Monetary Business Cycle Accounting for Sweden*

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Abstract

When creating competing models of economic fluctuations, researchers typically introduce frictions in their models aiming to replicate the observed movements in the data. This paper implements a business cycle accounting procedure for the Swedish economy. Both the 1990's and 2008 recessions are given a special focus. I found the labor wedge to be the most relevant distortion to be modeled, being qualitatively and quantitatively relevant for both nominal and real variables during the 1990's recession. The irrelevance of the efficiency wedge is in contrast with previous applications of business cycle accounting exercises. For the 2008 crisis, the efficiency and labor wedges are the most determinant in order to replicate movements in real aggregates but for financial variables, the asset market and taylor wedges are both determinant.

FIRST DRAFT - VERY PRELIMINARY!!

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1 Introduction

This paper aims at measuring the quantitative relevance of different types of distortions with respect to business cycle fluctuations in Sweden. Sweden experienced two major recession episodes in the last 30 years, in the early 1990s and during the current financial crisis. What is it that they have in common and what is that makes them different is one of the main focus of the paper. This way the hope is that we get a better grasp of which theories hold most promise in explaining these two recessions.

The issue of business cycle fluctuations in Sweden has been studied before. Hassler et al. (1992) go through 130 years of macroeconomic data to establish some stylized facts about the Swedish business cycle. Though departing from a more statistical approach they nonetheless bring to light a series of correlations between macroeconomic aggregates that successful theories of business cycle fluctuations must replicate. They establish the countercyclicality of the real wage as a key feature that distinguishes the Swedish labor market from other economies. They also find no link between Swedish output and foreign demand, only having a meaningful impact in the inter war period.

Assarsson and Jansson (1998) address the issue of unemployment persistence in Sweden, focusing precisely in the 1990s recession and conclude that shocks to the natural rate of unemployment was a key determinant of the course of unemployment during and after the crisis.

Hassler (2010) suggests structural different explanations for both crisis. The 1990s movements in the labor market are more associated to the destruction of non-competitive jobs and claims that the current crisis is fundamentally different in the sense that is it is much more connected to a huge drop in capacity utilization and labor hoarding as a reaction.

In more recent work, Christiano et al. (2011) create a small open economy model for the Swedish economy where they find that financial and employment frictions are important in measuring the contribution of financial and export demand shocks during the recent recession. The very same frictions seem also determinant to model inflation and the nominal interest rate.

As referred before, the purpose of this paper is to provide researchers guidance for their modeling exercises so they can successfully replicate the observed movements in the data. It also provides evidence that can be used to explain why past attempts of modeling business cycle fluctuations in Sweden may have had different degrees of success.

Methodologically this paper uses the prototype economy that Sustek (2010) sets up but doesn't limit itself to analyze the lead-lag correlation structure of inflation and the nominal interest rate with respect to output as Sustek (2010). It proceeds as Chari et al. (2007a) in analyzing time paths of simulated economies and comparing them with data to analyze the quantitative relevance of each wedge for the two recessions, but in a model that enables us explicitly to gather evidence with respect to the dynamics of variables as inflation and the nominal interest rate.

In fact, most applications to date of business cycle accounting exercises have been straight applications of the Chari et al. (2007a) methodology. Gao and Ljungwall (2009) analyze business cycle fluctuations for China and India, Simonovska and Söderling (2008) in the case for Chile, Kobayashi and Inaba (2006) for Japan and Lamas (2009) for Argentina, Brazil and Mexico. Their findings are similar to Chari et al. (2007a) who find that distortions that manifest themselves as time-varying labor income taxes and time-varying fluctuations to total factor productivity hold the most potential in explaining the movements in the data, though for Japan and Argentina the labor wedge seems to be the most quantitatively relevant one.

Other changes to the Chari et al. (2007a) methodology have been brought forth. Lamas (2009) provides a novelty in the methodology in explicitly modeling international borrowing. He also includes a distortion that manifests itself as a time-varying tax on capital returns rather than on investment as in most applications. Otsu (2009) extends Chari et al. (2007a) to a two-country setting and applies it to the US and Japan, though their main findings still remain the same as in previous studies.

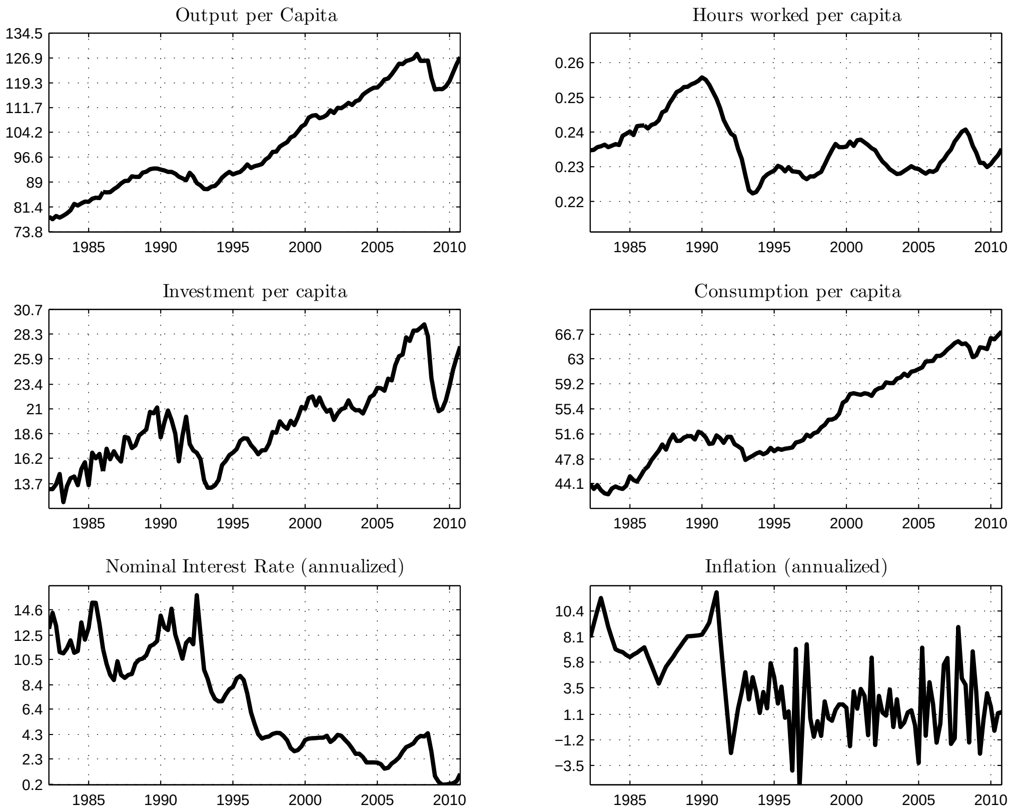
In retrospective, the very notion that detailed economies are equivalent to a prototype economy with primitive shocks, from the perspective of equilibrium allocation and prices, can be traced back to Mulligan (2002). The overall idea of the research agenda is to find which classes of extensions to the business cycle model are of quantitative relevance.

The prototype economy laid out by Sustek (2010) has the merit of including a theoretical extention to the standard business cycle model that has become prevalent, namely a Taylor rule for nominal interest rate setting. On the other side, both historically and especially in the current macroeconomic context, including government bonds allows us to monetize the model.

2 Swedish Economy from 1982 to 2010

In Figure 1 below we have the six macroeconomic aggregates that are the focus of this paper. Both crisis can be seen from the series, especially from observing output, hours worked, investment and consumption per capita. We see a declining trend since 1982 of the nominal interest and inflation rates, in line with the developments in other developed economies. Even though we can see both crisis in the data, we can also draw some initial conclusions

Figure 1: Macroeconomic Aggregates 1982-2010



Output, Investment and Consumption in billions of 2010 SEK. Hours as average fraction of a day.
Nominal interest and Inflation rates in percentage
Source: OECD and NIER.

about how they compare to each other. Output and investment experience similar drops in the current recession and in the 1990's. However, the fall in and out of recession was much quicker in the current crisis. It took about six years for output to recover to the same level as it was before 1990 where it took around half that time for the current crisis.

With respect to investment, even though it hasn't recovered to the same levels as the pre-2008 crisis in almost three years (last quarter of 2010) it is already at 94% of its value in the first quarter of 2008. For the 1990s recession, it took eight years for investment to grow back to the same level it was in the last quarter of 1989.

Consumption behaves somehow different from the previous two aggregates in the sense that though it shares the same slower decline and slower recovery pattern for the 1990s recession compared with 2008 i.e. eight years versus four for consumption to bounce back to its pre-crisis levels, the decline was also deeper in the 1990s.

Hours worked is the aggregate that exhibits the greatest change during this sample period. There was an enormous decline starting in 1990 from which the economy never went back to. In the current crisis however, hours exhibit a pattern similar to investment. They show a strong decline but are bouncing back fast and they are already in the last quarter of 2010 at around 97% of what they were in the first quarter of 2008.

With respect to the nominal interest rate setting, we can see that there was a much more agressive response to the current crisis then what took place in the 1990's. Sweden was in fact in the middle of a burst of a real estate bubble that left banks in such a liquidity crisis that the government had to take over almost a quarter of all banking assets. The government deficit reached 12% of GDP in 1993. Since there was a fixed exchange rate regime that lasted until the the third quarter of 1992, instead of the typical response of lowering interest rates to stimulate the economy, large interventions were taken to defend the Swedish Kronor.

The interest rate actually increased during the start of the recession and only after the exchange rate regime change it started its declining trend. This is in stark contrast with the context of the 2008 crisis. The government had a relatively high fiscal surplus and low debt before the crisis. This put little to no pressure on government bond prices and at the same time the flexible exchange rate regime allowed the central bank to lower interest rates in order to stimulate the economy.

With respect to inflation, there is an overall declining trend since the 1980s in line with what has been observed in other developed economies.

3 Methodology

The idea behind business cycle accounting is that a large class of detailed economies where distortions with structural foundations are introduced to the business cycle model are equivalent, allocation-wise, to a prototype economy with time-varying wedges. This is what Chari et al. (2007a) call the *the equivalence principle* .

The wedges are named *efficiency wegde, labor wedge, investment wedge* and *government consumption wedge* precisely because they look like time-varying productivity, labor income, investment taxes and government consumption.

Chari et al. (2007a) derive *equivalence theorems* i.e. mappings from distortions in the detailed economies to wedges in the prototype economy such that both economies are allocation-wise equivalent.

As referred before, the monetary business cycle accounting procedure was introduced by Sustek (2010). In his paper, he extends the methodology brought by Chari et al. (2007a) to include financial variables, such as the nominal interest rate and price level. This is achieved by including an Euler equation in bonds and a Taylor rule. Two new wedges are introduced in these equations, called the asset market wedge and the monetary policy or Taylor wedge respectively and as in Chari et al. (2007a), equivalence theorems are also derived.

3.1 The Prototype Economy

The prototype economy consists of a neoclassical growth model with labor-leisure choice, a monetary policy rule, six wedges and nominal bonds. For a detailed description of the prototype economy check Sustek (2010). There is an infinitely-lived representative household that solves

$$\max E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, 1 - l_t) \tag{1}$$

subject to the budget constraint:

$$c_t + (1 + \tau_{x,t})x_t + (1 + \tau_{b,t}) \left[\frac{b_t}{(1 + R_t)p_t} - \frac{b_{t-1}}{p_t} \right] = (1 - \tau_{lt})w_t l_t + r_t k_t + T_t \tag{2}$$

capital accumulates according to:

$$k_{t+1} = (1 - \delta)k_t + x_t \tag{3}$$

The production function is given by

$$y_t = A_t F(k_t, (1 + \gamma_A)^t l_t) \tag{4}$$

and aggregate resource constraint consists of

$$c_t + x_t + g_t = y_t \tag{5}$$

The nominal interest rate rule is of the form:

$$R_t = (1 - \rho_r)[R + \omega_y(\ln y_t - \ln \bar{y}_t) + \omega_\pi(\pi_t - \pi)] + \rho_R R_{t-1} + R_t \tag{6}$$

There is a representative firm that maximizes profits and pays the products their marginal products. Both households and firms are price takers in all markets.

3.2 Equilibrium

The conditions that will define the equilibrium prices and allocations consist of the labor-leisure choice

$$[1-\tau_{lt}]A_t(1+\gamma_A)^t F_{lt}u_{ct} = u_{ht} \tag{7}$$

an Euler equation for consumption

$$E_t\left[\beta\frac{u_{c,t+1}}{u_{c,t}}\frac{(1+\tau_{x,t+1})(1-\delta)+A_{t+1}F_{k,t+1}}{1+\tau_{x,t}}\right]=1 \tag{8}$$

and an Euler equation in bonds.

$$E_t\left[\beta\frac{u_{c,t+1}}{u_{c,t}}\frac{1+\tau_{b,t+1}}{1+\tau_{b,t}}\frac{p_t}{p_{t+1}}[1+R_t]\right]=1 \tag{9}$$

The nominal interest rate rule and aggregate resource constraint close the model. These six conditions will determine the equilibrium allocations and prices:

$$c_t^*, x_t^*, y_t^*, l_t^*, p_t^*, R_t^* \tag{10}$$

Note that each equilibrium condition has an associated wedge. A_t, the *efficiency wedge* is a time-varying parameter that makes the production hold for all t i.e. what is commonly referred in the literature as the Solow residual. Following the same reasoning, the leisure-labor condition includes the *labor wedge* $\tau_{l,t}$ and the Euler equations for consumption and bonds an *investment wegde* $\tau_{x,t}$ and *asset-market wedge* $\tau_{b,t}$. Finally the aggregate resource constraint includes the *government wedge* g_t and the nominal interest rate rule a *Taylor rule* wedge $\tilde{R}_t$. All these wedges are exogenous random variables, measurable functions of the history of events.

3.3 The equivalence principle

As referred before, detailed models that introduce distortions to the business cycle model are allocation-wise equivalent to the prototype economy described above, given that a suitable mapping from the distortions to the wedges is found.

Chari et al. (2007a) call these mappings equivalence theorems. They show that a detailed economy with sticky wages is equivalent to a prototype economy with a labor market wedge. They also show that a model with input-financing restrictions is equivalent to a prototype economy with an efficiency wedge. With respect to the efficiency wedge, Chari et al. (2007a) also show that a model with variable capacity utilization is equivalent to a prototype economy with an efficiency wedge. Sustek (2010) shows that the detailed economy brought forth by Christiano and Eichenbaum (1992) with costs of adjusting sectoral flow of funds is equivalent to a prototype economy with a Taylor rule wedge.

As a final example, Sustek (2010) also shows that a sticky prices model is equivalent to a prototype economy with capital[1] and labor market wedges.

3.4 The accounting principle

By measuring the wedges over time we have a quantitative assessment of their impact in a given period of fluctuations. The identification of the quantitatively relevant wedges will help direct research efforts towards mechanisms that express themselves as one or more wedges. These mechanisms will therefore have a much higher potential to match the data.

Once measured, feeding back the wedges back to the prototype economy as shocks and simulating the model makes model equilibrium allocations and data to be the same. This should not come as a surprise since by construction, the wedge are precisely time-series that make the equilibrium conditions of the model hold.

The interesting question is what happens if we do not feed back one of the wedges to the model i.e. if we fix one wedge to its steady-state level. Model equilibrium allocations and data will no longer be the same but how far off will we be? By fixing one wedge at a time, but feeding back the other wedges as shocks to the model and comparing simulated data with real data we learn about the quantitative relevance of each wedge for a given period of economic fluctuations.

3.5 Data

For estimation and simulation of the prototype and simulated economies, data is needed for investment, output, government expenditures plus net exports and hours worked, price level and the nominal interest rate on the three month treasury bill. Most national accounts data is obtained from the National Institute of Economic Research (NIER). Hours worked, population

[1]In the prototype economy, the wedge appears as a tax to investment rather than capital holdings. Chari et al. (2007b) show that in theory it makes no difference. However it does affect the probability space for the wedges when we work with approximated economies, though the effect of including a wedge that shows as a tax to investment versus capital holdings is found by Sustek (2010) to be quantitatively irrelevant in the context of the US economy

and prices (GDP deflator) are taken from OECD Economic Outlook database and data on sales taxes from OECD Tax Statistics.

The data covers the period from the first quarter of 1982 until the last quarter of 2010. Since sales taxes data are annual, the quarterly variation in consumption is used to interpolate sales taxes to quarterly frequency and remove it from real GDP in order to get model output. Data on population is also annual but interpolated to quarterly values. Investment is the outcome of total real gross fixed capital formation plus real net changes in inventories and finally we add to real government final consumption expenditures the difference between real exports and imports of goods and services.

Finally it is important to notice that the GDP deflator is interpolated from yearly to quarterly frequency up to 1993. Hours worked are also interpolated from quarterly to yearly frequency until 1992 which means that quarterly variation on hours worked per capita up to 1992 comes mostly from total employment.

3.6 Functional forms, calibration and estimation

The functional forms and most of the calibration follow Chari et al. (2007). The production function is linear homogeneous

$$F(k_t, l_t) = k_t^{\alpha}((1+\gamma_A)^t l_t)^{1-\alpha} \tag{11}$$

and instantaneous utility is a weighted sum of leisure and consumption in logarithms.

$$u(c_t, 1-l_t) = \lambda \ln c_t + (1-\lambda)\ln(1-l_t) \tag{12}$$

The calibration targets are computed by taking averages over the entire sample and the capital-output ratio is the same Domeij and Flodén (2006) find for the Swedish economy.

KY ratio	**Labor fraction**	**XY ratio**
12.4360	0.2359	0.1917

(13)

This calibration implies values for λ, δ and β:

β	δ	λ
0.9949	0.0104	0.2152

(14)

The other parameters are standard in the business cycle literature. In particular ω_π is set to be greater than one to avoid explosive inflation paths:

α	γ_A	γ_N	ρ_R	ω_Y	ω_π	π
0.3500	0.0040	0.0010	0.7500	0.1250	1.5000	0.0089

(15)

The wedges are modeled as a six dimensional vector autoregressive of order one where the error process is assumed to be multivariate normal with mean zero and variance-covariance matrix $Q = B'B$ as described below:

$$\omega_{t+1} = P_0 + P\omega_t + \epsilon_{t+1}, \ \epsilon \sim MVN(0, B'B) \tag{16}$$

The estimates for P_0, P and B are shown below. To obtain these estimates, I proceed as Sustek (2010). First the calibration targets are met. Then, steady state values are computed and the equilibrium found. Equilibrium decision rules are derived and a state-space representation of the model is built. The data is used as observables and the Kalman filter is used to back out the innovations to the unobserved states (wedges). Under the assumption of normality, a likelihood function is built as a function of the parameters for the stochastic process described above. The final step is to maximize the likelihood function. The results are presented below:

$$P_0 = [\ \text{-}0.0527 \quad 0.6937 \quad 1.5984 \quad \text{-}0.1586 \quad \text{-}0.4636 \quad 0.0493\ ] \tag{17}$$

$$P = \begin{bmatrix} 0.0055 & -0.1048 & 0.1197 & 0.0435 & -0.2917 & -0.0540 \\ 0.4149 & 0.7662 & -0.2892 & 0.4180 & 0.1349 & -0.3637 \\ 0.7435 & -0.3706 & 0.6818 & 1.1149 & 0.5271 & 1.0596 \\ 0.9548 & 0.5654 & 0.5698 & 1.0770 & 0.7484 & 0.7058 \\ -0.0621 & -0.4658 & -0.8339 & -0.7196 & 0.1632 & -0.6720 \\ -0.5673 & 0.0538 & 0.2391 & 0.1630 & 0.0331 & 0.2588 \end{bmatrix} \tag{18}$$

$$B = \begin{bmatrix} 0.0076 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ -0.0051 & 0.0086 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ 0.0074 & -0.0312 & -0.0058 & 0.0000 & 0.0000 & 0.0000 \\ -0.0015 & -0.0108 & -0.0313 & -0.0010 & 0.0000 & 0.0000 \\ -0.0161 & 0.0260 & 0.0465 & -0.0087 & -0.0044 & 0.0000 \\ 0.0118 & -0.0035 & -0.0112 & 0.0136 & 0.0034 & 0.0038 \end{bmatrix} \tag{19}$$

The steady state values for the wedges and endogenous variables are

(20)

A	τ_L	τ_X	g	τ_B	$\tilde{R}$
0.9245	0.1850	0.3897	0.2986	0.0000	0.0000

(21)

y	k	x	c	l	R
0.8124	10.1031	0.1558	0.3581	0.2359	0.0181

3.7 Business cycle properties of the estimated wedges

As in Sustek (2010) and Chari et al. (2007a), business cycle statistics for the wedges are provided. The table below shows the correlation structure of the wedges with respect to output across the sample. The first column shows the standard deviation of each of the wedges relative to the standard deviation of output (1.63). All data is HP filtered with a smoothing factor of 1600 before correlations are computed.

Table 1: Correlation of Y_t with $\omega_{i,t+j}$

	$\sigma_\omega^2/\sigma_Y^2$	-3	-2	-1	0	1	2	3
$\ln A_{t+j}$	0.78	0.39	0.43	0.55	0.56	0.41	0.15	-0.04
$\tau_{l,t+j}$	1.70	-0.01	-0.13	-0.27	-0.40	-0.81	-0.78	-0.70
$\tau_{x,t+j}$	1.84	0.32	0.38	0.45	0.34	0.27	0.05	-0.13
$\ln g_{t+j}$	1.46	0.09	0.08	0.04	-0.10	-0.39	-0.43	-0.29
$\tau_{b,t+j}$	2.20	-0.34	-0.34	-0.34	-0.18	0.21	0.40	0.42
$\tilde{R}_{t+j}$	0.26	-0.20	-0.13	-0.08	0.19	0.14	0.02	-0.12

The efficiency wedge is slightly more volatile in this case than what Chari et al. (2007a) and Sustek (2010) find for the US economy (0.8 vs 0.63), though not as strongly correlated. The countercyclicality of the labor wedge is something that is in line with Sustek (2010) but not Chari et al. (2007a) though the relative volatility is much higher than either findings (1.70 vs 0.92). The investment wedge is particularly more volatile in comparison with Chari et al. (2007a) and much more than in Sustek (2010), of 1.18 and 0.50 respectively. However, in all the three cases it correlates positively with output at all lags, though at slightly different magnitudes.

When it comes to the government wedge, the relative volatility is very similar - 1.42 vs 1.51 in Chari et al. (2007a) and Sustek (2010) respectively. Both papers also show that for the US the government wedge is strongly countercyclical across all leads/lags. In the case for Sweden however, the correlation of output with past and contemporaneous realizations of the government wedge is very small but the correlation with future realizations is much higher in magnitude and countercyclical as in previous findings.

The fact that the cross-correlation structures of the wedges for the real side of the economy seem to be of lower magnitude than the ones previous found by Chari et al. (2007a); Sustek (2010) hints to researchers that promising structural explanation of the wedges should not be as strongly connected to changes in output as it is the case for the US economy.

Turning now to financial variables, in the case of the Taylor wedge, the volatilities are in the same magnitude (0.15 vs 0.19) though Sustek (2010) finds a consistently positive pattern of cross correlations where for Sweden, a consistently negative cross correlation structure is found. With respect to the asset market wedge, Sustek (2010) finds strong and positive cross correlation structure though for Sweden though the cross correlation structure is the same i.e. positive across all leads, lags and contemporaneously, it is nonetheless much weaker. The relative volatility is also twice the size for Sweden. As Sustek (2010) argues the high volatility of the asset market wedge comes from the fact that Euler-equation based pricing models tend to have very poor performance in explaining volatility in asset prices which in our case just shows that such failure is even bigger in the case for Sweden.

Another interesting feature of the business cycle statistics of the wedges is how do they correlate with each other contemporaneously. As mentioned before, detailed economies can be mapped into the prototype economy through more than just one wedge. Hence, below in Table 2, are documented the contemporaneous cross-correlations for the wedges.

Table 2: Contemporaneous cross-correlation of the wedges

	$\ln A$	τ_l	τ_x	$\ln g$	τ_b	$\tilde{R}$
$\ln A$	1.00	0.00	0.00	0.00	0.00	0.00
τ_l	-0.20	1.00	0.00	0.00	0.00	0.00
τ_x	0.71	-0.22	1.00	0.00	0.00	0.00
$\ln g$	0.14	0.34	-0.09	1.00	0.00	0.00
τ_b	-0.64	-0.27	-0.46	-0.80	1.00	0.00
$\tilde{R}$	0.48	0.02	0.24	0.13	-0.34	1.00

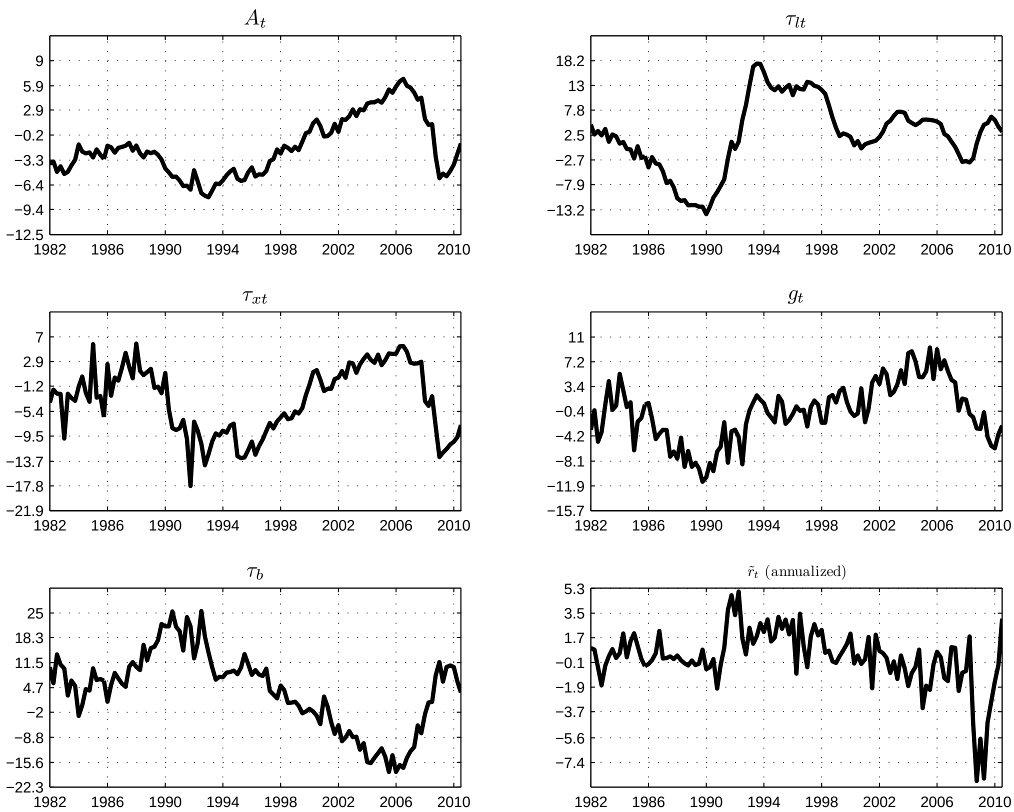
The two major distortions that affect the real economy are relatively weakly correlated (0.20). This suggests that structural explanations of the labor wegde (real frictions such as search and matching for example) need not be strongly correlated with fluctuations to total factor productivity and vice-versa. The same is also observed for the labor and investment wedges.

The correlation between the government and asset market wedge (-0.80) is consistent with the general view that Euler-based equations tend to have severe performance problems in pricing assets Hansen and Singleton (1983). In the case of the 1990's recession, the increase in the government deficit is consistent with the dynamics of the asset-market wedge as a correction mechanism for the misspricing of the Euler equation. Other sizable correlations are between the efficiency and investment wedges and between the efficiency and asset market wedges, though the former is cyclical and the latter countercyclical.

4 Measured wedges and simulated economies

Below in Figure 2, we can observe the measured wedges in deviation from their steady state values.From a univariate perspective, they seem to share a structural break precisely around the 1990s. However for the current crisis the wedges seem to exhibit a much stronger mean reversion, with the exception perhaps of the government wedge. This seems to lend support to Hassler (2010) who claims that as the Swedish economy entered into the 1990s it "(...) *quite soon became clear that substantial and painful structural changes needed to be undertaken* (...)"(pp.5).

Figure 2: Wedges in deviation from Steady State



$\tilde{r}_t$ in absolute % deviation from steady state. All others in relative % deviations.

The strong mean reversion in the wedges referred before fits into the idea of the "crisis from outside" and in the good prospects of recovery that are suggested in Figure 1. More important though, it means that in spite of the fact that the business cycle model fails to capture fully the amplitude of the distortions during the recession, the mean reversion of the wedges suggests that whatever hidden mechanisms in the wedges that are driving forces of the business cycle, they don't seem to fundamentally change relative to the pre-crisis periods. Some amplification mechanisms are clearly needed or we wouldn't see the current crisis in some of the wedges as big deviations from their normal processes.

This is one of the main findings. Whatever modeling attempts of the 1990s recession, they must reflect structural changes in which business cycles where generated before and after the 1990's crisis. However it doesn't seem to be the case for the current crisis.

5 The 1990s recession

Next are going to be presented, sets of "economies" where all but one of the wedges are fed back to the model as shocks. The "missing" wedge will be set to a constant and equal to its steady state value. Since no longer all wedges are fed, simulated data will, in general, deviate from real data and, as referred before, the magnitude of the deviations from the real data for each economy and each macroeconomic aggregate in particular will provide hints of the quantitative relevance of each of the wedges. Also, for each variable, the linear correlation coefficient $(\rho) between real and simulated data is computed.$

5.1 No efficiency wedge economy

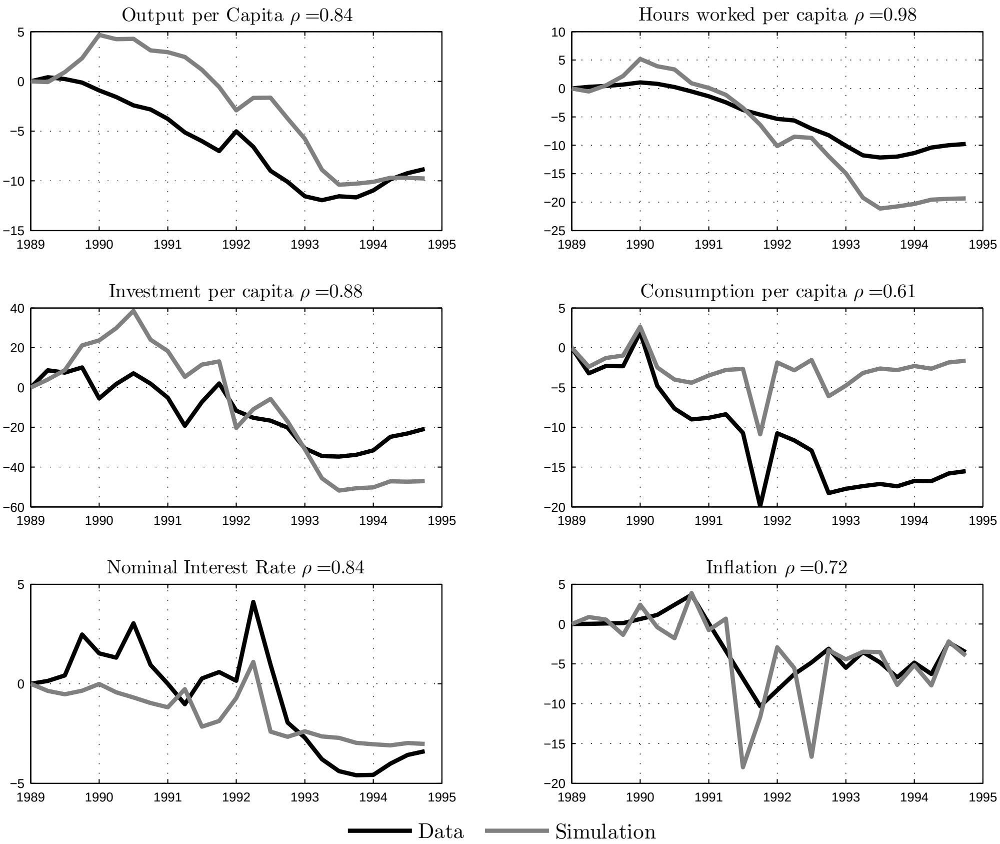
In contrast with much of previous findings, the efficiency wedge does not seem to be important to match most variables in general. Simulated output does not fall below the first quarter of 1989 value until the fourth quarter of 1991 and the efficiency wedge seems important to match the decline that started in the second quarter of 1989. However the correlation for the sample window shown in Figure 3 on what ouput is concerned is high (0.84) and from this perspective, simulated data resembles well observed data.

With respect to hours worked the simulated economy correlates with real data very well though it overstates the recession, especially in the later stages.

Consumption seems to correlate well, though simulated data fails to capture the severity of the decrease. With respect to nominal variables, the correlation is also reasonably high even if simulated data shows excess volatility in the case of inflation or too little of it in the case of the nominal interest rate.

The overall conclusion for observing Figure 3 is that the efficiency wedge is not a key margin to address, especially when compared with the relevance of other wedges as it can be depicted below. This is in contrast with previous findings of most business cycle accounting exercises.

Figure 3: No efficiency wedge economy



Percentage deviations from 1989Q1 values

5.2 No labor wedge economy

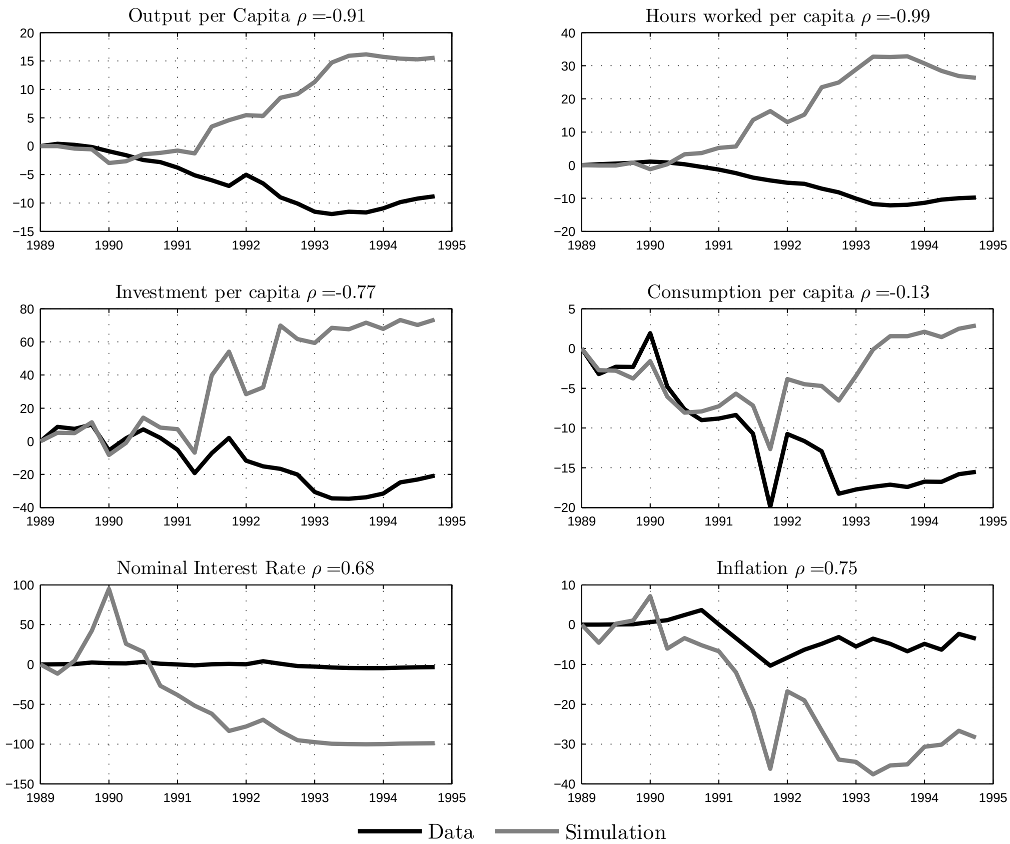
The interesting insight of the no labor wedge economy is that the model seems to perform reasonably well in replicating movements in real variables at least until the second quarter of 1990. After that, the model fails in matching any real variable movements. Simulated variables differ qualitatively from real data since all correlation coefficients for the real variables are negative.

This gives strength to the argument from before that the structural changes in the labor market that took place, fundamentally changed business cycle dynamics during the 1990s crisis.

The change of the exchange rate regime is a tentative explanation as it created the need for the restructuring of large shares of important sectors, as Hassler (2010) argues.

With respect to the nominal variables, though the correlations are reasonably high - 0.68 for the nominal interest rate and 0.75 for inflation - the magnitude of the fluctuations is greatly overstated and the labor wedge seems to be determinant even to match movements in the nominal variables.

Figure 4: No labor wedge economy



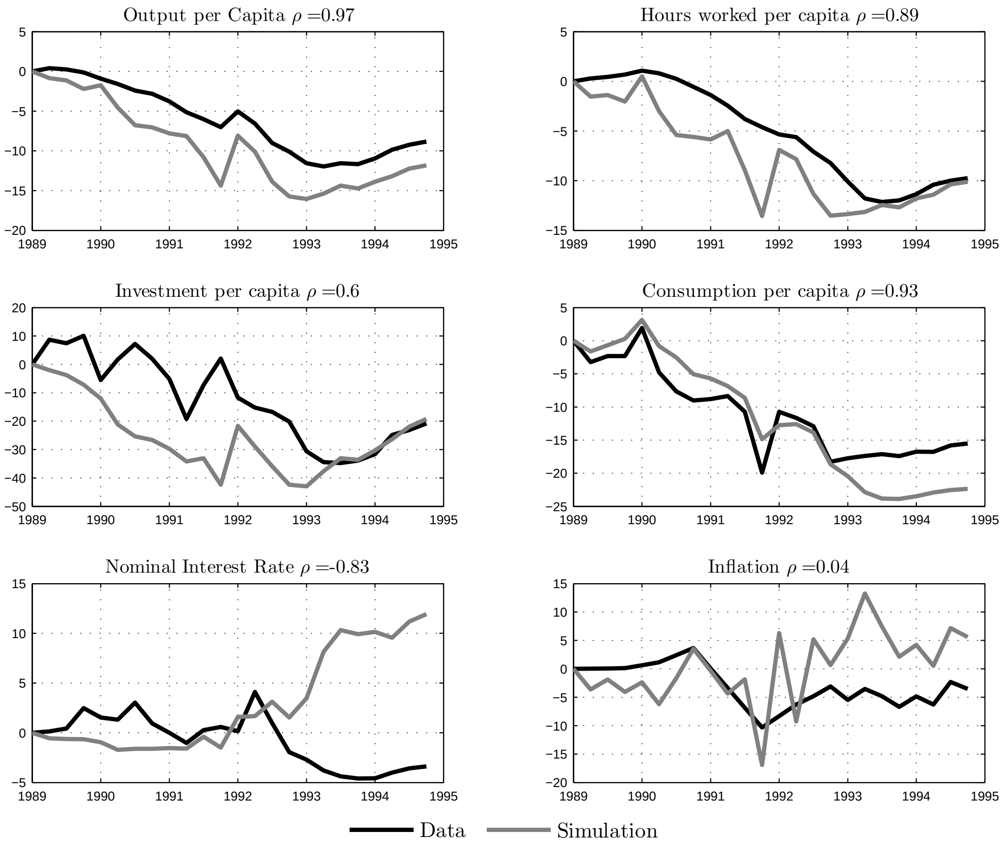
Percentage deviations from 1989Q1 values

5.3 No investment wedge economy

For the no investment wedge economy, the results for the real variables at least, seem to be in line with previous findings from Chari et al. (2007a) in the context of the 1981 recession in the US and the Great Depression. The real side of the economy seems to be well replicated, correlation wise, in spite of the model over-stating the level impact of the recession.

However, by not including the investment wedge, the nominal interest rate cannot me matched after the change in the exchange rate regime. The predictions are qualitatively wrong and in the case of inflation, simulated data bears little correlation with observed data.

Figure 5: No investment wedge economy



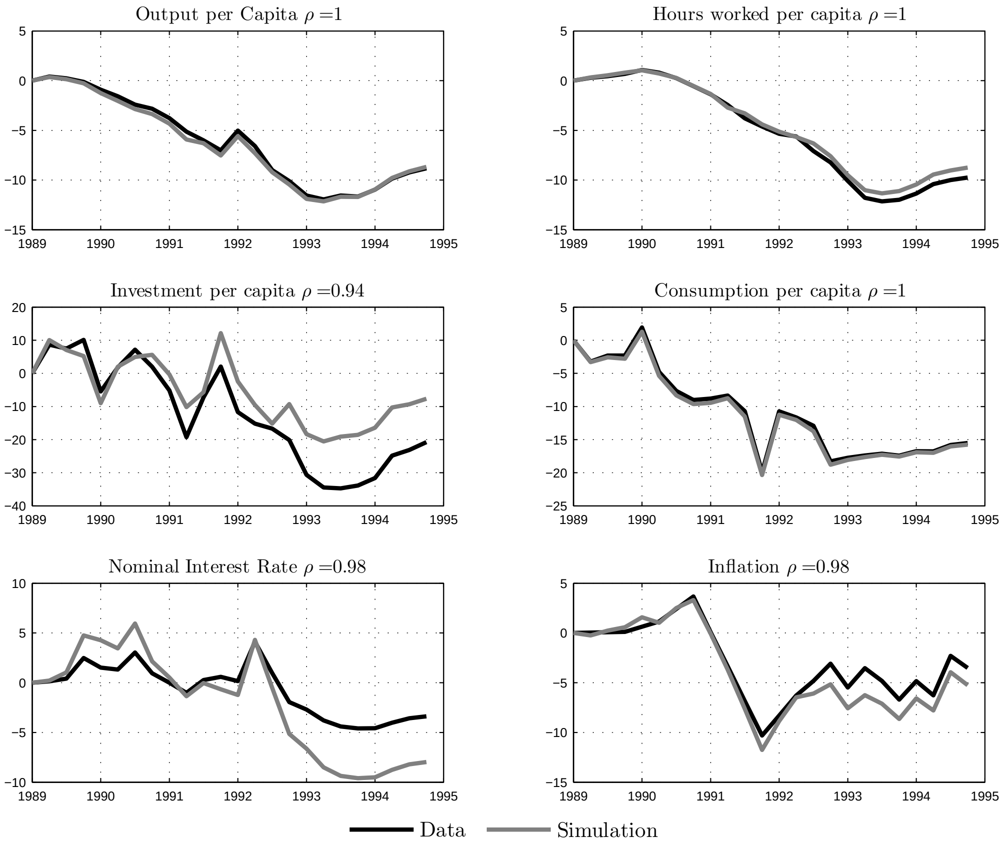
Percentage deviations from 1989Q1 values

5.4 No government wedge economy

The results in Figure 6 are also in line with what Chari et al. (2007a) find. Government wedge is relatively irrelevant both correlation and level wise. Not including it leads the simulated economy to overstate the fall of the nominal interest rate and understate the decrease in investment but the model in general performs comparably well.

As referred before, the developments of the 1990s crisis lead the government to take over huge liabilities from the banking sector and incur in a budget deficit in 1993 of around 12%. However these events and their impact in the economy from the business cycle model perspective, need to express themselves through other margins in order to be able to have a role in generating fluctuations in the observed variables during the 1990's recession.

Figure 6: No government wedge economy



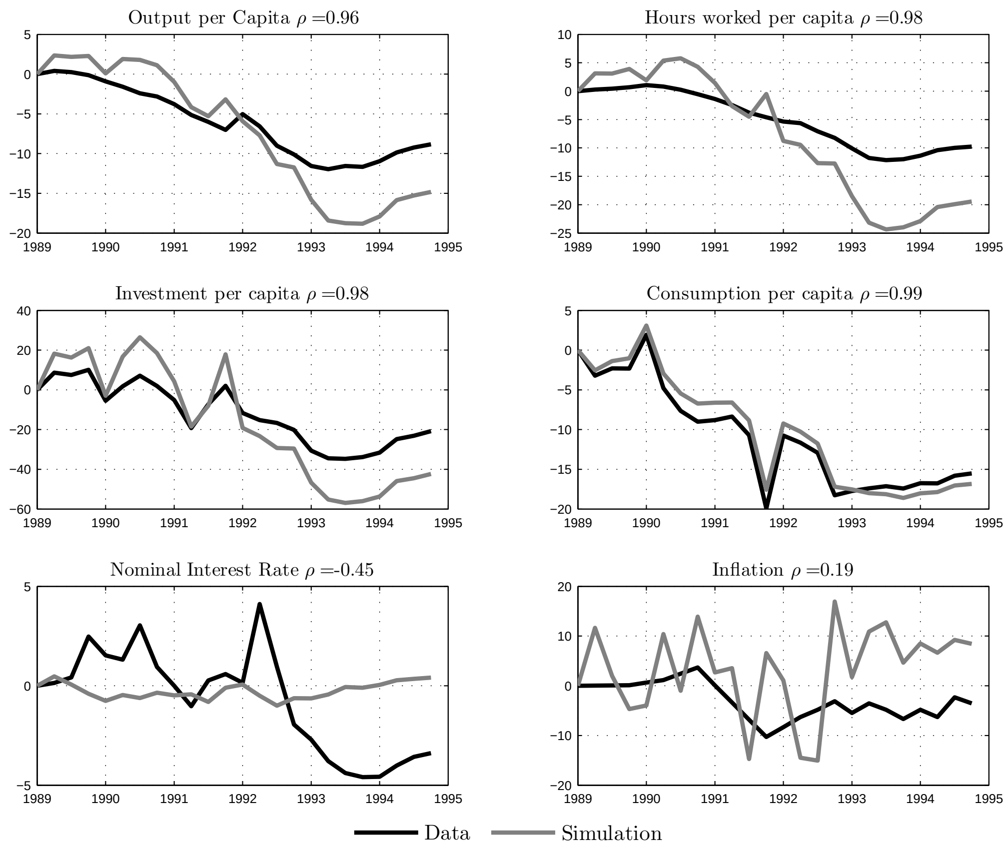
Percentage deviations from 1989Q1 values

5.5 No asset market wedge economy

According to Figure 7, the asset market wedge has some relevance in making the simulated economy match the real side of the economy in the sense that, except for consumption, simulated data overstate the impact of the recession. However the correlations between simulated and observed data for these variables is very high.

Not including the asset market wedge impairs the simulated economy of generating the observed movements in the nominal interest rate. However, when it comes to inflation, the model behaves reasonably well until the second quarter of 1992, especially if we take into account that, as referred before, data on inflation is interpolated at quarterly frequency up to 1993.

Figure 7: No asset market wedge economy

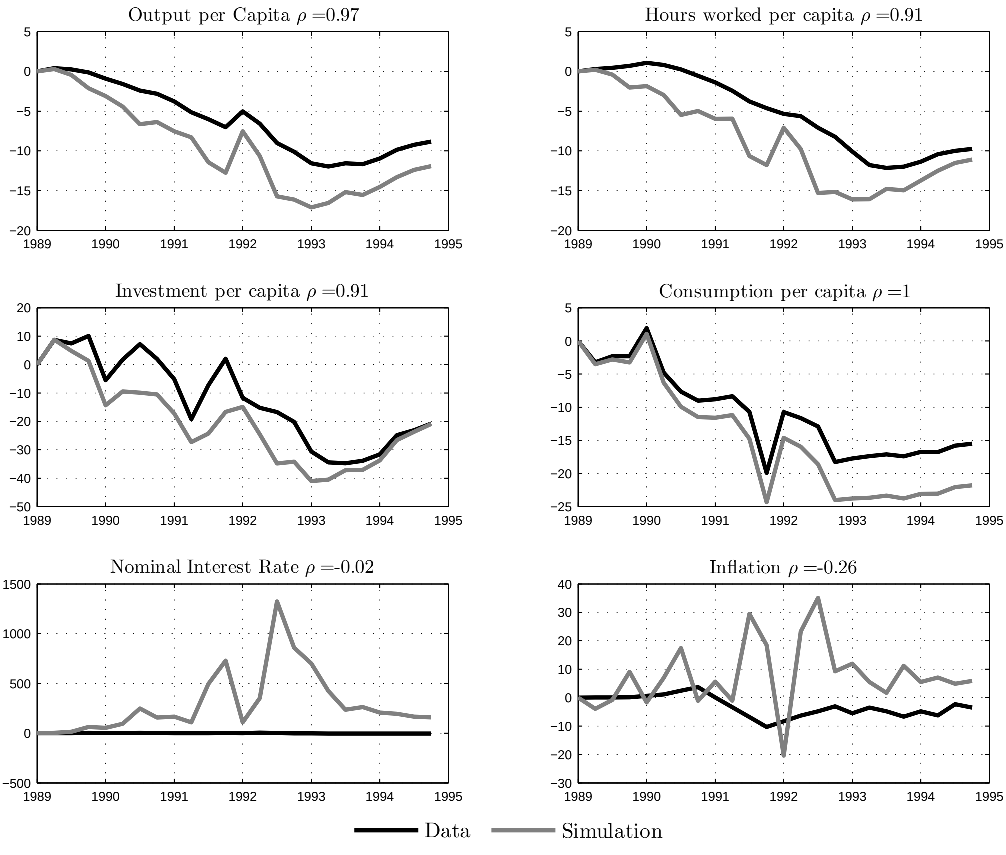


Percentage deviations from 1989Q1 values

5.6 No Taylor rule wedge economy

In Figure 8 we can observe that the Taylor rule wedge has also some quantitative relevance for real variables though from a correlation perspective simulated data is relatively close to real data since all correlations are above 0.9. However, with respect to the interest rate, leaving the Taylor rule wedge equal to its steady state value leads to movements that dramatically differ from real data both from a level and correlation perspective. With respect to inflation, the results are close to what was found for the no asset market wedge economy i.e. the model matches real data at the yearly frequency in the early stages of the recession but decouples afterwards.

Figure 8: No Taylor rule wedge economy



Percentage deviations from 1989Q1 values

5.7 Summary of the 1990s recession

The analysis before suggests that the labor wedge is the key defining wedge for real variables and has the second most quantitave relevance in order to get the nominal interest rate right. Structural extensions to the business cycle model must provide mechanisms that express themselves as distortions to the labor-leisure condition.

The fact that the efficiency wedge plays a comparably modest role is a finding that is in contrast with previous applications of business cycle accounting to other economies. Also in common is the fact that the investment wedge seems to be of little importance when modeling movements in real variables.

Sustek (2010) finds that both the efficiency and asset market wedges are the most quantitatively relevant wedges in order to match the lead-lag structure between output and the nominal interest and inflation rates. For the 1990's recession in Sweden the results show that, in order to match the movements in the observed variables, not only the efficiency wedge is of comparably lesser importance, but the asset market is not the most quantitatively relevant either. It is the economy without a Taylor rule wedge that produces the largest deviations from observed data on what nominal variables is concerned.

6 The 2008 recession

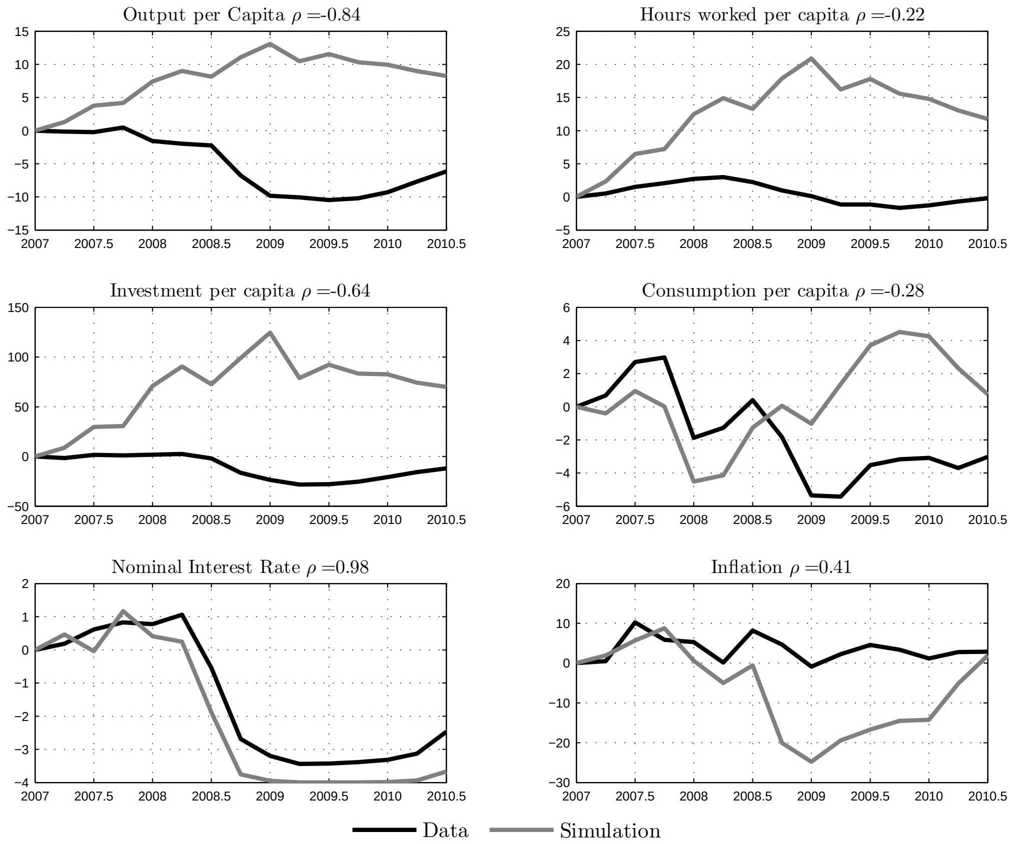
As before, simulated economies with all but one wedge will be compared with real data to assess the quantitative relevance of each wedge.

6.1 No efficiency wedge economy

As we can see in Figure 9 below, fixing the efficiency wedge to its steady state value leads the simulated economy to produce paths for all real variables that are both qualitatively and quantitatively far off from real data. All correlations for the real variables are negative and the movements in hours worked and investment are much stronger than observed.

On what the nominal variables is concerned, the interest rate is well replicated by the model, with a correlation of 0.98. However, when it comes to the inflation rate, the correlation is comparably smaller (0.41) and the magnitude of the predicted drop in inflation is not observed.

Figure 9: No efficiency wedge economy



Percentage deviations from 2007Q1 values

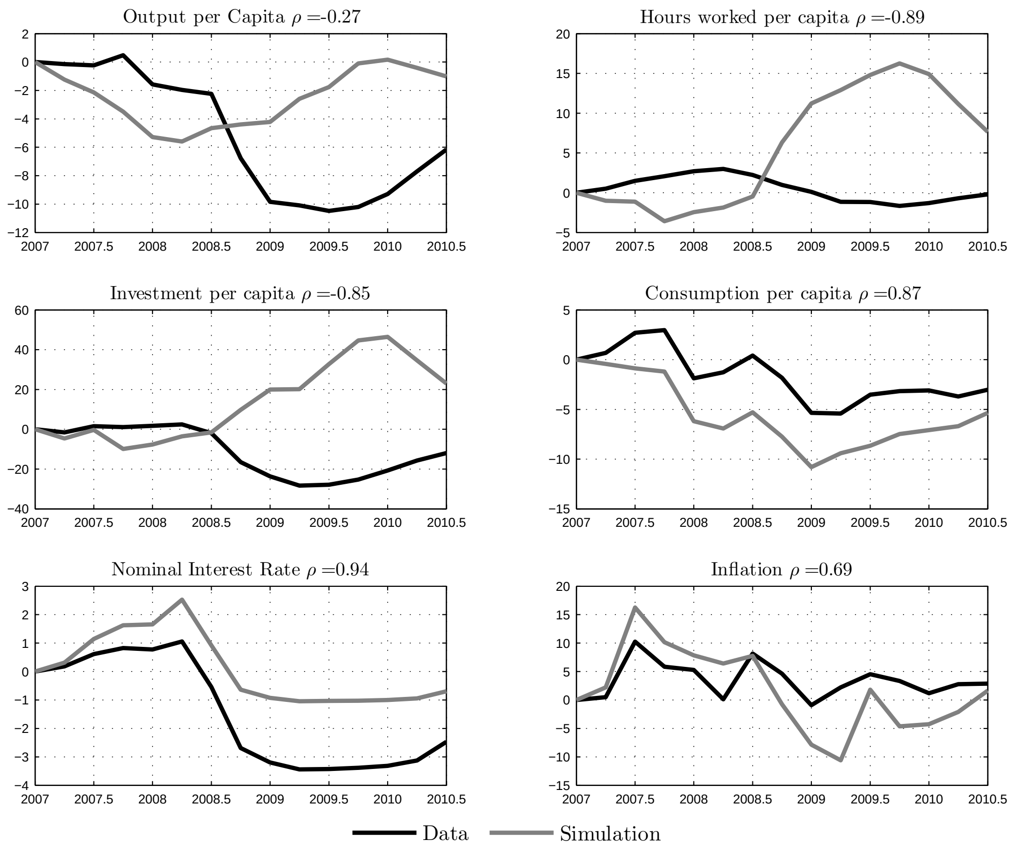
6.2 No labor wedge

Figure 10 shows that the labor wedge remains important. The simulated economy has a reasonable performance at the start of the crisis but after the second quarter of 2008 simulated data diverges from real data. With respect to output, the model doesn't capture the depth of the recession and antecipates the recovery by four quarters.

The dynamics of hours worked get completely reversed. Consumption is reasonably captured but the movements in investment, as in the case for output, are only reasonably captured up to the second quarter of 2008. After that simulated investment actually increases instead of decreasing as observed.

Nominal variables however are reasonably captured, though the nominal interest rate dynamics fail to capture the depth of the decrease that took place.

Figure 10: No labor wedge economy



Percentage deviations from 2007Q1 values

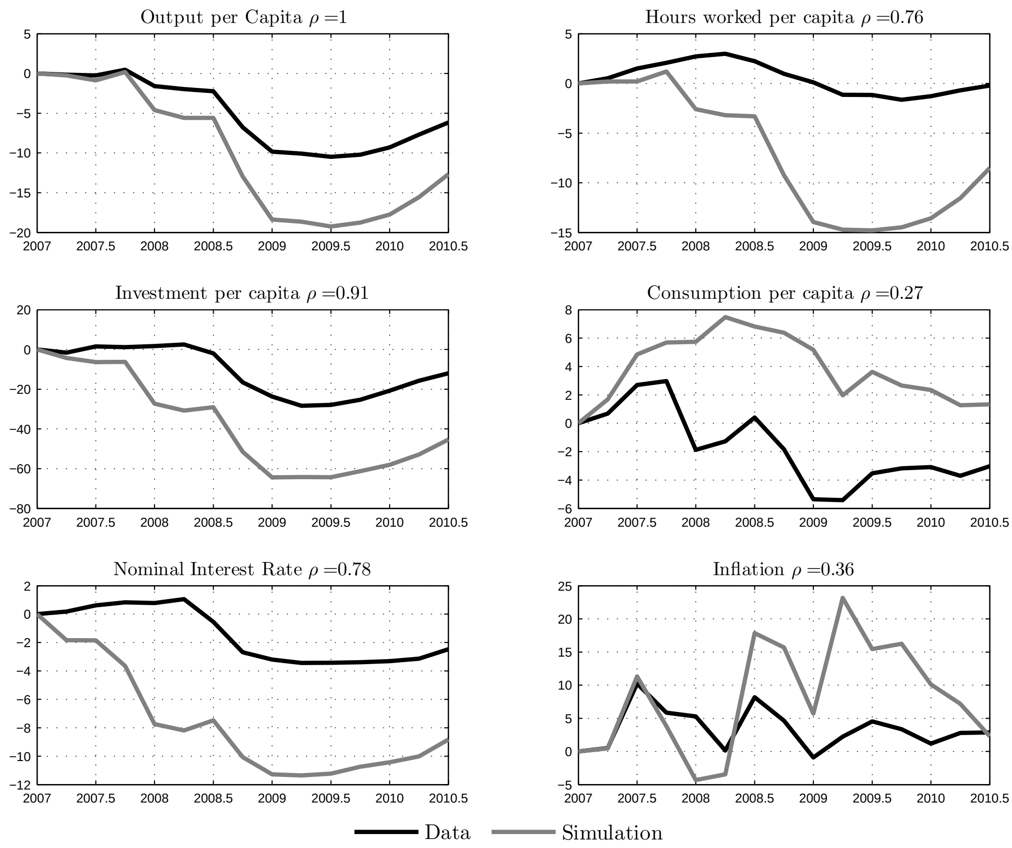
6.3 No investment wedge

As we can see in Figure 11, the no investment wedge economy replicates output fairly well from a correlation perspective but overstates the depth of the recession. On what hours is concerned, the simulations show an initial decline that is not observed in the data. After the second quarter of 2008 the movements in simulated data are qualitatively in synchrony with real data but quantitatively far from it.

The same can be said about the dynamics of the rest of the variables. Simulated data antecipates the contraction and from a correlation perspective, investment and the nominal interest rate dynamics are reasonably captured - correlations of 0.91 and 0.78 respectively - even if the model, as before, exacerbates the impact of the recession.

When it comes to consumption and inflation, the correlations are comparably lower - 0.36 and 0.27 respectively. In the case of consumption the model predicts an expansion for all of the sample period when realized consumption suffered a contraction. For inflation the model seems to behave better though it shows excess volatility when compared with real data.

Figure 11: No investment wedge economy

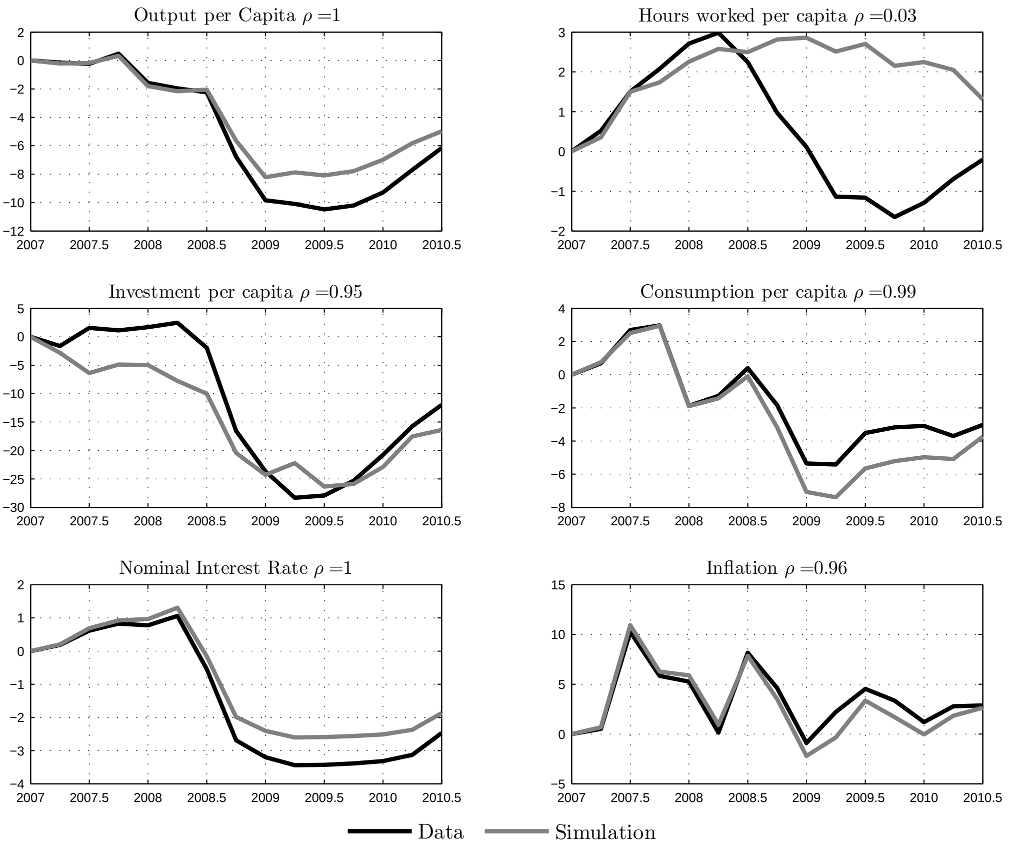


Percentage deviations from 2007Q1 values

6.4 No government wedge

With the exception of hours worked, the movements in all other variables are very well matched, a finding that is not only similar to the 1990's recession but typical of business cycle accounting applications. The movement in hours is replicated, as before, only until the second quarter of 2008 but the magnitude of the fluctuations is overall relatively small.

Figure 12: No government wedge economy

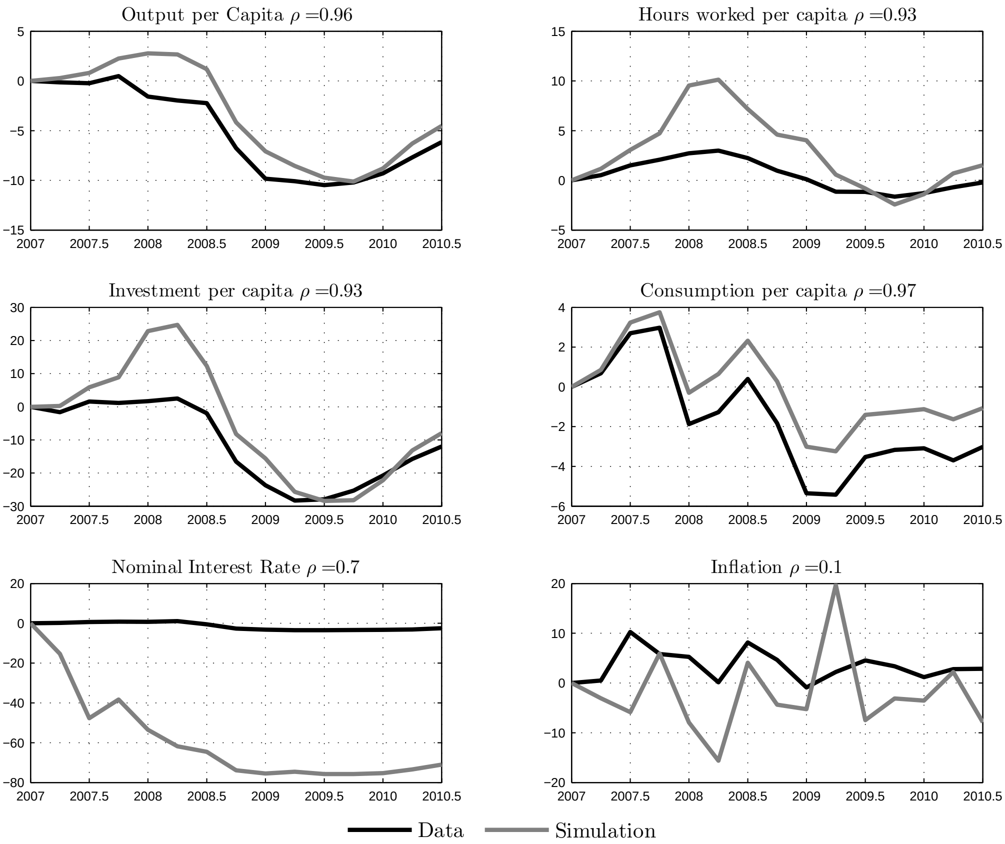


Percentage deviations from 2007Q1 values

6.5 No asset market wedge

The asset market wedge doesn't seem to be as relevant to match real variables. Though overestimating real variables, simulated data correlates quite well with real data. However, with respect to nominal variables, Figure 07 shows that an economy without the asset market wedge will generate a path for the nominal interest rate that is very far from reality and inflation, from a pure correlation perspective doesn't fair that well either.

Figure 13: No asset market wedge economy



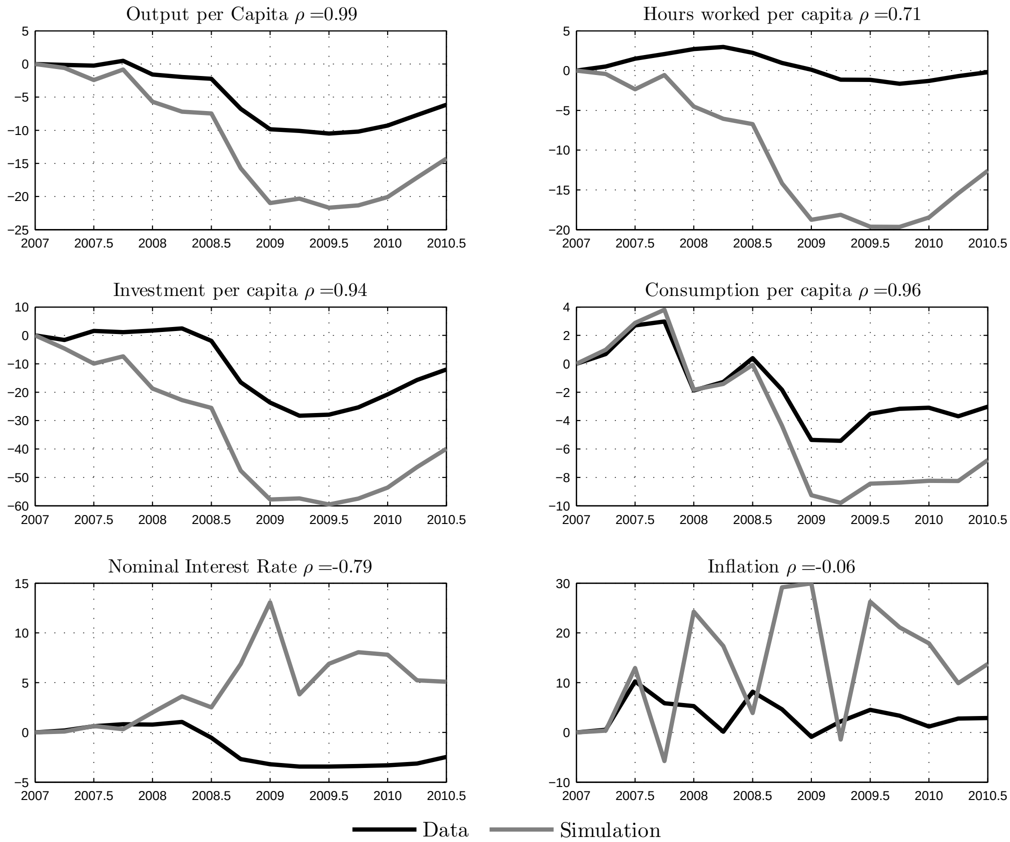
Percentage deviations from 2007Q1 values

6.6 No taylor rule wedge

With respect to real variables, the Taylor wedge seems to be relevant in order to match hours worked. Without it, the model predicts a fall in hours of a magnitude that is not observed in the data.

With respect to the other real variables, the model has a relatively good performance with all correlations being higher than 0.9, though the common denominator is that it consistently overestimates the impact of the recession. In the case of the nominal interest rate, the simulated economy is in complete contrast to the data. The Taylor rule wedge seems to be determinant in order to match movements in the nominal interest rate. Finally, inflation dynamics are not well captured at all. As Figure 14 suggests, the model generates an inflation path that is not correlated with the data and that misses out on the levels.

Figure 14: No Taylor rule wedge economy



Percentage deviations from 2007Q1 values

6.7 Summary of the 2008s recession

In all, this recession looks much more in line with previous business cycle accounting exercises made, in particular for the US economy by Chari et al. (2007a); Sustek (2010). It is clear that the efficiency wedge matters a lot, both quantitatively and qualitatively especially for real variables. The labor wedge matters also a great deal to match output, hours worked and investment after the second quarter of 2008. The investment wedge seems comparably less important.

The government wedge seems quite irrelevant for the 2008s crisis and tentative models of this crisis should focus in other wedges when explaining the data. The asset market bears some relevance but it's relatively unimportant for real variables. When it comes to nominal variables, it is quite relevant for the interest rate and inflation dynamics but the Taylor rule wedge seems comparably more determinant in order to match the movements in real data from a qualitative and quantitative perspective.

7 The comparative relevance of the wedges for the 1990s vs the 2008 recession

The first striking difference between the 1990s and the 2008 recession is the role of the efficiency wedge. To be able to generate fluctuations that resemble movements in real data, the efficiency wedge is not relevant during the 1990's recession but it is the most relevant, at least for real variables, during the 2008 crisis.

The second difference is the relevance of the labor wedge. From Figure 1, we could see that there was a structural change in hours worked in the 1990s recession, something that was also clear in the estimated labor wedge. In fact, as referred above, the labor wedge was the most qualitatively and quantitatively relevant wedge for most macro aggregates for the 1990s recession. The distinctive feature about the labor wedge for the 2008 recession when compared with the 1990's is that, though still relevant, it doesn't have the same impact for nominal variables and for real variables as it does for the 1990's recession when a no labor wedge model gives quantitatively and qualitatively wrong paths for real variables.

The investment wedge seems comparably unimportant for both recessions though for output, hours and investment, its impact in the 1990's was somehow stronger than in the current recession. Consumption is the exception. With respect to the nominal variables, the investment wedge was important during the 1990's recession, in particular after the second quarter of 1992 in order to match the data from a qualitative perspective. This is not observed for the current crisis though, where an economy without an investment wedge produces paths for the nominal interest and inflation rates that are qualitatively closer to real data - correlations of 0.78 and 0.36 respectively for the 2008 recession vs -0.83 and 0.04 for the 1990's crisis.

The asset market wedge is, as in the case for the government wedge, irrelevant in order to match movements in real variables, and it is so for both crisis. However, though the government wedge remains irrelevant too for nominal variables, the asset market wedge is relevant for nominal variables and for both recessions.

Finally, the Taylor rule wedge seems to matter much more for the 2008 financial crisis than it did for the 1990's recession. Correlation-wise, with the exception of hours worked, an economy without a Taylor rule wedge produces paths for real variables that are much closer to real data during the 1990's than since 2008. However, when it comes to nominal variables, the Taylor rule seems quite relevant for both crisis.

8 Conclusion

In this paper a monetary business cycle accounting exercise was conducted along the lines of Sustek (2010). By constructing a business cycle model with time-varying parameters that capture the unexplained components of each of the equilibrium conditions of the model i.e. the wedge, one is able to identify the relevant distortions to be modeled and have a quantitative assessment of their potential to explain periods of economic fluctuactions.

The aim of the paper was to make an analysis of business cycles in Sweden for for the last 30 years and in particular to identify the main frictions and distortions that drive business cycle fluctuations in Sweden. In particular to look at two major recessions episodes that took place, namely in the 1990s and in 2008 and see what these episodes have in common and what makes them different. The goal was that by providing answer to these questions we would guide researchers towards models that would have higher quantitative relevance.

The two crisis seem different in nature from the perspective of the prototype economy, at least on what movements in real variables is concerned. Evidence was provided for dynamics of distortions to the first order conditions of the business cycle model for both recessions. Theories that aim in explaining business cycle fluctuations for the 1990's crisis should focus primarily on providing structural explanations for the dynamics of the labor wedge. With respect to the 2008 crisis, both the efficiency and labor wedges are relevant to match real variables, a result more in line with previous work, namely what Chari et al. (2007a) find for the US in the context of the 1981 recession and the Great Depression.

Though the 1990's transformations in the labor market seem to be beyond a simple business cycle phenomena, the labor wedge for the current crisis seems much more in line with typical labor distortions measured at business cycle frequencies.

Distortions to the labor-leisure choice and total factor produtivity are not that correlated, whereas the latter seems to be strongly correlated with distortions to the agent's savings decisions. This provides evidence that the structural explanations of such distortions may very well be connected.

The special importance of the efficiency wedge still stands and Chari et al. (2007a) words that "(...) The challenging task is to develop detailed models in which primitive shocks lead to fluctuations in efficiency wedges (...)"(pp.828) still apply, given that, as they argue, extensive work has been done in producing models that create fluctuations in labor wedges (see Merz (1995) as an example). This is not the case for the 1990's crisis but still applies with respect to the 2008 recession.

The high correlation between the government wedge and the asset-market wedge (-0.80) shows that strong corrections to the pricing mechanisms of the model need to be introduced particularly in times of large increases of government deficits. The similarities to the current financial context of countries like Portugal, Greece, Spain, Italy and Ireland face is striking and it would be interesting to see to what extent the conclusions drawn here would apply.

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