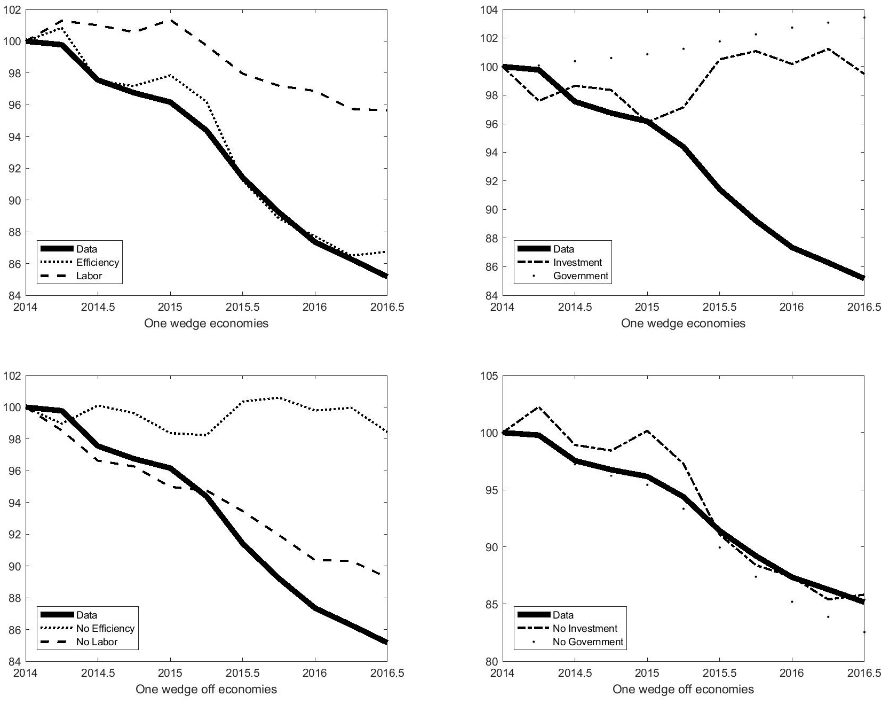
Regarding the "one wedge off" simulations, the performance after removing the efficiency wedge is the worst among the four cases. The other three follow the observed output fall, even though the accuracy changes among them. Both one wedge and one wedge off simulations seem to corroborate the hypothesis of a TFP depression. Formally, we can test it with some statistics. Table 4.4 presents four of them: success ratio, linear correlation, root mean-square error (RMSE) and a ϕ statistic following Brinca et al. (2016), defined 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. Therefore, the value is the contribution of each wedge for explaining output movements.

As we can see the efficiency wedge accounts for 72.1% of output movements and its role increases to 98% since 2014. Moreover, even if previous business cycles might have been driven by a secondary role of other wedges (each account for around 9% of output movements), the Brazilian depression is driven solely by the efficiency wedge.

Figure 4.7: Simulated economies during the depression



4.4.2 The Brazilian Quantitative Easing

From the synthetic control results, data seems to indicate that any attempt to model the Brazilian depressions should encompass mainly domestics features. The business cycle accounting results favor the efficiency wedge as the main driver of the depression.

One important feature of the last decade in Brazil is the growing participation of earmarked credit in total credit. Figure 4.8 presents the share of earmarked over total amount of credit.

Earmarked credit represented 36% of total credit in the end of the first quarter of 2007. In the second quarter of 2016 the share achieved 50%. A great part of this is issued by the BNDES (*Banco Nacional de Desenvolvimento Econômico e Social* in the Portuguese acronym)[9]. The public bank share in 2007 was 33.1% of total credit, whereas its participation rose to 41.5% at the beginning of 2015, diminishing marginally to 39.1% at the end of the sample.

Due to importance of BNDES credit in the Brazilian economy and the role of the efficiency wedge in the Brazilian depression, a question emerges: what is the relation between the efficiency wedge and BNDES outlays? A simple model will help to build the expectations regarding what data might tell us.

[9]BNDES credit outlays are mostly with earmarked resources.

Table 4.4: BCA decomposition statistics

Statistic	Efficiency	Labor	Investment	Government
One wedge economies - full sample				
Success Ratio	0.790	0.457	0.420	0.185
Correlation	0.858	0.539	-0.406	-0.753
RMSE	0.028	0.078	0.078	0.079
ϕ_i^y	0.721	0.094	0.094	0.092
One wedge off economies - full sample				
Success Ratio	0.407	0.864	0.765	0.963
Correlation	-0.230	0.661	0.836	0.992
RMSE	0.077	0.031	0.046	0.009
$1-\phi_i^y$	0.279	0.906	0.906	0.908
One wedge economies - 2014 depression				
Success Ratio	0.727	0.818	0.455	0.000
Correlation	0.989	0.949	-0.589	-0.977
RMSE	0.008	0.131	0.074	0.115
ϕ_i^y	0.980	0.004	0.012	0.005
One wedge off economies - 2014 depression				
Success Ratio	0.545	0.909	0.727	1.000
Correlation	-0.089	0.983	0.979	1.000
RMSE	0.104	0.037	0.052	0.010
$1-\phi_i^y$	0.020	0.996	0.988	0.995

Success ratio: relative frequency when simulated and observed data had the same sign; Linear correlations between simulated and observed data; RMSE: root of the mean-square error; ϕ statistic following Brinca et al. (2016).

A simple model

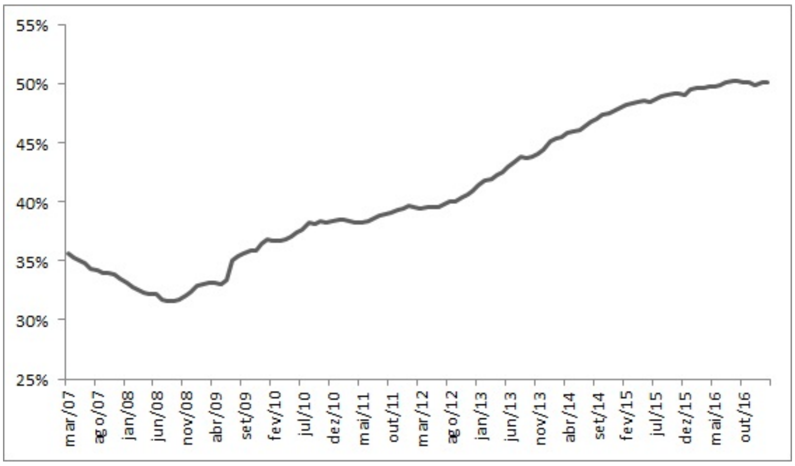
Let us work within a two-period, perfectly competitive framework. The economy has two sectors: a totally privately-funded, sector A, and a totally publicly-funded, sector B. In the first period, agents choose the optimal allocation of resources given their expectations for the efficiency shocks that will manifest themselves in the second period. Final goods output (Y_t) is obtained by combining production of each sector ($y_{i,t}, i \in \{A, B\}$) as follows:

$$Y_t = (y_{A,t})^{\mu}(y_{B,t})^{1-\mu}$$

Each sector combines capital per unit of effective labor ($k_{i,t}, i \in \{A, B\}$) according to the following production technologies

$$y_{A,t} = A_{A,t}k_{A,t}^{\alpha}$$

Figure 4.8: Earmarked credit share share



Source: Brazilian Central Bank; Author's elaboration

$$y_{B,t} = A_{B,t}k_{B,t}^{\theta\alpha}$$

where α stands for the capital per unit of effective labor share in the procution of each sector. For sector B, this share is multiplied by θ, allowing a different marginal productivity of capital. All markets are perfectly competitive. Firms in sector A maximize profits ($\Pi_{A,t}$) and finance capital accumulation with private funds:

$$\max_{k_{A,t}} \Pi_{A,t} = y_{A,t} - r_t k_{A,t}$$

Firms in sector A maximize profits ($\Pi_{A,t}$) and finance capital accumulation with public funds:

$$\max_{k_{B,t}} \Pi_{B,t} = y_{B,t} - r_t k_{B,t}$$

In perfectly competitive markets the marginal product of capital must be equal in both sectors. Using this result we may rewrite aggregate output as follows

$$Y_t = AK_{B,t}^{\alpha}$$

where

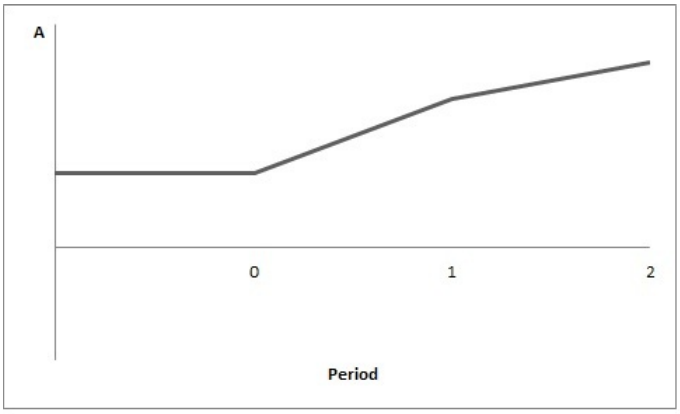
$$A = A_A^{\mu - \frac{\mu}{\alpha-1}} A_B^{\frac{\mu}{\alpha-1}+1-\mu} K_{B,t}$$

is the efficiency wedge. This provides the intuition for the relationship between the efficiency wedge and BNDES outlays. In the first period, just by accumulating more capital in sector B, aggregate total factor productivity (the efficiency wedge) would rise. But would the wedge also rise in the second period? It depends. After making all the decisions in the first period, at $t = 2$ there is a shock on the productivity of each sector. If the shock is positive, the efficiency wedge keeps rising, whereas if the shock is negative, the efficiency wedge decreases. Therefore we have two possible scenarios: good news and bad news.

Good News Scenario

One hypothesis is that the public bank targeted projects with high social returns. If this is the case, let us assume that after the increase in efficiency wedge in the first period, positive spillovers would manifest in the second period, increasing productivity in both sectors, augmenting the efficiency wedge even more. Figure 4.9 provides a representation of the dynamics of the efficiency wedge throughout time under the good news scenario.

Figure 4.9: Efficiency wedge with positive social returns



Author's elaboration

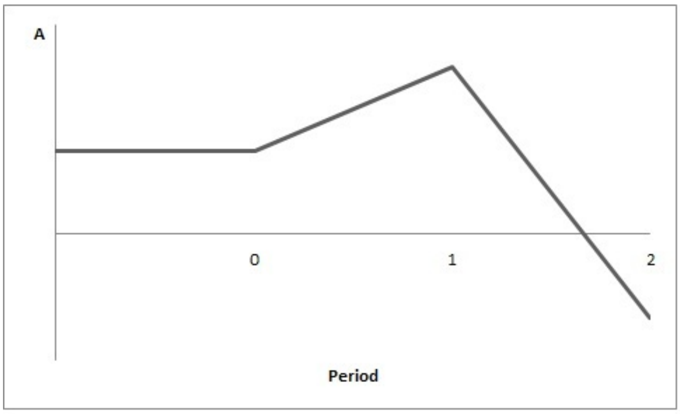
This would allow the economy to grow faster than dictated by factor accumulation.

Bad News Scenario

What if public sector investments were made poorly? For instance, the subsidized interest rate in public lending might induce an adverse selection problem through the selection of low-return projects – that would not occur in the first place if the interest rate was higher. If this was the case, in the second period, a negative shock on the productivity of sector B would produce negative spillovers on sector

A. Therefore, the efficiency wedge would fall at $t = 2$, as is represented in Figure 4.10.

Figure 4.10: Efficiency wedge with negative social returns



Source: Author's elaboration

What does the data tell us?

VAR analysis

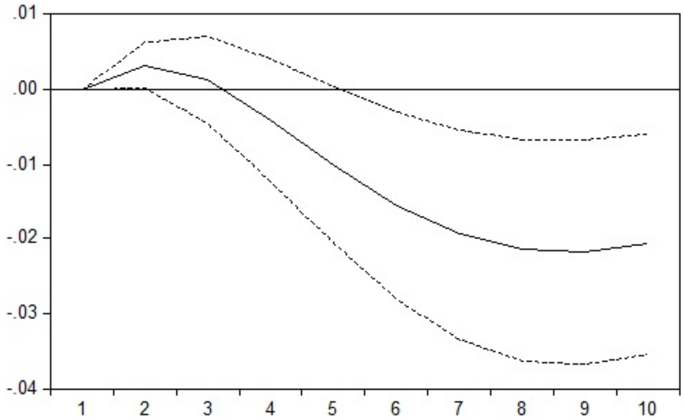
In order to answer the question of which scenario describes better what happened in Brazil, a unrestricted VAR was estimated with the efficiency wedge from the BCA (A_t^c) and the log of BNDES outlays (B_t^c; HP filtered and seasonally adjusted). Both original series were multiplied by a 1999-crisis dummy (δ_{1999}), which assumes a value equals to two between the first quarter of 1996 and the last quarter of 2001, and a value equals to one from the first quarter of 2002 to the second quarter of 2016.

$$\begin{bmatrix} A_t^c \cdot \delta_{1999} \\ B_t^c \cdot \delta_{1999} \end{bmatrix} = \beta_0 + \beta_1 \cdot \begin{bmatrix} A_{t-1}^c \cdot \delta_{1999} \\ B_{t-1}^c \cdot \delta_{1999} \end{bmatrix} + \beta_2 \cdot \begin{bmatrix} A_{t-2}^c \cdot \delta_{1999} \\ B_{t-2}^c \cdot \delta_{1999} \end{bmatrix} + \begin{bmatrix} \epsilon_t^A \\ \epsilon_t^B \end{bmatrix}$$

where β_0 is the vector of constants, β_1 and β_2 are matrices of coefficients and ϵ_t^A and ϵ_t^B stand for the errors. The Schwarz and Hannan-Quinn information criteria favor the model with two lags. Figure 4.11 presents the ten-period accumulated response of the efficiency wedge to a one standard deviation shock on BNDES outlays using the Cholesky decomposition (results are robust to changes in variables order) with 95% confidence intervals (doted lines).

As can be seem, the point estimation for the response of the efficiency wedge initially rises, but the accumulated effect is negative (and statistically significant) from the sixth quarter onwards. This corroborates with the idea of a "bad news case" as described before. By choosing projects with low efficiency, the long run

Figure 4.11: Response of the efficiency wedge to BNDES outlays



effects may be negative. During the sample period, this long run effects may have been offset by new outlays, whereas de depression may also be a combination of too much credit and a fall in this "Brazilian Quantitative Easing", in a sort of balance-sheet recession for both public and private agents.

The results are in line with the evidence that government-driven credit expansion in Brazil, since they have been destined to larger and older firms, may have served as counter-cyclical measure, but its continuity may have distorted resources allocation (Bonomo et al., 2015). Moreover, the subsidies seem to have no impact on market valuation and investment, only on the cost of funding, at least for publicly-traded companies (Lazzarini et al., 2015).

4.4.3 Detailed economy

The importance of the public bank in the credit market justifies a model that not only i) has a domestic trigger for the depression, ii) has an efficiency wedge as the main driver of economic fluctuations, but also encompasses the role of the BNDES in the Brazilian economy. With all that in mind, the model from Gertler & Karadi (2011) is adapted to analyze to depressions. The model was originally used to evaluate quantitative easing policies (QE). In some sense, the BNDES is responsible for a sort of Brazilian QE.

Households

A continuum of identical households save, consume and supply labor. A fraction f of the households members is composed by bankers. The probability of staying as a banker in the next period is given by θ. Households solve the following maximization problem:

$$\max_{C_t,L_t} E_t \sum_{t=0}^{\infty} \beta^t [\ln(C_t - hC_{t-1}) - \frac{\chi}{1+\varphi} L_t^{1+\varphi}], \tag{4.1}$$

subject to a budget constraint given by

$$C_t = W_t L_t + \Pi_t - T_t + R_t B_t - B_{t+1} \tag{4.2}$$

where C_t is consumption, L_t stands for labor, B_{t+1} and R_t are the short term debt and its gross real return; Π_t is the transfer from households to those entering in the banking business and T_t are lump-sum taxes. The first order conditions are:

$$(C_t - hC_{t-1})^{-1} - \beta h(C_{t+1} - hC_t)^{-1} = \lambda_t, \tag{4.3}$$

$$\lambda_t W_t = \chi L_t^{\varphi}, \tag{4.4}$$

$$\beta E_t R_{t+1} \frac{\lambda_{t+1}}{\lambda_t} = 1. \tag{4.5}$$

Financial intermediaries

The financial firm j obtains funds from households' savings in bonds and its stock of wealth, $N_{j,t}$. Given the relative price (Q_t) on financial claims, the total lend to non-financial companies $(S_{j,t})$ evolves according to the following balance sheet dynamics:

$$Q_t S_{j,t} = N_{j,t} + B_{j,t+1}. \tag{4.6}$$

The evolution of banker's capital is given by:

$$N_{j,t+1} = R_{k,t+1} Q_t S_{j,t} - R_{t+1} B_{j,t+1}. \tag{4.7}$$

Replacing the balance sheet dynamics into the previous equations yields:

$$N_{j,t+1} = Q_t S_{j,t}(R_{k,t+1} - R_{t+1}) + R_{t+1} N_{j,t}. \tag{4.8}$$

Let $\Lambda_{t,t+1} = \lambda_{t+1}/\lambda_t$ and define $\beta^t \Lambda_{t,t+1}$ as the stochastic discount factor for each banker. The risk-adjusted premium is thus $E_t \beta^t \Lambda_{t,t+1}(R_{k,t+1} - R_{t+1}) \geq 0, \forall t$. Financial intermediates maximize expected wealth $(V_{j,t})$ and to to avoid an indefinitely expansion of assets (moral hazard problem), funds will flow to the banker if

$$V_{j,t} \geq \Omega Q_t S_{j,t}, \tag{4.9}$$

where Ω is the fraction of funds the banker diverts instead of transferring them back to households. Therefore, the expected wealth is equal to:

$$V_{j,t} = v_t Q_t S_{j,t} + \eta_t N_{j,t}, \tag{4.10}$$

with

$$v_t = E_t[(1-\theta)\beta \Lambda_{t,t+1}(R_{k,t+1} - R_{t+1}) + \beta \Lambda_{t,t+1}\theta x_{t,t+1} v_{t+1}], \tag{4.11}$$

$$\eta_t = E_t[(1-\theta) + \beta \Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}], \tag{4.12}$$

$$x_{t,t+1} = \frac{Q_{t+1} S_{j,t+1}}{Q_t S_{j,t}}, \tag{4.13}$$

$$z_{t,t+1} = \frac{N_{j,t+1}}{N_{j,t}}, \tag{4.14}$$

where v_t is the expected discounted marginal gain of expanding assets and η_t is the expected discounted gain of marginal wealth given the amount of assets. The incentive constraint is thus

$$Q_t S_{j,t} = \frac{\eta_t}{\Omega - v_t} N_{j,t} = \phi_t N_{j,t}, \tag{4.15}$$

where ϕ_t is the leverage ratio. Assume it is the the same for each firm and we have:

$$Q_t S_t = \phi_t N_t. \tag{4.16}$$

Banker's net wealth evolves according the following dynamics:

$$N_{j,t+1} = (\phi_t(R_{k,t+1} - R_{t+1}) + R_{t+1}) N_{j,t}. \tag{4.17}$$

Total net wealth (N_t) is a combination of the net wealth of existing bankers ($N_{e,t}$)

$$N_{e,t} = \theta[(R_{k,t} - R_t)\phi_{t-1} + R_t] N_{t-1}, \tag{4.18}$$

and the net wealth of new bankers ($N_{n,t}$), financed with "start up" money from households. The resources are a fraction (ω) of end-of-period assets of existing bankers:

$$N_{n,t} = \omega Q_t S_{t-1}. \tag{4.19}$$

The law of motion of N_t may be rewritten as follows:

$$N_t = \theta[(R_{k,t} - R_t)\phi_{t-1} + R_t]N_{t-1} + \omega Q_t S_{t-1}. \tag{4.20}$$

Credit Policy

The government issues debt to households to fund its credit policy. The cost of debt is the riskless interest rate and it lends to non-financial firms at market lending rates. However, government intermediation occurs inefficiently, bearing costs (τ) per unit of government loan ($Q_t S_{g,t}$). Public debt ($B_{g,t}$) will fund a fraction (ψ_t) of fund, i.e.:

$$Q_t S_{g,t} = \psi_t Q_t S_t, \tag{4.21}$$

$$B_{g,t} = \psi_t Q_t S_t, \tag{4.22}$$

Therefore, total amount of credit is the sum of private loans ($S_{p,t}$) and public loans:

$$Q_t S_t = Q_t S_{p,t} + Q_t S_{g,t}, \tag{4.23}$$

where $\phi_{c,t} = 1/(1 - \psi_t)$.

Intermediate goods firms

Value of capital acquired should be equal to the value of the claims to acquire capital:

$$Q_t K_{t+1} = Q_t S_t. \tag{4.24}$$

Firms produce intermediate goods (Y_t) according to the following technology:

$$Y_t = A_t(K_t \xi_t U_t)^{\alpha} L_t^{1-\alpha}, \tag{4.25}$$

where A_t is, K_t is the stock of capital, U_t stands for the utilization of capital and ξ_t is the shock in the value of capital, which is assumed to follow an AR process. Producers maximize profits taking the price of intermediate goods as given and accounting for the costs of replacing capital ($\delta(U_t) = U_t^{1+\zeta}/(1+\zeta)$). The first order conditions are

$$\alpha \frac{P_{m,t} Y_t}{U_t} = U_t^{\zeta} K_t \xi_t, \tag{4.26}$$

$$(1-\alpha)\frac{P_{m,t} Y_t}{L_t} = W_t. \tag{4.27}$$

Zero profits condition imply

$$R_{k,t} = \frac{\alpha \frac{P_{m,t+1} Y_{t+1}}{K_{t+1}\xi_{t+1}} + Q_{t+1} - \delta(U_t)}{Q_t} \xi_{t+1}. \tag{4.28}$$

Capital producing firms

Capital producing firms also maximize profits by choosing net investment ($I_{n,t}$) subject to adjustment costs ($f(I_{n,t}, I_{n,t-1})$). Optimal choice is given by

$$Q_t = 1 + \eta_i(I_{n,t}, I_{n,t-1}) - E_t \beta \Lambda_{t,t+1} \eta_i(I_{n,t+1}, I_{n,t}). \tag{4.29}$$

Final goods producers

From a cost minimization problem each the demand for each input ($Y_{f,t}$) is given by

$$Y_{f,t} = (\frac{P_{f,t}}{P_t})^{-\epsilon} Y_t, \tag{4.30}$$

which depends of each input's price ($P_{f,t}$), relative to total price index (P_t), given the parameter for preferences, ϵ. Define the price index as follows:

$$P_t = [\int_0^1 P_{f,t}^{1-\epsilon} df]^{\frac{1}{1-\epsilon}}. \tag{4.31}$$

Final goods producers set prices in a la Calvo, maximizing expected profits and only a fraction resets prices. Under this set up, inflation (π) is given by

Therefore

$$\pi_t^* = \frac{\epsilon}{\epsilon - 1} \frac{F_t}{Z_t} \pi_t, \tag{4.32}$$

where $\pi_t^* = \frac{P*_t}{P_{t-1}}$ and

$$F_t = Y_t P_{m,t} + E_t \gamma \beta \Lambda_{t,t+1} (\frac{\pi_{t+1}}{\pi_t^{\gamma_p}})^{\epsilon} F_{t+1}, \tag{4.33}$$

$$Z_t = Y_t + E_t \gamma \beta \Lambda_{t,t+1} (\frac{\pi_{t+1}}{\pi_t^{\gamma_p}})^{\epsilon - 1} Z_{t+1}. \tag{4.34}$$

Government and Central Bank

Differently from Gertler & Karadi (2011), government spending (G_t) is not constant. It is assumed evolve according to the following dynamics:

$$G_t = G_{t-1} + \epsilon_t^G, \tag{4.35}$$

where ϵ_t^G represents a fiscal policy shock and it is assumed to follow an $AR(1)$ process. The economy's resource constraint thus becomes:

$$Y_t = C_t + I_t + \frac{\eta_i}{2}(\frac{I_{n,t} + I_{ss}}{I_{n,t-1} + I_{ss}} - 1)^2(I_{n,t} + I_{ss}) + G + \tau\psi_t Q_t K_{t+1}. \tag{4.36}$$

The government expenditure is financed via lump-sum taxes and government financial intermediation

$$G + \tau\psi_t Q_t K_{t+1} = T_t + (R_{k,t} - R_t)B_{g,t-1}. \tag{4.37}$$

Monetary policy decisions are emulated by a Taylor rule (in this paper, a modified version than the one used in Gertler & Karadi (2011))[10]:

$$i_t = (1-\rho)(r_t^N + \kappa_\pi E_t\pi_{t+1} + \kappa_y(\ln Y_t - \ln Y)) + \rho i_{t-1} + \epsilon i_t, \tag{4.38}$$

where $lnY_t - \ln Y$ is the output gap and r_t^N is the natural real interest rate that would prevail within a flexible prices context (equals to the marginal product of capital). The real interest rate is obtained by the Fisher equation:

$$1 + i_t = R_{t+1}E_t\frac{P_{t+1}}{P_t}. \tag{4.39}$$

Finally, the dynamics of the public development, BNDES. The idea is that the bank injects resources on the economy considering its sensitivity to credit spreads and an exogenous shock (ϵ_t^ψ), which can encompass other determinants of the loans that are not technical, such as political will.

$$\psi_t = \psi + \nu E_t[(\log R_{k,t+1} - \log R_{t+1}) - (\log R_k - \log R_t)] + \epsilon_t^\psi. \tag{4.40}$$

After describing the model, the next section presents the output dynamics prescribed by the model, as well as the observed data.

[10] Gertler & Karadi (2011) use minus the price markup as a proxy for the output gap; moreover, they assume a slightly differente functional form.

Calibration and simulation

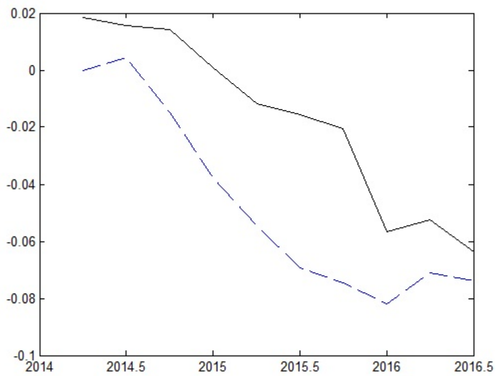
The model was calibrated following mainly Gertler & Karadi (2011), with a few exceptions for adjusting it to the Brazilian reality. For instance, the authors set the leverage ratio in the steady state equals to 4, whereas in this paper it set to 1.5, more suitable to a greater debt intolerance within emerging markets. Table 4.5 presents the other parameters:

Table 4.5: Parameters

Parameter		**Value**	**Source**
Households			
Discount factor	β	0.99	Gertler & Karadi (2011)
Habit parameter	h	0.815	Gertler & Karadi (2011)
Relative utility weight of labor	χ	3.409	Gertler & Karadi (2011)
Inverse Frisch elasticity of labor supply	φ	0.276	Gertler & Karadi (2011)
Financial Intermediaries			
Fraction of capital that can be diverted	Ω	0.381	Gertler & Karadi (2011)
Proportional transfer to the entering bankers	ω	0.002	Gertler & Karadi (2011)
Survival rate of the bankers	θ	0.972	Gertler & Karadi (2011)
Intermediate good firms			
Capital share	α	0.4	Ferreira et al. (2008)
Steady state depreciation rate	$\delta(U)$	0.05	Ferreira et al. (2008)
Elasticity of marginal depreciation with respect to utilization rate	ζ	7.200	Gertler & Karadi (2011)
AR coefficient of ξ	ρ_ξ	0.9	Gertler & Karadi (2011)
Capital Producing Firms			
Inverse elasticity of net investment to the price of capital	η_i	1.728	Gertler & Karadi (2011)
Final goods producers			
Elasticity of substitution	ϵ	4.167	Gertler & Karadi (2011)
Probability of keeping prices fixed	γ	0.779	Gertler & Karadi (2011)
Price indexation	γ_p	0.241	Gertler & Karadi (2011)
Public sector			
Inflation coefficient of the Taylor rule	κ_π	1.5	Gertler & Karadi (2011)
Output gap coefficient of the Taylor rule	κ_y	0.50/4	Gertler & Karadi (2011)
Smoothing parameter of the Taylor rule	ρ	0.8	Gertler & Karadi (2011)
Steady state proportion of government expenditures	$\frac{G}{Y}$	0.2	Gertler & Karadi (2011)

By assigning to the model the aforesaid parameters, one is able to see what would be the prescribed path of output during the Brazilian depression. Figure 4.12 presents the outcome of the log-linearized version of the model with HP-filter (Hodrick & Prescott, 1997) observed output data.

Figure 4.12: Output: data vs model



Notes: The outcome of a log-linearized model and the HP-filtered output data.

As can be seen, the model is able to account for the fall in output. Moreover, it also produces a brief marginal increase in 2016, followed by another marginal fall. This corroborates with the idea that the credit market is important to understand the transmission of the depression.

4.5 Final remarks

Brazil has been facing a real challenge in order to restore growth rates once experience until the mid-1970s. Even though it usually recovers from short-run falls relatively fast, the low productivity makes it difficult for the country to experience a better long-run performance.

The year of 2010 registered a high 7.5% growth rate, but since then the country seems to have lost its ability to grow. What is the reason? The econometric evidence in Section 4.3 points towards a domestic issue. If this is the case, what decisions have been made and are driving output during the 2014 depression? The BCA in Section 4.4 helps us to answer this question and reveals a great (almost exclusive) role for the efficiency wedge. The next step is to find a model that accounts for the dynamics of output with this sort of distortion.

Data from the Brazilian Central Bank shows that earmarked credit share on total credit rose systematically since 2007. Moreover, the Brazilian National Development Bank (BNDES) is the main player. The economy seems to have gotten used to rely on subsidized credit to grow. Furthermore, the econometric evidence of this paper indicates that the medium/long run consequences of BNDES's outlays are negative. To overlap possible negative effects, more loans were made, but the situation was unsustainable and eventually the net outlays were negative.

A DSGE model encompassing the role of the public bank was able to account for output dynamics and the dependence of the economy on BNDES, as well as the indebteness of other agents and the importance of the credit market in the Brazilian Depression.

Chapter 5

Final remarks

The opening question of this doctoral thesis is: what drives recessions and expansions? Even within the scope of a PhD program, in that general formulation, answering that question is a lifetime research agenda (with probably no exhaustive answers). Nevertheless, the work presented in the previous chapters moved knowledge regarding business cycles analysis a few steps forward. This section summarizes the main finds of this thesis and presents reflections on future research.

5.1 Summary of results

Modeling business cycles is a hard task, but the advent of Business Cycle Accounting brought an important tool for dealing with model selection. As can be seen in Chapter 2, the use of the method has grown throughout time. In the chapter, the comprehensive survey on BCA literature (and its extensions) revealed that, usually, hours of work are closely related to the labor wedge, as well as output to the efficiency wedge and the investment wedges to both aggregate investment and country risk spreads in an open-economy framework. The government consumption wedge very often does not play an important part in explaining macroeconomic variables, even though for a few papers, it has a secondary/tertiary role.

Besides the macroeconomic variables/wedges relations, the chapter also presents important broad conclusions. Whenever modeling contagion episodes or dealing with economic policy in emerging markets, the relative importance of the efficiency wedge decreases (even though is frequently the main driver of short run output fluctuation) and therefore the other wedges become more important. Major events such as the Great Depression and the 2008 financial crisis also present that feature.

Chapter 2 also provides three BCA exercises for US data. Focusing on the 1973, 1990 and 2001 recessions, this thesis fulfill a “gap” on BCA literature that does not account for analyzing the drivers of these specific episodes. In the first two recessions (1973 and 1990), despite the protagonism of the efficiency wedge, the labor wedge plays a secondary role. Both wedges explain 85-90% of output movements. On the latter recession, however, the secondary role is played by the government consumption wedge, an uncommon finding.

Another important result presented in Chapter 2 is related to the drivers of recessions and expansions in general. Do they change? That means, does the relative importance of each wedge change depending on the phase of the business cycle? The answer is yes. Expansions are usually driven by the efficiency wedge, but with a secondary role of the labor wedge, whereas recessions are mainly driven by the efficiency wedge (84% of output movements are explained by the efficiency wedge alone in recessions, while the same 84% are obtained with both the efficiency and the labor wedge in expansions).

The other dimension of BCA is the equivalence theorems, i.e., mappings between detailed DSGEs and the prototype economy with wedges. Chapter 3 presents a contribution in that dimension. By dealing with the fact that integration of goods market may change not only how output is produced, but also how international crises are transmitted, it proposes equivalences between the neoclassical growth model (for both the closed and open-economy formulations) and a small open-economy model augmented with intermediate imported goods in the production function.

Using the different recoveries Mexico experienced during "Tequila crisis" and the Great Recession, BCA was applied and the main driver of both episodes is the efficiency wedge. From the aforesaid equivalence results, the small open-economy model was able to explain both the rapid recovery from the 1995 episode as well as the slow recovery after the 2008 financial crisis.

Chapter 4 analyses the 2014-2016 economic depression in Brazil. Its contributions rely on the source of the depressions and the transmission of it. In the former, since the deceleration/contraction in Brazilian GDP was stronger than its peers and the expected path of its synthetic version, econometric estimations point towards a domestic-born episode, rejecting the hypothesis that the episode was a fault of the international environment.

Business Cycle Accounting was used and the driver of the Brazilian depression is the efficiency wedge. Due to the recent "quantitative easing" via the federal public development bank (BNDES in the Portuguese acronym), i.e., a strong expansion of loans via BNDES, the hypothesis that the relationship between efficiency wedge and BNDES's outlays was investigated. Econometric results find that after an increase in BNDES's outlays there is a small positive increase in the efficiency wedge in the first quarters, followed by a larger fall afterwards, offsetting the initial movements.

The hypothesis that the economic depression could be explained by a model that incorporates the credit market was tested by confronting the output prescribed by a DSGE model with financial frictions (adapted to Brazil) with observed data. According to econometric and modeling exercises, the depression is a result of both negative lagged effects of public credit expansion, short-run credit cuts and the dynamics of the rest of the credit market.

The results presented in this section are the pillars for guidelines on future research discussed in the next section.

5.2 Reflections for future research

From Chapter 2 we saw that recessions and expansions have different drivers. Would this result change according to economic policy? For instance, in the spirit of Brinca (2014), a "cross-section BCA" could explain whether the drivers of short run movements change if there is a specific orientation for economic policy such as the so-called macroeconomic populism (Dornbusch & Edwards, 1990). Using a sample of countries that experienced that sort of orientation, one could compare "populist years" with the period without populism regarding the dynamics, the distribution and the relative importance of wedges.

From Chapter 3 we learned that an international crisis may manifest itself via other wedges rather than as a balance-of-payments/government consumption driven issue. There may be other cases. For instance, Brinca et al. (2016) find that for Spain, Ireland, and Iceland, the main driver was the investment wedge. Was this result another case of balance-of-payments-variables influencing other distortions? For instance, the search may follow the link between international portfolios and business cycles in those countries.

From Chapter 4 we analyzed the real side of the economic depression in Brazil. What about the dynamics of inflation? Two paths may emerge. On one hand, in order to understand the drivers of inflation, a monetary business cycle accounting decomposition could be done. On the other hand, instead of departing from traditional business cycle accounting, one could rely on different mappings (see Chapter 2 for list of mappings) to focus exclusively on the drivers of inflation.

Appendices

Appendix A – Chapter 2

Data for the business cycle accounting exercises in Chapter 2 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; US Dollar [GDP]
- Gross domestic product, deflator, market prices; index (2009) [PGDP]
- Gross fixed capital formation, total, value. US Dollar [ITISK]
- Gross capital formation, deflator; index (2009) [PITISK]
- Private final consumption expenditure, value, GDP expenditure approach; US Dollar [CP]
- Private final consumption expenditure, deflator; index (2009) [PCP]
- Government final consumption expenditure, value, GDP expenditure approach; US Dollar [CG]
- Government final consumption expenditure, deflator; index (2009) [PGP]
- Imports of goods and services, value, National Accounts basis; US Dollar [MGSD]
- Imports of goods and services,deflator, National Accounts basis; index (2009) [PMGSD]
- Exports of goods and services, value, National Accounts basis; US 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]

Appendix B – Chapter 3

Parameterization

Table 5.1: Parameters for the model with SGU preference

Parameter	Value	Source
γ	2	Schmitt-Grohé & Uribe (2003)
δ	0.1	Schmitt-Grohé & Uribe (2003)
ϕ	0.028	Schmitt-Grohé & Uribe (2003)
ω	1.455	Schmitt-Grohé & Uribe (2003)
ψ	0.000742	Schmitt-Grohé & Uribe (2003)
d	0.7442	Schmitt-Grohé & Uribe (2003)
β	0.98	Kim (2014)
μ	0.98	Imports/GDP in Mexico as in Kim (2014)
ρ_e	0.73	Corsetti et al. (2008)

Investment wedge arising from different preferences

Considerer the prototype economy. A model with different preferences regarding consumption and leisure than those in BCA exercises match equilibrium allocations in the prototype economy with an investment wedge.

It is useful to rewrite equation 3.3 with BCA preferences:

$$\frac{1}{c_t(s^t)}(1+\tau_{x,t}(s^t)) = \beta E_t[\frac{1}{c_{t+1}(s^{t+1})}(A_{t+1}(s^{t+1})F_{k,t} + (1-\delta)(1+\tau_{x,t+1}(s^{t+1}) + \phi_{k_{t+1}}].$$

Define $(1+\tau_{x,t}(s^t)) = \frac{c_t}{(c_t(s^t)-\omega^1 l_t^{\omega}(s^t))^{-\gamma}}$. Replacing this in the previous equations yields

$$(c_t(s^t) - \omega^{-1}l_t^{\omega}(s^t))^{-\gamma} = \beta E_t[(c_{t+1}(s^{t+1}) - \omega^{-1}l_{t+1}^{\omega}(s^t))^{-\gamma}(A_{t+1}(s^{t+1})F_{k,t} + (1-\delta) + \phi_{k_{t+1}}],$$

which is the same as equation 3.3 rewritten with SGU preferences.

Appendix C – Chapter 4

Data description

- GDP: Gross domestic product in current values for the first quarter of 1996. For the second quarter onwards real growth was applied. Source: IBGE.
- Consumption: Household consumption in current values for the first quarter of 1996. For the second quarter onwards real growth was applied. Source: IBGE
- Durables goods consumption: Household consumption multiplied by durables goods consumption share. Author's calculation.
- Durables goods consumption share: using Brazilian input-output matrices from IBGE for years 2000 and 2005, the share was calculate following Ellery Jr et al. (2002); from 2006 to 2015, only a random shock was considered (using excel, a pseudo random number from a Normal distribution with mean equals to zero and variance equals to the series variance - seed: 13).
- Investment: Investment in current values for the first quarter of 1996. For the second quarter onwards real growth was applied. Source: IBGE.
- Exports: Exports in current values for the first quarter of 1996. For the second quarter onwards real growth was applied. Source: IBGE.
- Imports: Exports in current values for the first quarter of 1996. For the second quarter onwards real growth was applied. Source: IBGE.
- National accounts growth: Quarterly real growth. Source: OECD Statistics.
- Hours of Work: Average Annual Hours Worked by Persons Engaged for Brazil. For 2015 the same value of 2014 was used. Source: Penn World Table.
- Population: Working age population (15-64). For 2013, 2014 and 2015, the values were estimated using the average growth between 2012 and 1992. Source: OECD Statistics.
- Total earmarked credit: Data from the Brazilian Central Bank.
- Total non-earmarked credit: Data from the Brazilian Central Bank.
- BNDES outlays: Data from the Brazilian Central Bank.

Synthetic control

Table 5.2: Full sample

Antigua and Barbuda	Argentina	The Bahamas	Barbados
Belize	Bolivia	Brazil	Chile
Colombia	Costa Rica	Dominica	Dominican Republic
Ecuador	El Salvador	Grenada	Guatemala
Guyana	Haiti	Honduras	Jamaica
Mexico	Nicaragua	Panama	Paraguay
Peru	St. Kitts and Nevis	St. Lucia	St. Vincent and the Grenadines
Suriname	Trinidad and Tobago	Uruguay	Venezuela

Table 5.3: Country weights

Country	**Weight**
Belize	0.089
Ecuador	0.091
Guyana	0.178
Mexico	0.254
Peru	0.355
Venezuela	0.033

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