Output falls and the international transmission of crises

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Abstract

Economic crises are usually transmitted across countries via either price or quantity shocks on the balance of payments. This paper complements the literature on international trade and business cycles by analyzing the role of imported intermediates goods inputs during the Great Financial Crisis in small open economies. We find that in an increasingly integrated world, intra-industry international trade is an important channel of propagation of shocks. A depreciation of the real exchange rate rises to costs of intermediate output, which decreases production. Our quantitative model is able to reproduce both the intensity and the velocity of the crisis in Mexico.

Keywords: Great Recession, Intermediate goods, Business Cycle Accounting

JEL Classification: E27, E30, E32, E37

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1 Introduction

In the past 800 years, we have been dealing with several financial crises (Reinhart & Rogoff, 2009; Kindleberger & O'Keefe, 2001). The problem has grown and the frequency of financial crises has increased since the end of Bretton Woods, specially since the 1990s (Bordo et al., 2001; Eichengreen, 2002). 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 et al., 2010).

How was the crisis transmitted? Integration in goods and services markets may be a key component (as well as the financial integration). There is empirical evidence that bilateral trade implies a synchronization of business cycles (Frankel & Rose, 1998; Imbs, 2004), which could explain how countries were hit after the crisis manifest itself in the US, though economic policy may decrease this effect (Inklaar et al., 2008) and developing economies experience a lower synchronization (Calderon et al., 2007).

This paper complements the literature on international trade and business cycles by analyzing the role of imported intermediate goods inputs in the 2008 crisis. We depart from the usual international real business cycle and the study of co-movement between economies and follow Aguiar & Gopinath (2007) using Mexico as our benchmark case for an small open economy (SOE). We aim to understand the trade channel through which the Great Financial Crisis was transmitted to SOEs. In Chari et al. (2005), sudden stops are followed not only by output drops, but also by an increase in current account balance after exchange rate depreciation. This embeds a Marshall-Lerner condition for net exports rising after an exchange rate depreciation. Within the business cycles accounting (henceforth BCA) framework (Chari et al., 2007; Brinca et al., 2016), it is natural to think that this movement would be captured by an increasing protagonism of the government consumption wedge, which encompasses net exports. We claim that there is more to that story.

We approach Mexican data and use the so-called "Tequila crisis" in 1995 as a robustness check for our model. As we can see in Figure 1, the dynamics of both crises differed. The recovery in Mexico after the 2008 crisis was weak, with GDP and industrial production achieving pre-crisis levels only in 2011 (Ibarraet al. , 2015), whereas the recovery from the 1995 crisis was faster.

Even though both episodes differ in severity and duration, the primary role in the BCA decomposition as the most relevant distortion for explaining per worker output movements in Mexico during both crises is for the efficiency wedge (i.e., distortion in the production decisions). 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 intratemporal labor-leisure decision). For both episodes, the government consumption wedge (the distortion on the resource constraint) plays a small role.

What lies behind the relative importance of each wedge? After finding that the efficiency wedge is the main driver of GDP, we show that there is an equivalence between the prototype economy with wedges and a small open-economy model augmented with imports in the production function. This reveals an international channel "hidden" in the efficiency wedge. We simulate the model and compare with observed path of output and the model is able to replicate observed movements in output for both crises (1995 and 2008).

This paper is organized as follows. Besides this introduction, the next section presents a literature review of BCA. Section 3 presents the business cycle accounting exercise, the equivalences between the neoclassical growth model with wedges, both in the closed-economy version (proposition 1) and open-economy version (proposition 2), and the equivalences to the detailed economy. We also simulate output path given the real exchange rate movements and compare with observed data. We discuss the need of secondary role of the other wedges, namely labor and investment wedges, introducing them via a different utility function. The last section is dedicated to final remarks and conclusions.

2 Accounting for business cycles with wedges

Business cycle Accounting is a tool for understanding macroeconomic fluctuations. Following Brinca et al. (2016), this methodology has two components: an accounting procedure and equivalence results. Departing from the neoclassical growth model, distortions in the agents' optimal decisions are introduced and estimated as in Chari et al. (2007) (the accounting procedure). After identifying the distortions that explain short run movements in data, one could rely on mappings from the prototype economy to a class of detailed models (the equivalence results) and narrow the search for DSGE models that fit stylized facts.

The literature of BCA is extensive. Beside the application for the US data in Chari et al. (2007) and Ohanian (2010), other developed countries were approached such as France (Bridji, 2013), Japan (Kobayashi & Inaba, 2006; Saijo, 2008; Chakraborty, 2009), the UK (Kersting, 2008; Chadha & Warren, 2012), Italy (Orsi & Turino, 2014), Portugal (Cavalcanti, 2007) and Spain (López & García, 2014). Brinca (2014) and Brinca et al. (2016) apply BCA to OECD countries and Gerth & Otsu (2017) to European countries during the Great Recession. Usually, the efficiency wedge is the main driver.

Advances in BCA theory were made to encompass other frameworks. For instance, in order to analyze monetary issues, BCA could be extended to include inflation and interest rates as in Šustek (2011). For international drivers, an open-economy prototype model is used in Otsu (2010b), Lama (2011) and Hevia (2014), whereas the relationship between economies is addressed in Otsu (2010a). The list of applications of BCA (and its extensions) is extensive.

For Emerging Market Economies, the literature has found some different results than for those in developed economies[1]. For instance, Lama (2011) uses an open-economy Business Cycle Accounting framework for studying fluctuations in some Latin American countries during the 1990s and early 2000s. He finds the relevant wedges that explain business cycles are the efficiency wedge and the labor wedge. The bond wedge helps to explain changes in the trade balance, but it does not help to account for others variables movements. See Brinca et al. (2020) for a comprehensive literature review.

Hevia (2014) uses Canada to represent the developed world and Mexico for emerging markets in a open-economy version of the neoclassical growth model. He concludes that for advanced economies the efficiency and labor wedges play an important role, although bond and investment wedges help to explain movements in other aggregate variables. For the emerging markets, besides the efficiency and labor wedges amidst the main drivers, bond wedges become also important. He focuses on the 1995 Mexico Crisis episode.

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

[1]For more applications of BCA - and its extensions - to emerging market economies see Graminho (2006) and Brinca & Costa-Filho (2018) (Brazil), Cavalcanti et al. (2008) (Argentina), Chakraborty & Otsu (2013) (BRICs), Simonovska & Söderling (2008) (Chile), Hnatkovska & Koehler-Geib (2015) (Paraguay), Sarabia (2007) (Koerea), Gao & Ljungwall (2009) (India and China), He et al. (2009) (China), Cho & Doblas-Madrid (2013) (Asian crises)

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.

In order to estimate the wedges, data is confronted to the prescription from the prototype neoclassical growth model as follows. In the next section we describe the prototype economy for the BCA exercises.

2.1 The Prototype Economy

Let us work with discrete time t, in which the probability of a given state of nature (s_t) is given by $\pi_t(s^t)$, where $s^t = (s_0, ..., s_t)$ represents the history of events up to and including period t. We take initial state (s_0) as 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), we introduce adjustment costs ($\phi(\frac{x_t(s^t)}{k_t(s^{t-1})})$) into 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, g_t is the government consumption wedge, β is the discount rate, $U(.)$ represents for the utility function, N_t is the population (which has a growth rate of γ_N), x_t stands for 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 $b = \delta + \gamma + \gamma_n$. In perfectly competitive markets firms combine capital and labor in order to maximize profits Π_t, given the production technology $F(k_t(s^{t-1}), (1+\gamma)^t l_t(s^t))$, in which $A_t(s^t)$ is the efficiency wedge:

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

Combining first order conditions for the household's and firm's maximization problems, the production function and the resource constraint, we have the four equilibrium conditions of the model:

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

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

$$\begin{aligned} &U_{c,t}(s^t)(1+\tau_{x,t}(s^t)) = \\ &\beta \sum_{s^{t+1}} \pi_t(s^{t+1}|s^t)[U_{c,t+1}(s^{t+1}) \end{aligned} \tag{3}$$

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

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

3 International crises and business cycles: accounting and modeling

From the prototype economy 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[2].

The Mexican case is also addressed by Sarabia (2008) and Meza (2008). In both papers the efficiency wedge is the most important distortion, 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 1 presents data for two periods: the 1995 crisis and the Great Recession

[2]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

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.

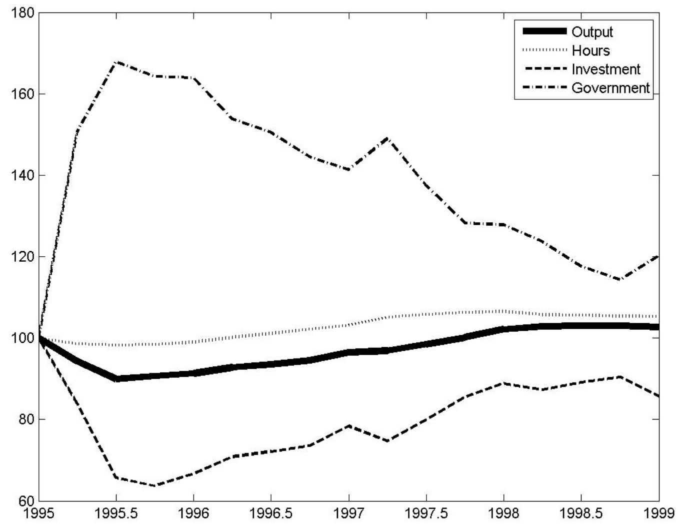
It is not only the dynamics of output that differed from one episode to another. In the 1995 episode, investment contracted more than 36% in the third quarter of 1995, while in the Great Recession the bottom was achieved with a 19.3% fall.

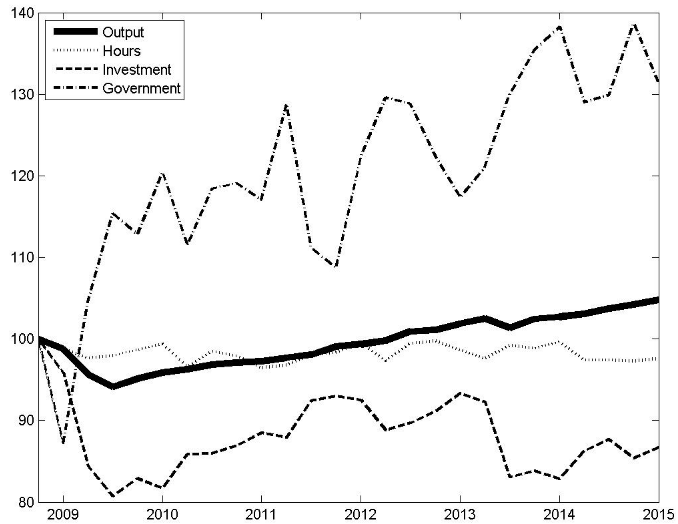
The dynamics of government consumption plus net exports also differed between episodes. In the “Tequila crisis", it rose after the shock, accumulating an almost 68% increase in the third quarter of 1995. During the Great Recession, however, the behavior was different. The initial response was a fall, 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 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

Figure 1: Macroeconomic variables in the 1995 and 2008 crises



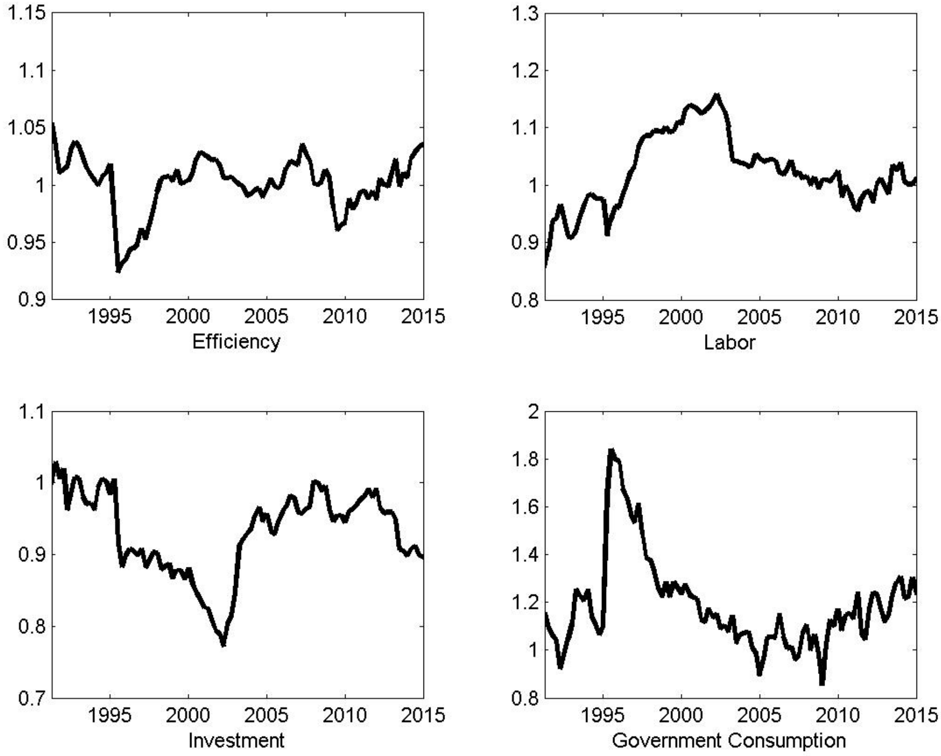


Notes: For the 1995 crisis (top graph), 1991Q1=100. For the 2008 crisis (bottom graph), 2008Q2=100.

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.

After measuring/estimating the distortions, it is possible to simulate vari-

Figure 2: Estimated HP-filtered wedges for the Mexican economy



ables paths to see which wedge helps to explain data movements. Following Chari et al. (2007), 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 and 4. Table 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):

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

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.

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) and a faster recovery in the Great Recession compared to actual data, calling for a (secondary) role of other wedges (see Figure 4).

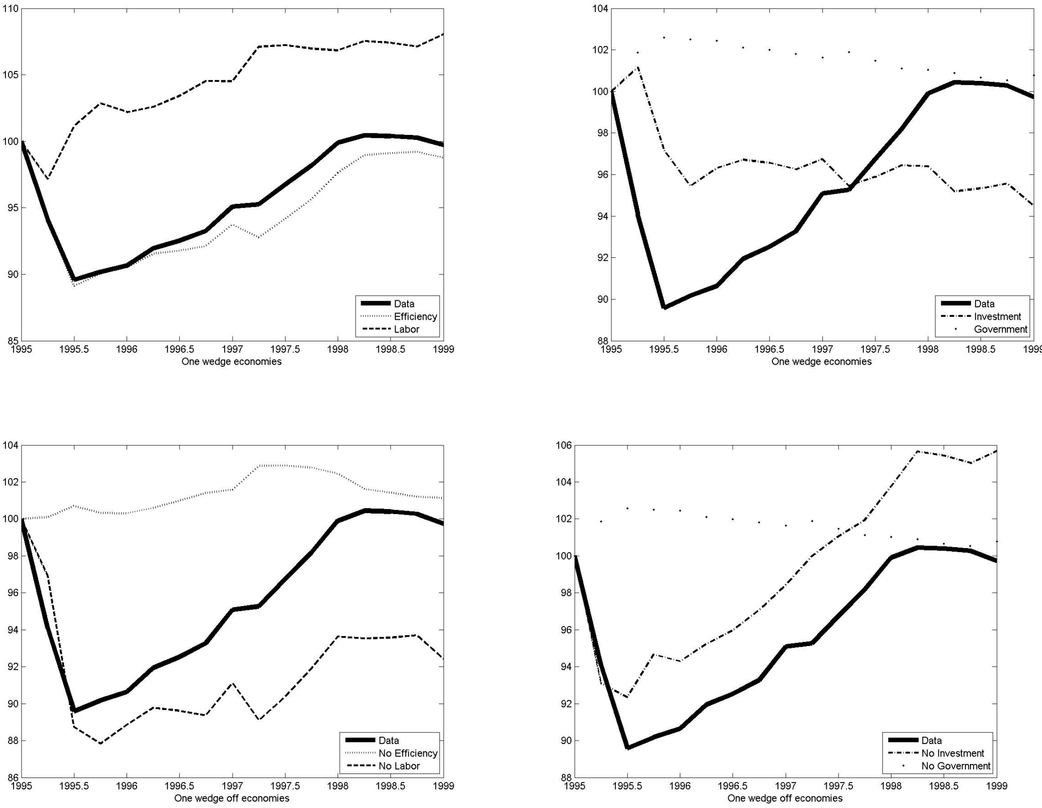
Table 1: BCA decomposition statistics

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).

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 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.

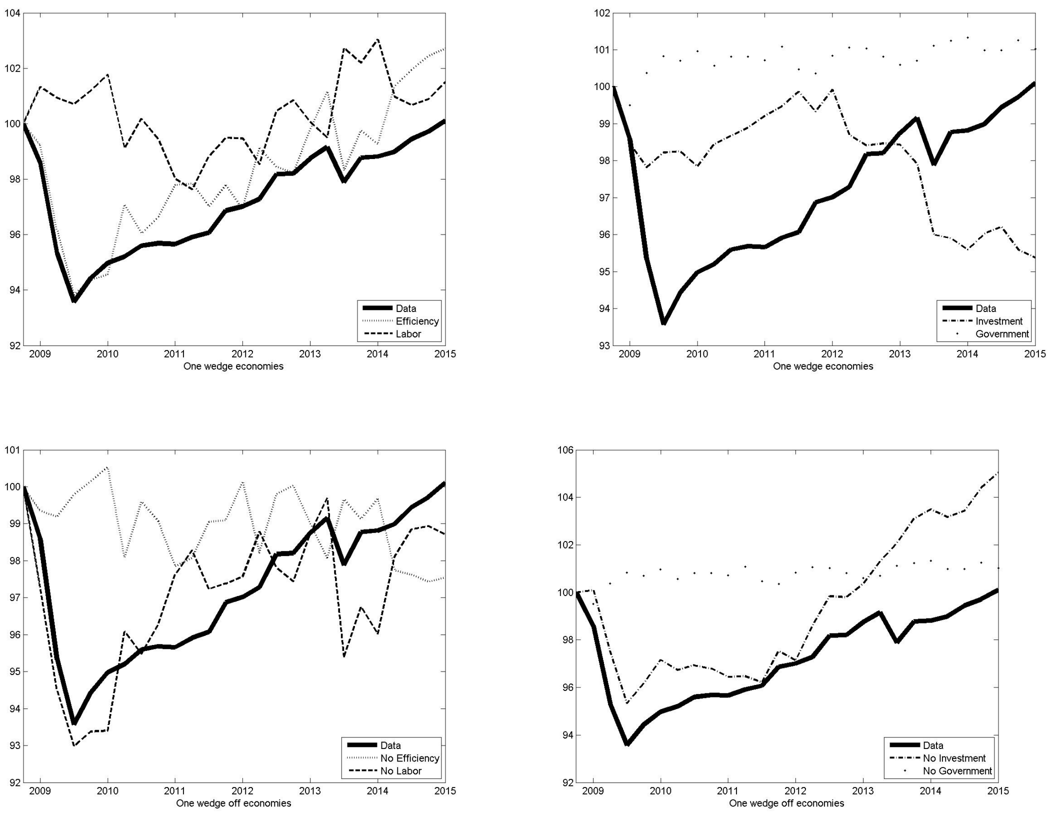
Figure 3: Simulated economies during the 1995 crisis



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 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.

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

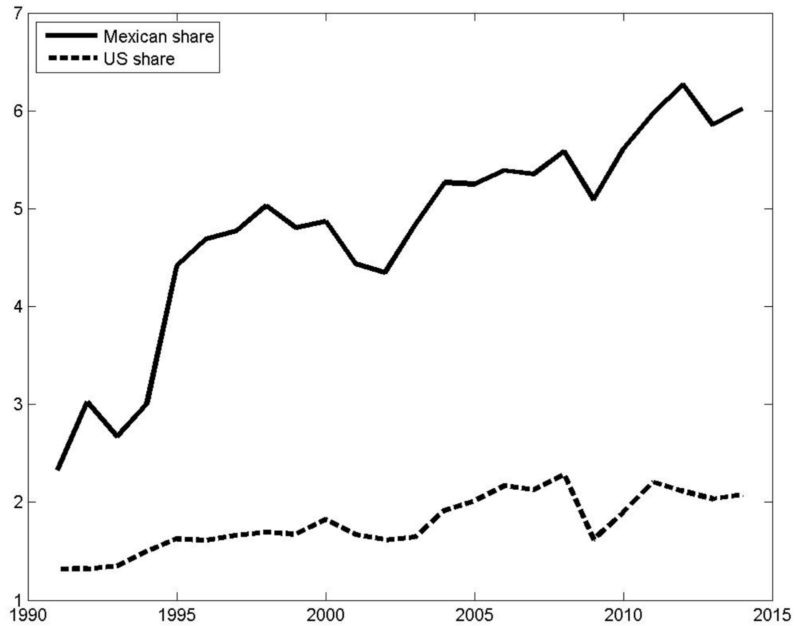
Figure 4: Simulated economies during the 2008 crisis



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 5 the share for Mexico. For a matter of comparison, the same proportion for the US is shown.

Figure 5: Intermediate goods imports - share of GDP



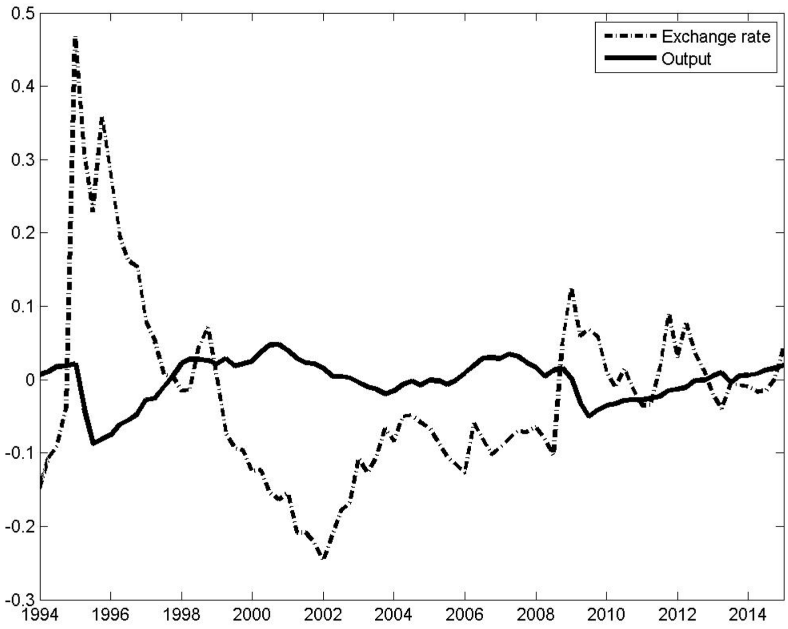
Total imports of intermediate goods not only rose since the 1990s (as one could expect since output trend growth is positive since then), but it has increased faster than GDP. The share of GDP destined to foreign intermediate goods is almost twice the level it was in 1995. Moreover, the Mexican economy 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 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[3]. 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-

[3]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.

Figure 6: HP-filtered per capita output vs Real exchange rate changes



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

goods in the production function to understand the crisis in Mexico[4].

3.1 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

[4]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.

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[5]:

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

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:

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

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

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:

$$\lambda_t = \beta E_t \lambda_{t+1}(1+r_t), \tag{5}$$

$$\lambda_t = U_{c_t}, \tag{6}$$

$$-\frac{U_{l_t}}{U_{c_t}} = (1-\alpha)(1-\mu)\frac{y_t}{l_t}, \tag{7}$$

$$\lambda_t(1+\phi(k_{t+1}-k_t)) = \beta E_t \lambda_{t+1}(\phi(k_{t+2}-k_{t+1}) + 1 - \delta + (1-\mu)\alpha\frac{y_{t+1}}{k_{t+1}}), \tag{8}$$

$$\frac{\partial \mathcal{L}}{\partial m_t} = 0 \Leftrightarrow \frac{\mu y_t}{m_t} = e_t, \tag{9}$$

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:

$$
\begin{aligned}
& y_t - c_t - x_t - g(k_{t+1}) - e_t m_t = (1 + r_{t-1})d_{t-1} - d_t, \\
& y_t - c_t - x_t - g(k_{t+1}) - e_t m_t = tb_t, \\
& 1 - \frac{c_t}{y_t} - \frac{x_t}{y_t} - \frac{g(k_{t+1})}{y_t} - e_t \frac{m_t}{y_t} = tby_t.
\end{aligned} \tag{10}
$$

3.2 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).

3.2.1 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:

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

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 (7), thus $(1 - \tau_{l,t}) = 0$. From equation (6) we have the marginal utility of consumption. The right hand side of equation (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 (8) to the left hand side of equation (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.

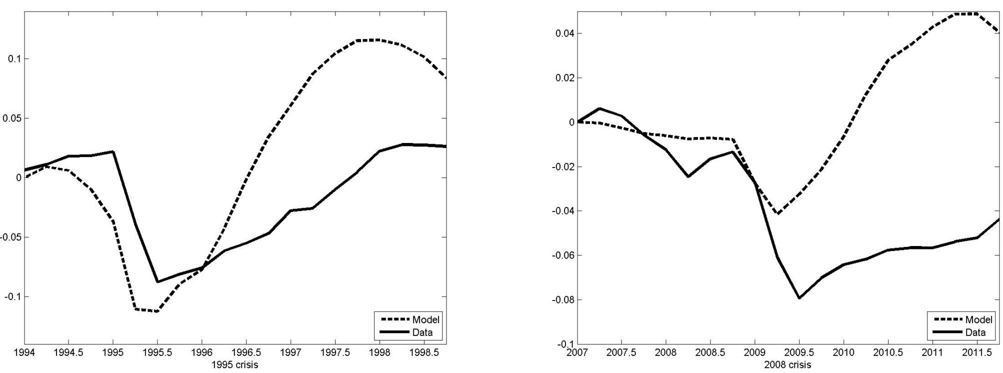
It is opportune to do also the equivalence with an extension of business cycle accounting that departs from an open-economy version of the prototype model.

Proposition 2. *Consider 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 7 presents the comparisons.

Figure 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)[6].

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

3.2.2 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:

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

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 as follows.

It is useful to rewrite equation (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

$$(c_t(s^t) - \omega^{-1} l_t^{\omega}(s^t))^{-\gamma} =$$

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

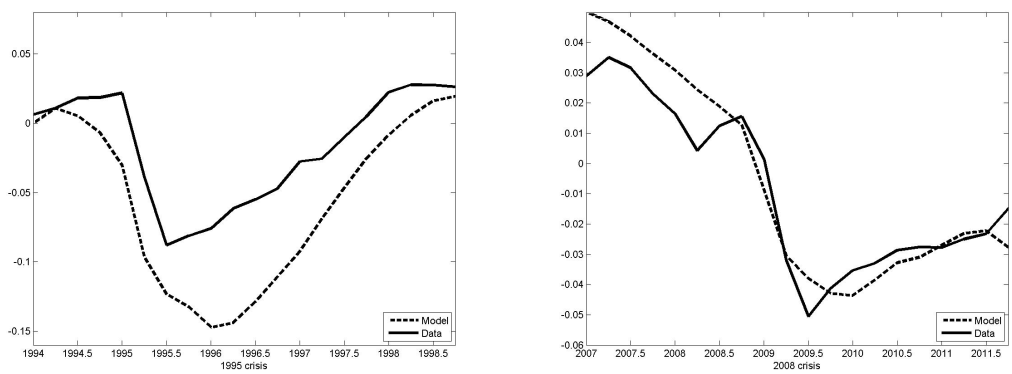
which is the same as equation (3) rewritten with SGU preferences.

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 8. See Table 2 for the parameterization.

Table 2: 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)

Figure 8: Output: data vs model with SGU preferences



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

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.

Table 3: 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.

4 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, specially if we compare GDP recovery between the 1995 crisis and the Great Financial Crisis.

The literature on business cycles synchronization may help to understand how real shocks propagate from one economy to the other. We complement the understanding of the international trade channel in small open economies that rely on intermediate foreign inputs relying on Mexico as a case study, in the same way Aguiar & Gopinath (2007) did. 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 underlying 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.

There is an equivalence between the neoclassical growth model with wedges and a small open economy model augmented with imported intermediate goods. The model produces an efficiency wedge, but is not able to fully replicate the observed path of output. With a different utility function, we introduce labor and investment wedges, which play secondary and tertiary roles according the BCA exercises, and the SGU preferences model is able to account for the dynamics of per capita GDP in both crises.

Given the growing economic integration the world has experienced, along with the fact that the frequency of financial crises has grown, it is important to dissect any role international trade may play in transmitting the crisis from one country to another. This do not diminish the importance of the other channels, but our paper has shown that, in order to account for real exchange rate shocks in small open economies with a great share of intermediate imported goods, one should consider the international link “hidden" within the efficiency wedge, rather than observing only the movements in the balance of payments from the government consumption wedge.

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