# Risk Shocks and Divergence between the Euro area and the US[1]

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This version: May 15, 2014

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**Abstract**

Why the Euro area and the US have diverged since 2011 while they were highly synchronized during the recession of 2008-2009? To explain this divergence, we provide a structural interpretation of these episodes through the estimation of a business cycle model with financial frictions (Christiano et al., 2014a) for both economies. Our results show that risk shocks, measured as the volatility of idiosyncratic uncertainty in the financial sector, play a crucial role in the divergence of US and Euro area economies because they stimulate US growth since the trough of 2009 whereas they are at the origin of the double dip recession in Europe.

Companion website: http://shiny.cepii.fr/

## 1. Introduction

Highly synchronized during the 2008-2009 recession, Euro area and US economies have diverged since the former entered a double dip recession, in the middle of 2011, while the latter pursued its expansion – see the solid lines in Figure 1 that compares the cumulated growth of real GDP per capita for both economies. The divergence is particularly striking given the strong similarity of the timing[2] and the magnitude[3] of the 2008-2009 recessions. Today, US economy has overtaken the pre-crisis level of output per capita, which is, in 2013Q4, 2.8 percent above the 2007Q4 level. Such a growth over six years may appear disappointing, a "Modest Recovery"

[1]The views expressed in this paper are those of the authors and do not necessarily reflect those of the Institutions to which they belong.

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[2]There is a difference of one quarter in the peak dates (2007Q4 for the US and 2008Q1 for the Euro area) and no difference in the trough dates (2009Q2 for both) according to the NBER and the CEPR. The date of the second peak for the Euro area is 2011Q3, still according to the CEPR.

[3]The cumulative loss of output between 2007Q4 and 2009Q2 is close to 5 percent in the Euro area and the US (5.4 and 5.2 respectively).

as qualified by the IMF (World Economic Outlook, October 2013), but it outweighs the 2.4 percent of negative cumulative growth in the Euro area. Actually, the renewed downturn before reaching prior peak in Euro area corresponds to the pattern of a "double dip recession" identified by Reinhart and Rogoff (2014) as typical after historical systemic banking crises. In this paper, we explain this divergence by risk shocks, measured as the volatility of idiosyncratic uncertainty in the financial sector.

Because of numerous differences in US and Euro area economies it is a tricky task to identify the key factors at the origin of this divergence path. A way to perform this task is to estimate dynamic and stochastic general equilibrium (DSGE) models to measure the contribution of shocks, frictions and policies to business cycles. Christiano et al. (2003) and Chari et al. (2007) have already shown the relevance of such models to study the Great Depression. Smets and Wouters (2005) use this methodology to compare Euro area and US business cycles.[4] Various recent papers also use this methodology to analyze the recent recessions. Our contribution to this literature is to provide a comparison between the Euro area and the US that covers the double-dip recession in the Euro area. Indeed, the most recent papers that focus on US economy do not consider the Euro area and the contributions on the Euro area do not study the whole double-dip recession.[5]

For comparison purpose, the choice of the model is delicate because the selected DSGE model should be mostly identical for each economy (otherwise estimation's results may be difficult to compare) while performing well for both (whom historical data are however different by definition). We choose the model of Christiano et al. (2014a) (CMR hereafter) for three reasons. First, CMR demonstrate the good empirical performances of this model for accounting US business cycles, especially for recent business cycles up to 2010Q2. It is therefore natural to extend its application to the last three years to get an insight on the origin of the US recovery. Second, this model can be viewed as a reduced version of the model developed by the authors in Christiano et al. (2010), that has been precisely estimated to compare US and Euro area business cycles. Third, the CMR model proposes a good compromise between its generality (that is necessary to be applied identically to the two economies) and its detailed features that allows to account for differences in market frictions (as consumption habit formation, capital adjustment costs, markups, wage/price stickiness, and agency problem in the financial sector), in shocks (associated with shifts in demand, technology, policy or financial risk), and in policies (fiscal or monetary).

[4] They estimate an identical DSGE model with real and nominal rigidities for the US and the Euro area and identify the similarities and the differences in their structural characteristics (e.g. type of shocks, propagation mechanisms, and monetary policy rules). The main result of their analysis is the difficulty to detect significant differences between the US and European structural characteristics of business cycles.

[5] See Galí et al. (2012), Del Negro et al. (2013) or Christiano et al. (2014a,b) for US economy – Sala et al. (2013) study the US, the UK, Sweden and Germany. For Euro area economy, the last point of the data sample is 2008Q2 in Darracq Pariès et al. (2011), 2008Q4 in Christiano et al. (2010), 2008Q3 in Villa (2013), and 2010Q1 in Coenen et al. (2012), 2010Q2 in Lombardo and McAdam (2012), 2011Q4 in Kollmann et al. (2013).

We estimate the CMR model for US and Euro area economies, with real and financial series over the period 1987Q1-2013Q4. Around the half of the business cycle variance in output is accounted for by risk shocks in both economies (55 percent for the US and 49 percent for the Euro area). This important role of risk shocks is consistent with the results previously reported in the literature by Christiano et al. (2010) and CMR. These authors give a non-trivial macroeconomic role to the financial risks following Bernanke et al. (1999), who consider a contract with asymmetric information between financial intermediary and entrepreneur based on the existence of costly-state verification *à la* Townsend (1979).[6] Risk shocks are useful to account for episodes of credit crunch, with contraction of both investment and ouptut, and high credit spread, defined as the difference between loan interest rate and risk-free rate. This sequence has been observed during the last recessions in US and Euro area economies – see figure 1.

According to our estimation results, risk shocks explain the recent divergence between the two economies: a steadily reduction of the risk supports the US expansion since the trough of 2009Q2 whereas a substantial increase in risk after the peak of 2011Q2 has plunged the Euro area into a double dip recession. These results are important because if there is relative consensus on the central role of financial shocks in the US recession of 2008-2009, it is not the case for the shocks at the origin of (*i*) the US "modest recovery" and (*ii*) the Euro area double dip recession. Our results show that the US have succeeded in reducing (and even in inversing) the risk problem in the economy whereas the Euro area have failed to manage this risk as exemplified by the longstanding tensions in its banking sector highly affected by the sovereign debt crisis of 2011.

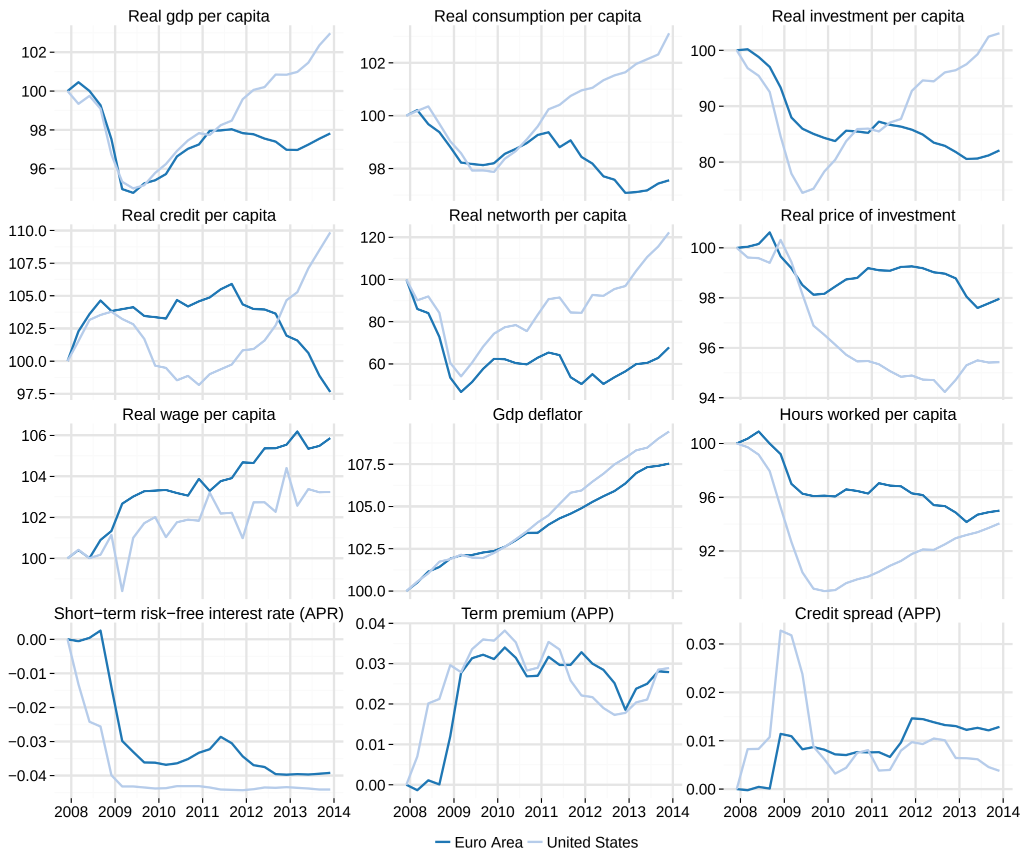
The remainder is organized as follows. The section 2 provides a brief summary of the CMR model and describes the empirical strategy. The section 3 provides our structural interpretation of the divergence. The section 4 discusses our results and their relations to other narratives of the Great recession. The section 5 concludes.

## 2. Methodology

We use the CMR model as well as the programs proposed by the authors to solve numerically the model and estimate it using observed data for US and Euro area economies. A Companion

[6] In this model, the entrepreneur combines personal wealth and loan provided by the financial intermediary to transform raw capital into effective capital. The technology through this process is specific to each entrepreneur, approximated by an idiosyncratic shock applied to raw capital. Entrepreneurs who draws a low value of this idiosyncratic shock experience failure and lenders have to pay to check the state of the firm. The volatility of risk is then defined by CMR as the time-varying standard deviation of these idiosyncratic shocks. An increase in risk means a higher dispersion of idiosyncratic shocks and therefore a higher risk of default. The outcome of optimal financial contract is modified: the leverage ratio of entrepreneurs falls to limit the size of financial losses and the loan interest rate rises to cover the higher risk taken by the lender. This point makes risk shocks different from financial shocks on the wealth of borrowers also referred as equity shocks (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011).

**Figure 1 – Comparison of macroeconomic and financial variables between the Euro area and the US (2007Q4-2013Q4)**




Note: Base 100 = 2007Q4, except for interest rates and spreads which are in Annual Percentage Rate (APR) and Annual Percentage Points (APP) respectively.

Website to this paper is available at http://shiny.cepii.fr/. It provides the main results reported in this paper but can also be used to generate supplementary results and robustness checks.

## 2.1. The CMR's model

We invite to read the CMR paper for a detailed exposition of the model and its economic foundations. The purpose of this section is to provide a brief summary of the CMR model that allows the reader to understand the estimation results provided below. We describe the general equilibrium structure of the model with a focus on the definition of shocks.

### 2.1.1. The general equilibirum model

The CMR model belongs to the class of DSGE models with real and nominal rigidities developed by Christiano et al. (2005), Smets and Wouters (2003), and Smets and Wouters (2007), augmented to include financial accelerator mechanism *à la* Bernanke et al. (1999).

The economy is populated by identical households. Each household contains a unitary continuum of workers and a large number of entrepreneurs. The source of funds of the household are the labor earnings, the bond yields, the revenues of capital which is accumulated by households, and other lump-sum transfers. The household allocates funds to consumption purchases, short-term and long-term bond acquisition, and the purchases of investment goods and existing capital in the economy. The long-term bond interest rate is determined in the model by the expectations for the short-term rate. A shock is included in the long-term bond interest rate to match the term premium in the data. This shock is referred as the "term structure shock". The representative household maximizes the expected value of the discounted utility of its members derived from leisure time and from consumption with habit formation. Preference shocks affect the household utility function. This shock is referred as the "consumption preference shock".

The final good is produced using a continuum of intermediate goods according to a Dixit-Stiglitz technology. The elasticity of substitution among intermediate goods is stochastic to account for markup fluctuations. This shock is referred as the "price markup shock". The producers of intermediate goods use the services of the physical capital and of the labor, according to a stochastic Cobb-Douglas production function subject to transitory shocks on the total factor productivity and growth shocks on the trend of labor technological progress. These shocks are referred as the "temporary technology shock" and the "persistent technology growth shock", respectively. The second source of growth of the model is an investment specific technology growth, which decreases the price of investment. It is also submitted to a shock referred as the "investment price shock".

Prices and wages are subject to nominal rigidities *à la* Calvo. Monopoly suppliers of labor and of intermediate goods can reoptimize their wage and price only periodically (with an exogenous probability) otherwise they follow an indexation rule that depends on the target inflation rate fixed by the monetary authority. This target is submitted to the "inflation target shock". In addition of targeting inflation, monetary authority sets the nominal interest rate given its past value, the deviations of inflation and output with respect to their steady-state values, and a stochastic disturbance, which is referred as the "monetary policy shock". A second policy shock is introduced through the government consumption of final good, which is affected by a stochastic disturbance referred as the "government consumption shock".

Households accumulate raw capital by purchasing the existing undepreciated capital of the economy and investment goods, which are subject to adjustment costs. Adjustment costs are stochastic because of a shock on the marginal efficiency of investment in producing capital, which is referred as the "marginal efficiency of investment shock". Raw capital cannot be directly used in the production sector that uses effective capital. Households sell raw physical capital to entrepreneurs who transform it into effective capital. To buy raw capital, entrepreneurs use their personal wealth and a loan obtained from a financial intermediary. The loan contract is characterized by agency problems subject to financial shocks. Given the importance of financial shocks for our analysis, we provide a more detailed description of these shocks below.

### 2.1.2. The financial shocks

The agency problems are associated with the asymmetric information between the entrepreneur and the financial intermediary that makes costly checking the state of defaulting entrepreneur (hence the expression costly-state verification).

Let $N$ be the personal wealth of the entrepreneur and $B$ the size of the loan.[7] The purchase of $K$ units of raw capital at price $Q_K$ satisfies $Q_K K = N + B$. The $K$ units of raw capital are transformed into $\omega K$ units of effective capital that will be sold to the final good producers. $\omega$ is the idiosyncratic shock that makes risky the business of entrepreneurs. It is observed by the entrepreneur after its purchases of raw capital. If the realized value is too low, namely $\omega < \bar{\omega}$, the entrepreneur defaults because it cannot reimburse the loan. The equilibrium value of $\bar{\omega}$ satisfies

$$R^k \bar{\omega} Q_K K = BZ, \tag{1}$$

where $R^k$ is the return on effective capital and $Z$ the loan interest rate. In this case, the financial intermediary gets the share $1 - \mu < 1$ of the assets of the bankrupt entrepreneur (the collateral) where $\mu$ measures the size of the state verification costs.

The risk shock modifies the standard deviation of the idiosyncratic shocks $\omega$, which has a unit-mean log normal distribution. The standard deviation of $\log(\omega)$ is denoted $\sigma_t$ and evolves as follow

$$\log(\sigma_t/\sigma) = \rho_\sigma \log(\sigma_{t-1}/\sigma) + u_t, \tag{2}$$

where $u_t$ is an iid innovation to the risk in the economy, $\rho_\sigma$ the persistence of the risk shock, and $\sigma$ the steady-state level of risk. An increase in $\sigma_t$ makes higher the cross-sectional dispersion in $\omega$. Because the mean of $\omega$ is unchanged, it means higher probabilities for low realizations of $\omega$ and therefore higher default risk in the economy. This shock is referred as the "risk shock".

The second financial shock modifies the net wealth of entrepreneurs. With a stochastic probability, the household takes all the wealth of the entrepreneur. The entrepreneur can however still get a loan thank to an exogenous transfer from the households, but the agency problems are reinforced because the value of its assets (or the collateral) is reduced. This shock is referred as the "equity shock".

Finally, CMR consider news on the risk shock that evolves as follows

$$u_t = \xi_{0,t} + \xi_{1,t-1} + \ldots + \xi_{p,t-p}, \tag{3}$$

where $\xi_{0,t}$ is the unanticipated component of $u_t$ and $\xi_{j,t-j}$ for $j > 0$ is the anticipated (or news) components of $u_t$. These shocks are referred to "news shocks".

[7] To simplify the presentation we omit the time index.

## 2.2. Inference about parameters

### 2.2.1. Presentation of data

We use quarterly observations on twelve variables covering the period 1987Q1-2013Q4. These include eight variables that are standard in bayesian estimation of DSGE models: GDP, consumption, investment, inflation, wage, price of investment, hours worked and short-term risk-free interest rate. As CMR, we also use four financial variables: credit, slope of the term structure of interest rates, entrepreneurial networth and credit spread. See Appendix A for all the details about the different series.

For Euro area, we use the Area-wide Model (AWM) database (Fagan et al., 2001), up to 2010Q4.[8] We then link, where it is feasible, the data contained in the orginal AWM database to the official euro area data. This is consistent because the AWM database has been constructed using both euro area data reported in the ECB Monthly Bulletin and other ECB and Eurostat data where available.

Credit spread is a key variable in the estimation of a model with financial frictions. So the choice of a different definition from CMR in the European case has to be explained. Indeed, corporate bond spread appears as a good proxy of credit spread where lending is mostly done by financial markets, as in the US. However, when financial system is dominated by banks, as in the Euro area, it seems more appropriate to choose an average of the retail bank interest rates.[9]

### 2.2.2. Calibration

Table 1 contains a description of the parameters that we fix during the estimation.

### 2.2.3. Estimation

The model is estimated through Bayesian procedures surveyed by An and Schorfeide (2007). Tables for estimated structural parameters and shock processes are detailed in Appendix B.

Table 2 report the steady-state properties of the model when parameters are set to their mode under the posterior distribution. The table also reports the corresponding values in the data.

[8]Here we use the 11th update of the AWM database.

[9]Gilchrist and Mojon (2014) construct credit risk indicators for the Euro area as the average spreads that private sector issuers have to pay in addition to the interest rate paid by the German federal government for similar maturities. Even if both series present strong similarities, notably an increase of credit spread since the beginning of 2011, it could be interesting to check the robustness of our estimation using their series.

**Table 1 – Calibrated parameters**

| | | EA | US |
|---|---|---|---|
| $\beta$ | Discount rate | 0.9998 | 0.9987 |
| $\psi_L$ | Disutility weight on labor | 0.7705 | 0.7705 |
| $\delta$ | Deprecation rate of the economy | 0.020 | 0.025 |
| $\alpha$ | Power on capital in production function | 0.34 | 0.40 |
| $\sigma_L$ | Curvature on disutility of labor | 1 | 1 |
| $\Upsilon$ | Growth rate of investment specific technological change (APR) | 0.40 | 1.70 |
| $\mu_z$ | Growth rate of the economy (APR) | 1.90 | 1.66 |
| $\lambda_w$ | Steady state markup, suppliers of labor | 1.05 | 1.05 |
| $\lambda_f$ | Steady state markup, intermediate good firms | 1.20 | 1.20 |
| $1-\gamma$ | Fraction of entrepreneurial net worth transferred to households | 1-98.50 | 1-98.50 |
| $W^e$ | Transfer received by new entrepreneurs | 0.005 | 0.005 |
| $\Theta$ | Share of resources for state verification | 0.005 | 0.005 |
| $\eta_g$ | Steady state government spending-GDP ratio | 0.21 | 0.20 |
| $\pi^{target}$ | Steady state inflation rate (APR) | 2.00 | 2.43 |
| $\tau^c$ | Tax rate on consumption | 0.195 | 0.05 |
| $\tau^k$ | Tax rate on capital income | 0.256 | 0.32 |
| $\tau^l$ | Tax rate on labor income | 0.381 | 0.24 |

Note: For US data, .

# 3. Explaining the divergence

## 3.1. The role of risk shocks in business cycles

The fluctuation of risk shocks is clearly an important source of business cycles for both economies not only for the last years, as shown in figure 2 and sum up in table 3. Around the half of the business cycle variance in output is accounted for by the risk shock in both economies (55 percent for the US and 49 percent for the Euro area), and more than three-quarters for the variance in investment (81 percent for the US and 78 percent for the Euro area). The importance of risk shocks in the business cycles is consistent with CMR and Christiano et al. (2010).[10]

Risk shocks explain much of credit spread fluctuations. As demonstrated by CMR, the fluctuations of risk are necessary to explain episodes of credit crunch with increase in the credit spread. Given the level of risk, credit spread is the premium asked by lenders given the risk of default. Because the risk of default increases with the entrepreneur's leverage, there is a positive relation between the amount of credit and the credit spread, once again for a constant level of risk. Risk fluctuation implies negative co-movements between credit spread and the growth rate of credit:

[10]See also Darracq Pariès et al. (2011) who conclude that roughly 50 percent of unconditional variances of real macroeconomic variables are explained by financial and housing-specific shocks. Other contributions have concluded on a minor role of financial shocks to explain the volatility of real macroeconomic variables in Europe as Quint and Rabanal (2013). The discrepancy between these strands of the literature can be explained by differences in the definition of financial shocks. In Quint and Rabanal (2013) the financial accelerator mechanism is placed on the household side and the risk shocks concern the quality of housing stock.

**Table 2 – Steady state properties : Model versus Data**

| | | Model EA | Data EA | Model US | Data US |
|---|---|---|---|---|---|
| $c/y$ | private consumption/GDP | 56% | 57% | 54% | 59% |
| $i/y$ | investment/GDP | 23% | 21% | 26% | 24% |
| $g^c/y$ | public consumption/GDP | 21% | 21% | 20% | 16% |
| $n/(k-n)$ | equity to debt | 0.9 | 1.6 | 1.0 | 1.3-4.7 |
| $R-R^k$ | external finance premium (APP) | 3.1% | 1.7% | 3.0% | 2.1% |
| $\pi$ | inflation (APR) | 2.0% | 2.0% | 2.4% | 2.5% |
| $R$ | short-term risk free rate (APR) | 4.0% | 4.0% | 4.7% | 4.8% |
| $\mu_z^*$ | GDP per capita growth (APR) | 1.9% | 1.9% | 1.6% | 1.9% |
| $\Upsilon$ | investment technology growth (APR) | 0.4% | 0.4% | 1.7% | 1.0% |

Note: For US data, all sample averages are computed over the period 1985Q1:2008Q2, except inflation, short-term interest rate and finance premium, which are computed over 1987Q1:2008Q2. For Euro area data, all sample averages are computed over the period 1987Q1:2008Q2, except inflation, short-term interest rate and external finance premium, which are computed over 1994Q1:2008Q2 (from the beginning of the Maastricht Treaty) and the equity to debt ratio (for non financial corporations), from 1999Q1.

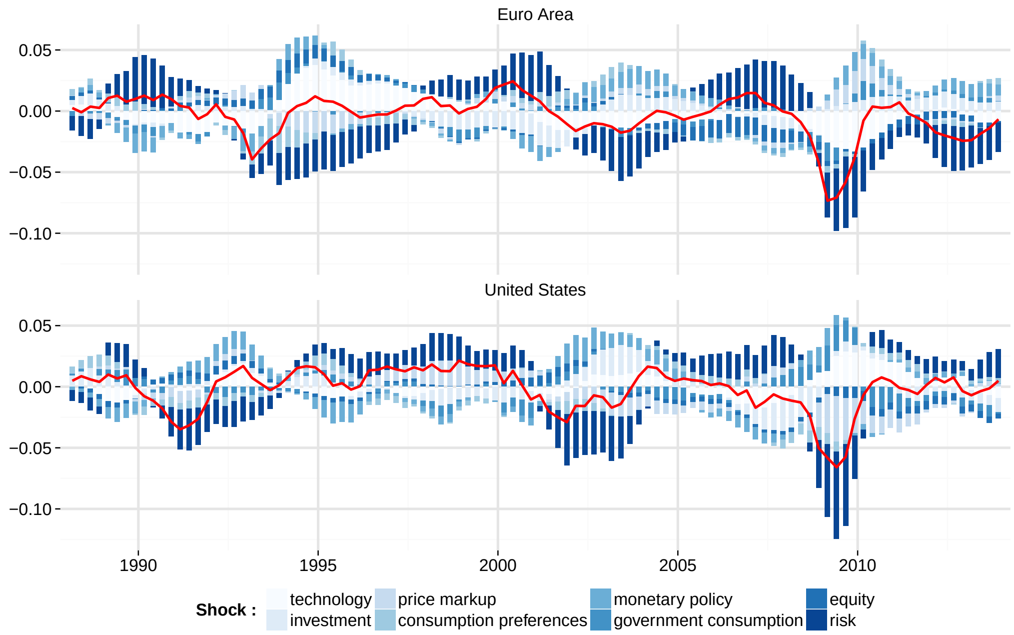
when risk is higher, lenders lent less and asked a greater premium. The figure 3 shows the bayesian impulse response functions of these variables to an unanticipated innovation in the risk shock.

### 3.2. The role of risk shocks in the divergence

Figures 4 and 5 focus on the period since 2007. Figure 4 compares historical real GDP per capita with its simulated values, feeding only risk shocks to the model. Figure 5 provides a detailed view of the role of risk shocks in the business cycles for four key variables: credit spread and growth rates of GDP, investment, and credit. As shown in Figure 5, risk shocks have negatively contributed to growth in the US between 2008Q3 and 2010Q1, with a trough in 2009Q2. After this period, we observe a reversal in risk shocks that contribute positively to the US output growth since 2010Q2. Actually, the US recovery would have been even weaker without this reversal in risk shocks. As shown in Figure 4, real GDP per capita growth is 2.8 percent between 2007Q4 and 2013Q4 whereas it would have been more than 10 percent without any shocks (given the steady-state growth) and 7.4 percent with only risk shocks, despite their negative contribution to growth during the recession.

The contribution of risk shocks to growth has been different in the Euro area. First, the deterioration of risk in the financial sector comes later with lesser impact on growth during the first recession than in the US. Indeed, the first recession in the Euro area started in 2008Q1 but the negative contributions of risk shocks to growth started in 2008Q4 – see Figure 5. However, the key difference between the two economies is the absence of risk reversal in the Euro area. Actually, it is even worse for the Euro area because the negative contribution of risks increases after 2011Q1 giving rise to the double-dip recession. As shown in Figure 4, the real GDP per capita growth is -2.4 percent between 2007Q4 and 2013Q4 whereas it would have been more

**Figure 2 – Historical shock decomposition of the growth rate of real GDP per capita, year-on-year (1988Q1-2013Q4)**




Note : The red line is the growth of actual real GDP per capita (year-on-year). Risk is the sum of the contributions explained by anticipated and unanticipated components of the risk shocks, investment is the sum of the contributions explained by investment price and investment efficiency shocks and technology is the sum of the contributions explained by temporary technology and persistent technology growth shocks. Business cycle frequency is measured through an Hodrick-Prescott filter with $\lambda = 1600$.

than 10 percent without any shocks (given the steady-state growth) and -6.4 percent with only risk shocks.

Since 2007, risk fluctuations are at the origin of the sharp rise and fall in the US credit spread associated with the credit crunch followed by a rapid credit growth that drives the growth of investment and output – see Figure 5. For the Euro area, we do not observe a substantial fall of the credit spread after first recession of 2008-2009, on the contrary it increases once again in 2011. Consequently, credit growth has continued to fall and the growth rates of investment and output are still below their steady-state value.

Cumulated growth since the beginning of the crisis is 5 percentage points higher in the US than in the Euro area nowadays, whereas it would have been three times higher if only risk shocks had occured in these economies. It means that other shocks have increased growth in the Euro area and decreased it in the US in a way that dampens the divergence between the two economies.

**Table 3 – Variance decomposition at business cycle frequency (Percent)**

| | risk | equity | investment | technology | markup | cons. pref. | monetary | gov. exp. |
|---|---|---|---|---|---|---|---|---|
| gdp | 54 | 0 | 7 | 14 | 8 | 3 | 2 | 13 |
| consumption | 11 | 0 | 9 | 26 | 14 | 36 | 3 | 1 |
| investment | 79 | 0 | 14 | 1 | 3 | 0 | 1 | 0 |
| credit | 48 | 29 | 11 | 3 | 7 | 1 | 1 | 0 |
| networth | 65 | 2 | 28 | 0 | 1 | 0 | 2 | 0 |
| credit spread | 93 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| inflation | 47 | 0 | 10 | 10 | 30 | 2 | 1 | 0 |
| hours worked | 60 | 0 | 10 | 10 | 12 | 2 | 2 | 3 |
| wage | 0 | 0 | 0 | 90 | 8 | 0 | 0 | 0 |
| interest rate | 64 | 0 | 12 | 5 | 11 | 3 | 5 | 0 |
| slope | 63 | 0 | 9 | 2 | 9 | 1 | 6 | 0 |
| invest. price | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| gdp | 44 | 1 | 4 | 12 | 9 | 14 | 4 | 11 |
| consumption | 0 | 0 | 9 | 14 | 10 | 60 | 3 | 2 |
| investment | 72 | 2 | 18 | 3 | 4 | 0 | 2 | 0 |
| credit | 13 | 61 | 8 | 4 | 12 | 0 | 2 | 0 |
| networth | 57 | 5 | 34 | 0 | 1 | 0 | 4 | 0 |
| credit spread | 90 | 2 | 8 | 0 | 0 | 0 | 1 | 0 |
| inflation | 14 | 0 | 8 | 14 | 59 | 1 | 2 | 0 |
| hours worked | 41 | 1 | 13 | 14 | 15 | 10 | 3 | 3 |
| wage | 0 | 0 | 1 | 72 | 25 | 0 | 0 | 0 |
| interest rate | 32 | 1 | 16 | 8 | 27 | 2 | 14 | 0 |
| slope | 33 | 1 | 10 | 4 | 22 | 1 | 14 | 0 |
| invest. price | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |

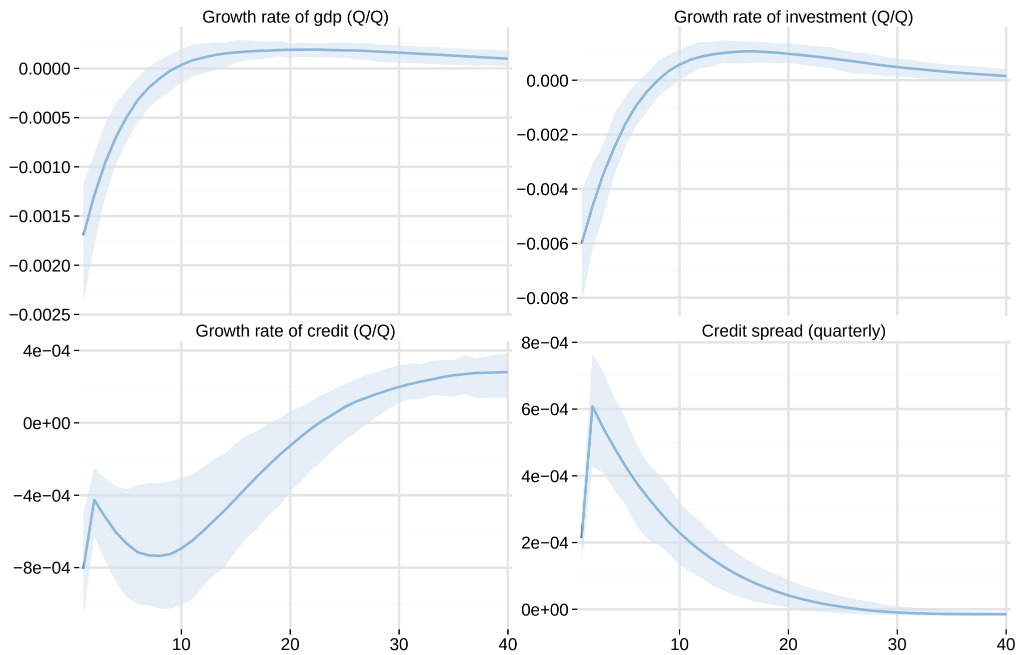
Note : For each variable in row, risk column is the sum of the variance explained by anticipated and unanticipated components of the risk shocks, investment column is the sum of the variance explained by investment price and investment efficiency shocks and technology column is the sum of the variance explained by temporary technology and persistent technology growth shocks. Numbers in each row may not add up to 100 as we ignore the correlation between the shocks when we add explained variances.

## 3.3. The role of other shocks and structure

Risk shocks are not the only reason of the 2008-2009 Euro area recession. The second reason is a sequence of negative temporary productivity shocks between 2008Q3 and 2010Q3. However, their contribution to the first recession is inferior to that of risk shocks, which is twice higher, and there is no substantial productivity growth during the second recession. Actually, risk shocks are by far the most important negative source of growth during the second recession. Three sources of shocks have helped to mitigate the effects of the rising risks: a temporary fall in price mark-up (only during the first recession.), improvements in marginal efficiency of investment, and monetary policy shocks. We find only small effects of government consumption shocks.

Risk shocks are not the sole reason of the first recession in the US. The second reason by order

**Figure 3 – Bayesian IRFs after increasing risk shock in the Euro area**




Note : 90% confidence interval.

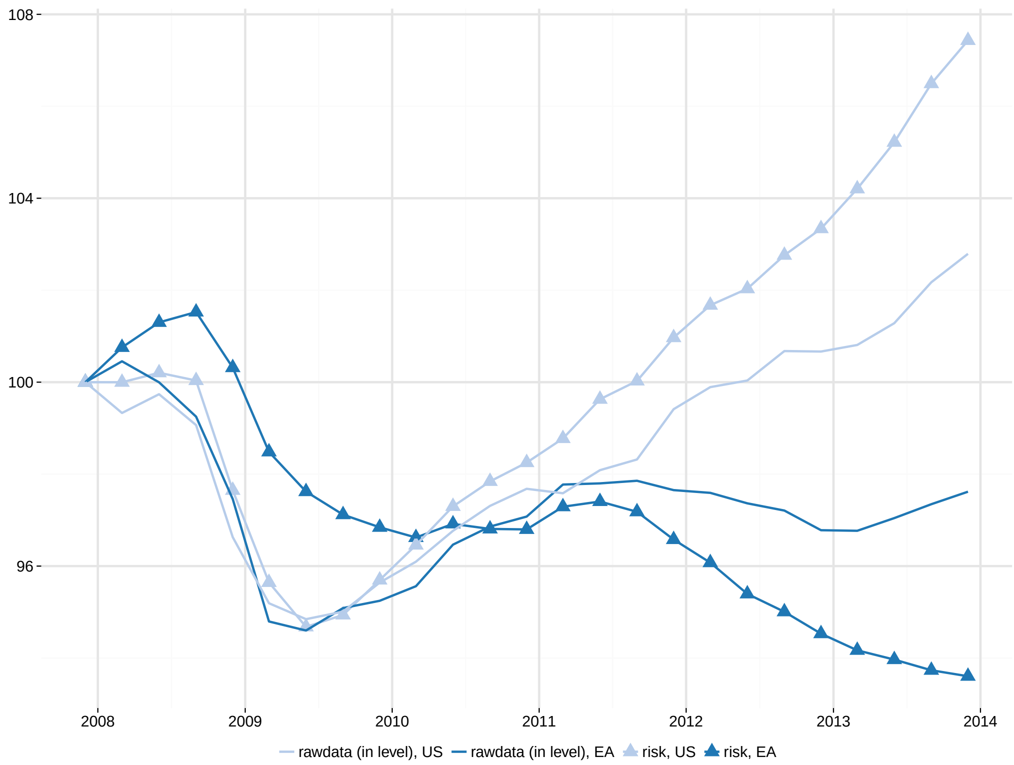
of importance is price markup shocks. The rise of risk and of price markup are mitigated by a positive temporary productivity shocks and positive government shocks (they turned negative after the recession).

Euro area and US economies differ with respect to the historical shocks and the structure of their economies. The economy's structure is characterized in our setup by the values of the structural parameters related with market frictions (as wage/price rigidity) and policy (as the coefficient of the taylor rule). To assess the role of structure in the divergence between Euro area and US two economies, we perform a counter-factual analysis that imposes in US economy the historical shocks of Euro area economy. Results in figure 6 show that differences in structure play a minor role when compared with the role of shocks. Importantly, the US economy would have also experienced a double-dip recession assuming the Euro area sequence of shocks and the US economic structure.

## 4. Relation to other narratives of the Great Recession

Why the Euro area economy fell a second time in 2011 and not the US economy? According to our estimation's results, risk shocks are central to explain the divergence because they are at the origin of both US recovery and Euro area double-dip recession. This section compares this interpretation with other narratives of these recent recessions.

**Figure 4 – Historical and simulated real GDP per capita in the US and the Euro area (base 100 = 2007Q4)**



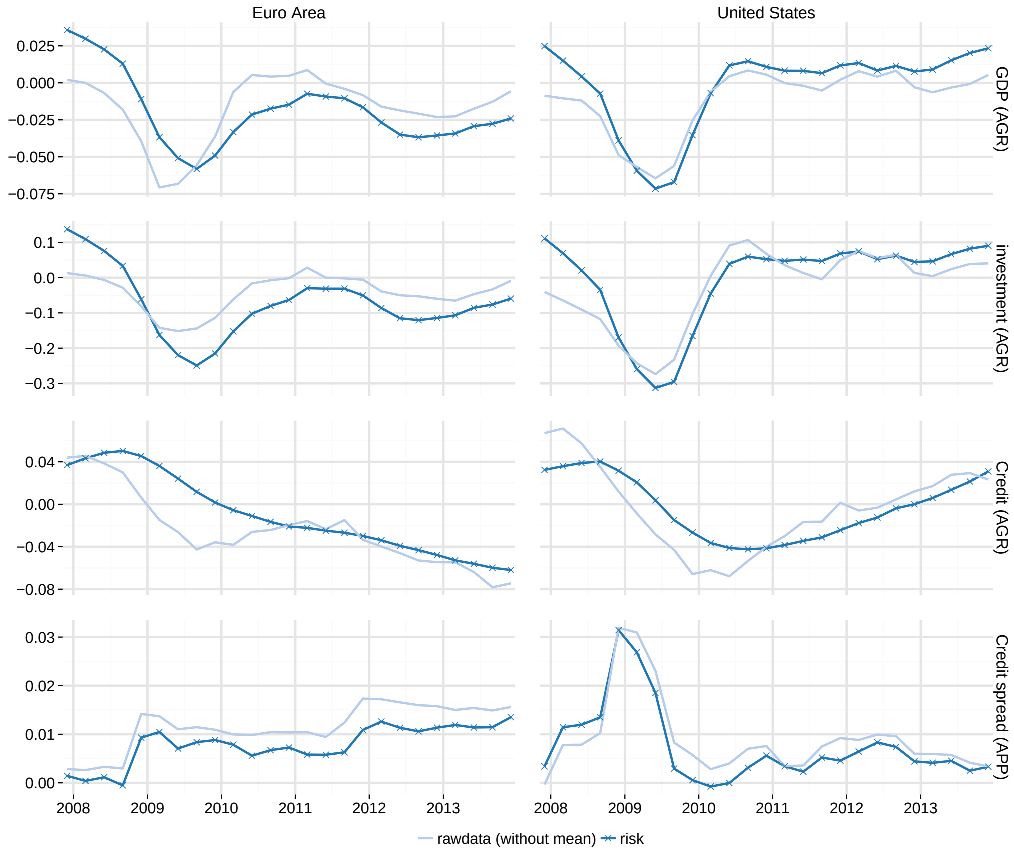

Note: The solid lines are the historical data and the starred lines are the simulated data, feeding only the estimated anticipated and unanticipated components of the risk shock to the model.

### 4.1. What drives the US "modest recovery"?

For the US economy, our analysis is by construction close to that of CMR since we use the theoretical setup and empirical methodology developed by the authors. Our contribution is to extend the sample of data up to 2013Q4 while the sample of CMR stopped in 2010Q2. CMR demonstrated that risk shocks account for the full magnitude of the GDP variations between 2008 and 2010. Our results complement this analysis by demonstrating the positive role of risk shocks between 2010 and 2013. After the financial crisis of 2007-2009, the amount of risk in the US economy not only return to its normal level, it goes below in such a way that it is the main source of growth of the current expansion. It is worth to emphasize that this interpretation of the recent US experience is still under debate especially for the last years. If there is a consensus on the role of financial shocks in the contraction/recovery of 2008-2010, it is not the case for the period after 2010.

In Del Negro et al. (2013), positive contributions of risk shocks are observed only during three quarters in 2009 and then turned negative in the subsequent quarters. Sala et al. (2013) and

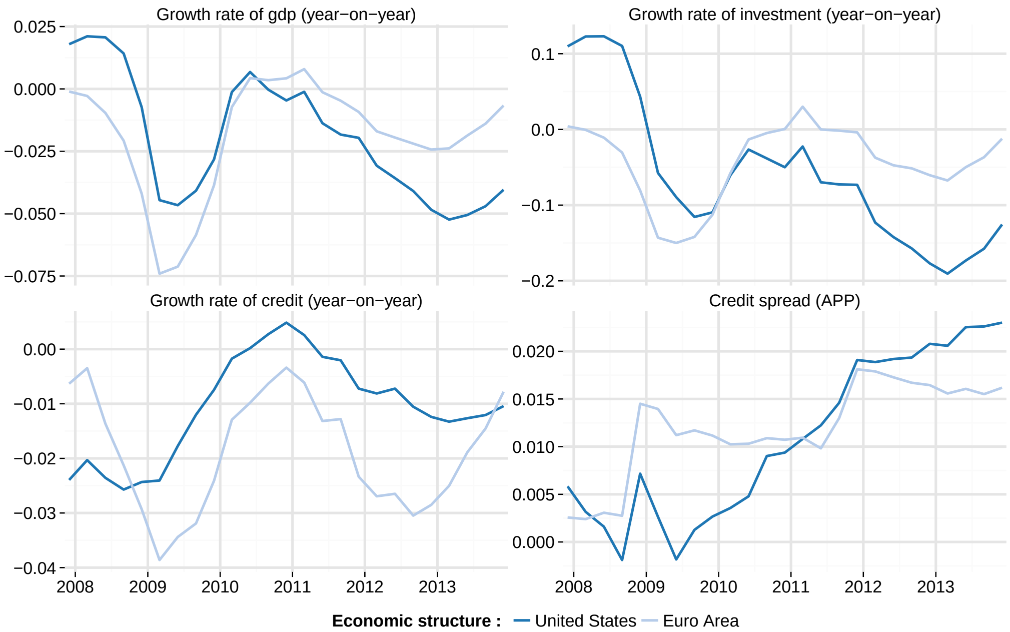
**Figure 5 – The role of the risk shock in observed variables in the Euro area ans the US (2007Q4-2013Q4)**




Note : The starred line is the result of feeding only the estimated anticipated and unanticipated components of the risk shock to the model.

Galí et al. (2012) estimate DSGE models with equity premium shocks as financial shocks (but no risk shocks) and conclude that the contribution of financial shocks to GDP is always negative between 2008 and 2011. To explain our results on the positive role of risk shocks, it is important to notice that contrary to Sala et al. (2013) and Galí et al. (2012) we consider risk shocks as financial shocks (and not only equity premium shocks) and that contrary to Del Negro et al. (2013) use both the total credit series to estimate the model, as suggested by CMR, and not only the credit spread as done by Del Negro et al. (2013). Actually, the credit spread returned to its average value or slightly above since 2010Q1 while credit growth is clearly above its average value during the 2012-2013 years, a situation that can be explained by a decrease of risk in the financial sector.

**Figure 6 – EA and US specific economic structures hit by all EA shocks**




Note :

## 4.2. Is Euro area double-dip recession financial?

The first Euro area recession of 2009 can be interpreted as a financial recession given the important contributions of risk shocks even if they do not account for the full magnitude as for the US case. This result confirms the earlier finding of Christiano et al. (2010) who compare the role of financial frictions in Euro area and US business cycles up to 2008Q2. In a similar vein, Gerali et al. (2010) and Kollmann et al. (2013) attribute the output contraction of 2008-2009 to shocks originating in the banking sector.[11] Less evidences are provided in the literature to the second recession of 2011, which is one of our contribution to this literature. An exception is Sala et al. (2013), but they report a weak role for financial shocks in the business cycles of three European countries (namely the UK, Sweden, and Germany)[12] during the period 2007-2011. However, first, they do not consider risk shocks as financial shocks but risk premium shocks and, second, the three selected countries do not experienced a double-dip recession as observed by ourselves for the Euro area and by Reinhart and Rogoff (2014) for the following members of the Euro area: France, Ireland, Italy, Netherlands and Portugal.

To the best of our knowledge, we provide the first structural interpretation based on an estimated DSGE of the 2011 recession in the Euro area and attribute it to an increase of the risk in the

[11] In Lombardo and McAdam (2012), financial shocks contribute strongly to the fluctuations of house prices and to a lesser extent to that of output between 2008 and 2010.

[12] Even if the first two countries does not take part of the Euro area, Germany is the biggest.

financial sector. The years around 2011 have been marked in Europe by the sovereign debt crisis of state members of the Euro area as Greece, Portugal, Ireland, Spain, and Cyprus. Because of the "doom loop" between the sovereign and bank debts, the sovereign debt crisis has been a major source of tensions in the European banking industry detrimental to the real activity – see Reichlin (2014). How can we relate these key events to our structural estimation given the absence of sovereign and bank debts in our theoretical setup?

CMR explain that risk shocks can be interpreted as shocks on the riskiness of the business done by entrepreneurs or by financial firms because the households are the ultimate lenders. In the former case, there is no agency problem between households and intermediaries who lent to entrepreneurs with asymmetric information. In the latter, information is asymmetric between households and financial intermediaries, but not with the entrepreneurs. Using the second interpretation of the model, we can establish a link between the financial distress of banks during the sovereign debt crisis in Europe and the high contribution of shocks in the 2011 Euro area recession, which is characterized by high level of credit spread and negative growth rates of total credit in the economy.

## 5. Conclusion

The recent divergence between the Euro area and the US, abundantly commented in the press, will surely constitute an important field for future research. Why the Euro area economy fall a second time in 2011 and not the US economy? We proposed in this paper an answer based on the estimation of the DSGE model with financial frictions developed by Christiano et al. (2014a). According to our estimation's results, risk shocks are central to explain the divergence because they are at the origin of both the US recovery and the Euro area double-dip recession. The second financial recession of 2011 in Euro area can be explained by the sovereign debt crisis that has increased the risk in the financial sector given the "doom loop" between bank and sovereign debts. Explaining the sources of the reduction in financial risk after 2009 in the US is also puzzling and call for further research.

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# Appendix

## A. Data

- GDP
  - US : Real Gross Domestic Product, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate (Fred series)
  - EA :
    * 1987Q1 - 2010Q4 : Real Gross Domestic Product (AWM: YER)
    * 2011Q1 - 2013Q2 : Gross domestic product at market price, Chain linked volumes, reference year 2005, Quarterly, Working day and seasonally adjusted, EA 17 fixed composition (ECB series)
- Consumption
  - US : Real Personal Consumption Expenditures: Nondurable Goods + Real Personal Consumption Expenditures: Services, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate (Fred series1 + series2 and before 1999, BEA NIPA Table 2.3.3)
  - EA :
    * 1987Q1 - 2010Q4 : Real Private Consumption (AWM: PCR)
    * 2011Q1 - 2013Q2 : Final consumption of households and NPISH's, Chain linked volumes, reference year 2005, Quarterly, Working day and seasonally adjusted, EA 17 fixed composition (ECB series)
- Investment
  - US : Real Personal Consumption Expenditures: Durable Goods + Real Gross Private Domestic Investment, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate (Fred series1 + series2 and before 1999, BEA NIPA Table 2.3.3)
  - EA :
    * 1987Q1 - 2010Q4 : Real Gross Investment (AWM : ITR)
    * 2011Q1 - 2013Q2 : Gross fixed capital formation, Chain linked volumes, reference year 2005, Quarterly, Working day and seasonally adjusted, EA 17 fixed composition (ECB series)
- Inflation
  - US : GDP Implicit Price Deflator, Index 2009=100, Quarterly, Seasonally Adjusted (Fred series), logarithmic first difference
  - EA :
    * 1987Q1 - 2010Q4 : Deflator of Gross Domestic Product (AWM: YED), logarithmic first difference
    * 2011Q1 - 2013Q2 : Deflator of Gross domestic product at market price, Quarterly, Working day and seasonally adjusted, EA 17 fixed composition (ECB series), logarithmic first difference
- Price of investment
  - US : Gross Private Domestic Investment Implicit Price Deflator, Index 2009=100, Quarterly, Seasonally Adjusted (Fred series), divided by GDP Deflator
  - EA :
    * 1987Q1 - 2010Q4 : Deflator of Gross Investment (AWM: ITD), divided by GDP Deflator
    * 2011Q1 - 2013Q2 : Deflator of Gross fixed capital formation, Quarterly, Working day and seasonally adjusted, EA 17 fixed composition (ECB series), divided by GDP Deflator
- Hours worked
  - US : Nonfarm Business Sector: Hours of All Persons, Index 2009=100, Quarterly, Seasonally Adjusted (Fred series)
  - EA :
    * 1987Q1 - 1999Q4 : Hours worked by Total Employment, Annually, EA 12 fixed composition (The Conference Board Total Economy Database), converted to quarterly data by the weight of Total Employment, Quarterly, Working day and seasonally adjusted, EA 17 fixed composition (ECB series)

    - 2000Q1 - 2013Q2 : Hours of All Employees, Quarterly, Working day and seasonally adjusted, EA 17 fixed composition (ECB series)
- Wage
  - US : Nonfarm Business Sector: Compensation Per Hour, Index 2009=100, Quarterly, Seasonally Adjusted (Fred series), divided by GDP Deflator
  - EA :
    - 1987Q1 - 2010Q4 : Nominal Compensation to Employees (AWM: WIN), divided by Hours worked and by GDP Deflator
    - 2011Q1 - 2013Q2 : Compensation of Employees, received by Households and NPISH's, Quarterly, Seasonally adjusted, EA 17 fixed composition (Eurostat Quarterly sector accounts), divided by Hours worked and by GDP Deflator
- Short-term risk-free rates
  - US : Effective Federal Funds Rate, Percent, Quarterly, Not Seasonally Adjusted (Fred series)
  - EA :
    - 1987Q1 - 2005Q1 : Nominal Short-Term Interest Rate (AWM: STN) and Euribor 3-month, Historical close, Quarterly, average observation through period, Euro area changing composition (ECB series)
    - 2005Q2 - 2013Q2 : 3-month EONIA swap (Datastream: EUEON3M)
- Credit
  - US : Nonfinancial Noncorporate Business; Credit Market Instruments; Liability + Nonfinancial Corporate Business; Credit Market Instruments; Liability, Level, Billions of Dollars, Quarterly, Not Seasonally Adjusted (Fred series1 + series2), divided by GDP Deflator
  - EA : Loans to Non-MFIs excluding general government sector, Outstanding amounts at the end of the period (stocks), Monthly, Neither seasonally nor working day adjusted, Euro area changing composition (ECB series), divided by GDP Deflator
- Credit spread
  - US : Moody's Seasoned Baa Corporate Bond Yield, Percent, Quarterly, Not Seasonally Adjusted (Fred series), less 10-year Government Bond Yield
  - EA :
    - 1987Q1 - 1999Q4 : Weighted average of individual country historical lending rates (IMF International Financial Statistics), less Short-term risk free interest rate
    - 2000Q1 - 2013Q2 : Interest Rates on Loans to Non-Financial Corporations (other than revolving loans and overdrafts, convenience and extended credit card debt), Total amount, New business, Euro area changing composition (ECB series), less Short-term risk free interest rate
- Slope of the term structure
  - US : Long-Term Government Bond Yields: 10-year: Main (Including Benchmark) for the United States, Percent, Quarterly, Not Seasonally Adjusted (Fred series), less Effective Federal Funds Rate
  - EA :
    - 1987Q1 - 2010Q4 : Long-term Interest Rate (AWM: LTN), less Short-term Interest Rate
    - 2011Q1 - 2013Q2 : Long-term government bond yields (in most cases 10 years), Quarterly, average observation through period, Euro area 18 (OECD StatExtracts General Statistics, Key Short-Term Economic Indicators), less Short-term Interest Rate
- Entrepreneurial networth
  - US : Wilshire 5000 Total Market Index, Quarterly, Not Seasonally Adjusted (Fred series), divided by GDP Deflator
  - EA : Dow Jones Euro Stoxx Price Index, Historical close, Quarterly, average observation through period, Euro area changing composition (ECB series), divided by GDP Deflator
- Population
  - US : Working Age Population: Aged 15-64: All Persons for the United States, Persons, Quarterly,

Seasonally Adjusted (Fred series)

– EA :
  * 1987Q1 - 2004Q4 : Total Population from 15 to 64 years on 1 January, converted to quarterly data by interpolation (Eurostat Population)
  * 2005Q1 - 2013Q2 : Working Age Population: Aged 15-64: All Persons for the Euro Area, Persons, Quarterly, Seasonally Adjusted (Fred series, from OECD: Main Economic Indicators, Labour Force Survey)

# B. Other results from estimation

## B.1. Results for the US

**Table B.1 – Results from Metropolis-Hastings (parameters)**

| | Prior distribution | Prior mean | Prior s.d. | Posterior mean | Posterior s.d. | HPD inf | HPD sup |
|---|---|---|---|---|---|---|---|
| *xiw_p* | beta | 0.750 | 0.1000 | 0.737 | 0.0283 | 0.6889 | 0.7792 |
| *b_p* | beta | 0.500 | 0.1000 | 0.742 | 0.0384 | 0.6868 | 0.8060 |
| *Fomegabar_p* | beta | 0.007 | 0.0037 | 0.006 | 0.0012 | 0.0040 | 0.0079 |
| *mu_p* | beta | 0.275 | 0.1500 | 0.233 | 0.0394 | 0.1733 | 0.3010 |
| *sigmaa_p* | norm | 1.000 | 1.0000 | 3.123 | 0.7801 | 1.8239 | 4.4113 |
| *Sdoupr_p* | norm | 5.000 | 3.0000 | 9.360 | 1.3328 | 7.1847 | 11.6461 |
| *xip_p* | beta | 0.500 | 0.1000 | 0.798 | 0.0312 | 0.7495 | 0.8496 |
| *aptil_p* | norm | 1.500 | 0.2500 | 2.464 | 0.1460 | 2.2272 | 2.7001 |
| *rhotil_p* | beta | 0.750 | 0.1000 | 0.872 | 0.0131 | 0.8513 | 0.8940 |
| *iota_p* | beta | 0.500 | 0.1500 | 0.804 | 0.0699 | 0.6959 | 0.9151 |
| *iotaw_p* | beta | 0.500 | 0.1500 | 0.597 | 0.1193 | 0.3930 | 0.7784 |
| *iotamu_p* | beta | 0.500 | 0.1500 | 0.939 | 0.0218 | 0.9047 | 0.9735 |
| *adytil_p* | norm | 0.250 | 0.1000 | 0.359 | 0.0956 | 0.2017 | 0.5112 |
| *signal_corr_p* | norm | 0.000 | 0.5000 | 0.442 | 0.0727 | 0.3245 | 0.5598 |
| *rholambdaf_p* | beta | 0.500 | 0.2000 | 0.873 | 0.0341 | 0.8203 | 0.9290 |
| *rhomuup_p* | beta | 0.500 | 0.2000 | 0.971 | 0.0124 | 0.9536 | 0.9916 |
| *rhog_p* | beta | 0.500 | 0.2000 | 0.916 | 0.0238 | 0.8771 | 0.9528 |
| *rhomuzstar_p* | beta | 0.500 | 0.2000 | 0.066 | 0.0403 | 0.0117 | 0.1243 |
| *rhoepsil_p* | beta | 0.500 | 0.2000 | 0.959 | 0.0126 | 0.9395 | 0.9807 |
| *rhosigma_p* | beta | 0.500 | 0.2000 | 0.973 | 0.0080 | 0.9594 | 0.9848 |
| *rhozetac_p* | beta | 0.500 | 0.2000 | 0.916 | 0.0196 | 0.8897 | 0.9508 |
| *rhozetai_p* | beta | 0.500 | 0.2000 | 0.940 | 0.0130 | 0.9206 | 0.9613 |
| *rhoterm_p* | beta | 0.500 | 0.2000 | 0.921 | 0.0298 | 0.8714 | 0.9680 |
| *stdsigma2_p* | invg2 | 0.001 | 0.0012 | 0.035 | 0.0034 | 0.0302 | 0.0418 |
| *stdsigma1_p* | invg2 | 0.002 | 0.0033 | 0.008 | 0.0060 | 0.0006 | 0.0159 |

**Table B.2 – Results from Metropolis-Hastings (standard deviation of structural shocks)**

| | Prior distribution | Prior mean | Prior s.d. | Posterior mean | Posterior s.d. | HPD inf | HPD sup |
|---|---|---|---|---|---|---|---|
| *e_lambdaf* | invg2 | 0.002 | 0.0033 | 0.018 | 0.0039 | 0.0118 | 0.0242 |
| *e_muup* | invg2 | 0.002 | 0.0033 | 0.004 | 0.0003 | 0.0034 | 0.0045 |
| *e_g* | invg2 | 0.002 | 0.0033 | 0.019 | 0.0013 | 0.0169 | 0.0213 |
| *e_muzstar* | invg2 | 0.002 | 0.0033 | 0.010 | 0.0008 | 0.0088 | 0.0114 |
| *e_gamma* | invg2 | 0.002 | 0.0033 | 0.006 | 0.0007 | 0.0051 | 0.0075 |
| *e_epsil* | invg2 | 0.002 | 0.0033 | 0.006 | 0.0004 | 0.0056 | 0.0068 |
| *e_xp* | invg2 | 0.583 | 0.8250 | 0.421 | 0.0304 | 0.3740 | 0.4694 |
| *e_zetac* | invg2 | 0.002 | 0.0033 | 0.024 | 0.0026 | 0.0193 | 0.0279 |
| *e_zetai* | invg2 | 0.002 | 0.0033 | 0.083 | 0.0183 | 0.0538 | 0.1124 |
| *e_term* | invg2 | 0.002 | 0.0033 | 0.003 | 0.0013 | 0.0014 | 0.0054 |

**Table B.3 – Results from Metropolis-Hastings (standard deviation of measurement errors)**

| | Prior distribution | Prior mean | Prior s.d. | Posterior mean | Posterior s.d. | HPD inf | HPD sup |
|---|---|---|---|---|---|---|---|
| *c* | invg | 0.010 | 5.0000 | 0.018 | 0.0007 | 0.0173 | 0.0196 |

## B.2. Results for the EA

### Table B.4 – Results from Metropolis-Hastings (parameters)

| | Prior distribution | Prior mean | Prior s.d. | Posterior mean | Posterior s.d. | HPD inf | HPD sup |
|---|---|---|---|---|---|---|---|
| *xiw_p* | beta | 0.750 | 0.1000 | 0.837 | 0.0321 | 0.7868 | 0.8846 |
| *b_p* | beta | 0.500 | 0.1000 | 0.703 | 0.0815 | 0.5702 | 0.8097 |
| *Fomegabar_p* | beta | 0.007 | 0.0037 | 0.013 | 0.0030 | 0.0085 | 0.0177 |
| *mu_p* | beta | 0.275 | 0.1500 | 0.080 | 0.0146 | 0.0578 | 0.1052 |
| *sigmaa_p* | norm | 2.000 | 0.5000 | 2.170 | 0.4762 | 1.4166 | 2.9345 |
| *Sdoupr_p* | norm | 5.000 | 3.0000 | 11.495 | 2.6890 | 7.3950 | 15.6161 |
| *xip_p* | beta | 0.500 | 0.1000 | 0.773 | 0.0517 | 0.7012 | 0.8479 |
| *aptil_p* | norm | 1.500 | 0.2500 | 2.412 | 0.1755 | 2.1231 | 2.6975 |
| *rhotil_p* | beta | 0.750 | 0.1000 | 0.867 | 0.0158 | 0.8414 | 0.8944 |
| *iota_p* | beta | 0.500 | 0.1500 | 0.899 | 0.0434 | 0.8227 | 0.9639 |
| *iotaw_p* | beta | 0.500 | 0.1500 | 0.364 | 0.1068 | 0.1852 | 0.5239 |
| *iotamu_p* | beta | 0.500 | 0.1500 | 0.899 | 0.0381 | 0.8382 | 0.9605 |
| *adytil_p* | norm | 0.250 | 0.1000 | 0.385 | 0.0899 | 0.2484 | 0.5420 |
| *signal_corr_p* | norm | 0.000 | 0.5000 | 0.367 | 0.0886 | 0.2141 | 0.5010 |
| *rholambdaf_p* | beta | 0.500 | 0.2000 | 0.826 | 0.0820 | 0.6833 | 0.9405 |
| *rhomuup_p* | beta | 0.500 | 0.2000 | 0.954 | 0.0158 | 0.9273 | 0.9776 |
| *rhog_p* | beta | 0.500 | 0.2000 | 0.981 | 0.0175 | 0.9579 | 0.9991 |
| *rhomuzstar_p* | beta | 0.500 | 0.2000 | 0.168 | 0.0732 | 0.0394 | 0.2701 |
| *rhoepsil_p* | beta | 0.500 | 0.2000 | 0.932 | 0.0130 | 0.9115 | 0.9534 |
| *rhosigma_p* | beta | 0.500 | 0.2000 | 0.926 | 0.0249 | 0.8851 | 0.9646 |
| *rhozetac_p* | beta | 0.500 | 0.2000 | 0.741 | 0.1552 | 0.5317 | 0.9329 |
| *rhozetai_p* | beta | 0.500 | 0.2000 | 0.938 | 0.0244 | 0.8966 | 0.9701 |
| *rhoterm_p* | beta | 0.500 | 0.2000 | 0.956 | 0.0157 | 0.9303 | 0.9807 |
| *stdsigma2_p* | invg2 | 0.001 | 0.0012 | 0.041 | 0.0046 | 0.0330 | 0.0472 |
| *stdsigma1_p* | invg2 | 0.002 | 0.0033 | 0.077 | 0.0156 | 0.0551 | 0.1066 |

### Table B.5 – Results from Metropolis-Hastings (standard deviation of structural shocks)

| | Prior distribution | Prior mean | Prior s.d. | Posterior mean | Posterior s.d. | HPD inf | HPD sup |
|---|---|---|---|---|---|---|---|
| *e_lambdaf* | invg2 | 0.002 | 0.0033 | 0.016 | 0.0074 | 0.0063 | 0.0268 |
| *e_muup* | invg2 | 0.002 | 0.0033 | 0.003 | 0.0003 | 0.0030 | 0.0039 |
| *e_g* | invg2 | 0.002 | 0.0033 | 0.015 | 0.0012 | 0.0131 | 0.0170 |
| *e_muzstar* | invg2 | 0.002 | 0.0033 | 0.005 | 0.0005 | 0.0044 | 0.0059 |
| *e_gamma* | invg2 | 0.002 | 0.0033 | 0.014 | 0.0019 | 0.0109 | 0.0168 |
| *e_epsil* | invg2 | 0.002 | 0.0033 | 0.005 | 0.0004 | 0.0043 | 0.0057 |
| *e_xp* | invg2 | 0.583 | 0.8250 | 0.445 | 0.0336 | 0.3846 | 0.4957 |
| *e_zetac* | invg2 | 0.002 | 0.0033 | 0.019 | 0.0028 | 0.0146 | 0.0238 |
| *e_zetai* | invg2 | 0.002 | 0.0033 | 0.065 | 0.0240 | 0.0299 | 0.0970 |
| *e_term* | invg2 | 0.002 | 0.0033 | 0.002 | 0.0005 | 0.0011 | 0.0027 |

### Table B.6 – Results from Metropolis-Hastings (standard deviation of measurement errors)

| | Prior distribution | Prior mean | Prior s.d. | Posterior mean | Posterior s.d. | HPD inf | HPD sup |
|---|---|---|---|---|---|---|---|
| *c* | invg | 0.010 | 5.0000 | 0.014 | 0.0016 | 0.0117 | 0.0169 |