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

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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. Other key macroeconomic and financial variables display a similar pattern, as shown in Figure 1 for both economies since 2007Q4.[2] The divergence is particularly striking given the strong similarity of the timing and the magnitude of the 2008-2009 recessions.[3] In 2013Q4, US economy has overtaken the pre-crisis level of output per capita, which is, in 2013Q4, 3 percent above the 2007Q4 level. Such a growth over six years may appear disappointing, a "modest

[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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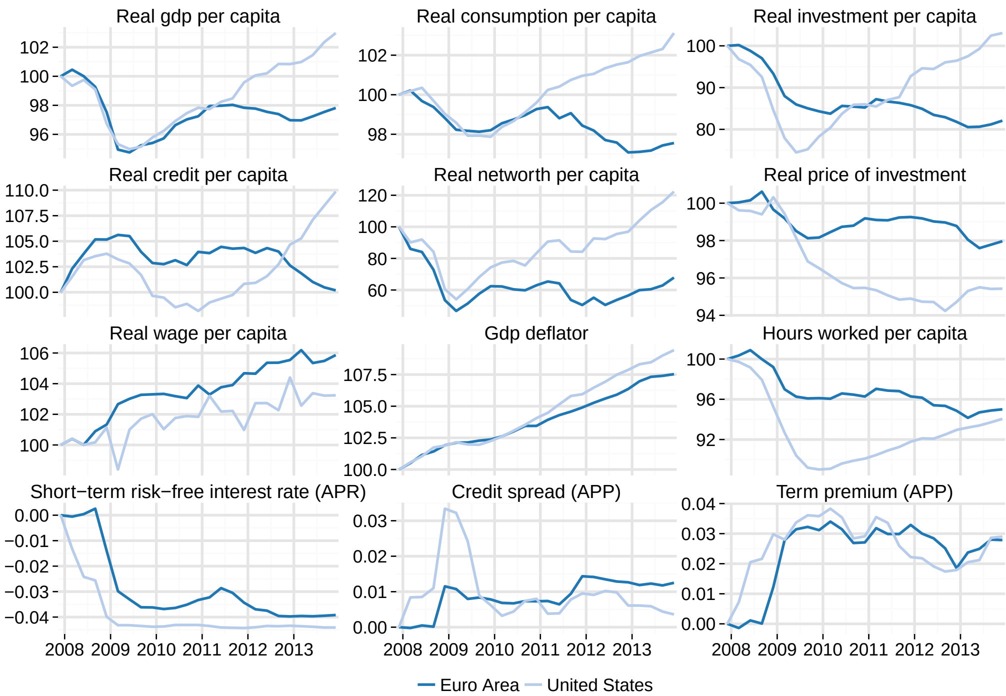
[2]2007Q4 corresponds to the peak date for the US and Euro area enters recession onne quarter later, in 2008Q1, according to the NBER and the CEPR respectively.

[3]There is no difference in the trough dates (2009Q2 for both). The date of the second peak for the Euro area is 2011Q3. The cumulative loss of output between 2007Q4 and 2009Q2 is close to 5 percent in the Euro area and the US (5.2 and 5.0 respectively).

recovery" as qualified by the IMF (2013c) in the World Economic Outlook, but it outweighs the 2.2 percent of negative cumulated 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 worst systemic banking crises. In this paper, we explain this divergence by risk shocks measured as the volatility of idiosyncratic uncertainty in the financial sector. Risk shocks have been introduced in business cycle models by Christiano et al. (2014a) consistently with the counter-cyclical behavior of microeconomic uncertainty measured by Bloom (2009) at the firm level.

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



Note: Index in base 100 = 2007Q4, except for interest rates and spreads which are in deviation from 2007Q4 value in Annual Percentage Rate (APR) and Annual Percentage Points (APP).

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

[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 or monetary policy rules). The main result of their analysis is the difficulty to detect significant differences between

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 Euro area economy do not study the whole double-dip recession.[5]

The choice of the model is delicate because, for comparison purpose, 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).

We estimate the CMR model for US and Euro area economies, with real and financial series over the period 1987Q1-2013Q4. An important part of the business cycle variance in output is accounted for by risk shocks in both economies (54 percent for the US and 41 percent for the Euro area). This important role of risk shocks is consistent with the results reported in Christiano et al. (2010, 2014a).[6] Risk shocks are particularly useful to account for episodes of

the US and European structural characteristics of business cycles.

[5]See Galí et al. (2012), Merola (2013), 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 year of the data sample is 2008 in Darracq Pariès et al. (2011), Christiano et al. (2010) and Villa (2013), 2010 in Coenen et al. (2012) and Lombardo and McAdam (2012) and 2011 in Kollmann et al. (2013).

[6]More precisely, 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). 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).

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. Such a sequence has been observed during the last recessions in US and Euro area economies, as shown in Figure 1.

According to our estimation results, risk shocks clearly dominate all the other shocks to 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 estimation strategy. The section 3 provides our structural interpretation of the divergence. The section 4 discusses our results and their relations to other explanations of the Great recession. The section 5 concludes.

2. Methodology

We use the CMR model and Dynare (Adjemian et al., 2011) to solve the model and estimate it using observed data for US and Euro area economies. A companion 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 display 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) and Smets and Wouters (2003, 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 purchase, short-term and long-term bonds acquisition, and the purchase 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 physical capital and 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 ωK units of effective capital that will be sold to the final good producers. ω 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 μ measures the size of the state verification costs.

The "risk shock" modifies the standard deviation of the idiosyncratic shocks ω, which has a unit-mean log normal distribution. The standard deviation of $\log(\omega)$ is denoted σ_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, ρ_σ is the persistence of the risk shock, and σ the steady-state level of risk. An increase in σ_t makes higher the cross-sectional dispersion in ω. Because the mean of ω is unchanged, it means higher probabilities for low realizations of ω 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 thanks 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 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. We acknowledge that 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, that we choose here.[9]

2.2.2. Calibration

Table 1 contains a description of the parameters that we fix during the estimation. We comment here only calibrated parameters which differ between the Euro area and the US. We set the growth rate μ_z of the unit root technology shock and the quarterly rate of investment-specific technological change Υ to 1.66 percent and 1.70 percent respectively for the US, and to 1.90 percent and 0.40 percent respectively for the Euro area. Short-term risk-free rate and inflation target are fixed at 4% and 2% respectively in annual percent rate for the Euro area and 4.7% and 2.4% for the US.[10] The discount rate are deduced to allow equality of Euler equation at the steady state. η^g is fixed to obtain an appropriate government spending ratio to GDP. For Euro area data, tax rates are sample measn of Eurostat implicit tax rates (1995-2011). Shares of capital in production function differ to account for a lower stock of capital in Euro area.

[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 that we discuss below, it could be interesting to check the robustness of our estimation using their series.

[10] Those figures correspond to the mean of each variable during the period of Great moderation.

Table 1 – Calibrated parameters

		EA	US
β	Discount rate	0.9998	0.9987
ψ_L	Disutility weight on labor	0.7705	0.7705
δ	Deprecation rate of the economy	0.025	0.025
α	Power on capital in production function	0.30	0.40
σ_L	Curvature on disutility of labor	1	1
Υ	Growth rate of investment specific technological change (APR)	0.40	1.70
μ_z	Growth rate of the economy (APR)	1.90	1.66
λ_w	Steady state markup, suppliers of labor	1.05	1.05
λ_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
Θ	Share of resources for state verification	0.005	0.005
η_g	Steady state government spending-GDP ratio	0.21	0.20
π^{target}	Steady state inflation rate (APR)	2.00	2.43
R	Short-term risk-free interest rate (APR)	4.00	4.70
τ^c	Tax rate on consumption	0.195	0.05
τ^k	Tax rate on capital income	0.256	0.32
τ^l	Tax rate on labor income	0.381	0.24

2.2.3. Estimation

The model is through Bayesian procedures surveyed by An and Schorfeide (2007). Prior and posterior of estimated structural parameters and shock processes are detailed in Appendix B. Table 2 reports the steady-state properties of the model when parameters are set to their mode under the posterior distribution. This table also reports the corresponding historical values.

For the US economy, results are compared with those reported by CMR to assess how estimation results are sensitive to the selected period. Actually, the single difference for the US economy is that our sample period is 1987Q1-2013Q4 against 1985Q1-2010Q2 in CMR. Our results for the Euro area must be compared with those of Christiano et al. (2010). Even if the model used by these authors in Christiano et al. (2010) is slightly different than the one used in CMR, the key parameters that determine the real, nominal and real frictions can be directly compared.

Our posterior median are close to that of CMR except for some parameters with a difference about 0.1, but no major changes.

We compare the 80 percent interval confidences to identify some structural differences between the two economies. The difference between two estimated parameter values is considered as significant when the two interval confidences do not overlap.

There is no significant difference for most structural parameters: rigidities of prices and wages, degree of habit formation, curvature of the investment and utilization-cost technologies, weights and persistence of the monetary policy rule. This conclusion is similar to that of Smets and

Wouters (2005) for real rigidities, who report significant differences only for nominal rigidities.

Actually, significant differences are observed only for the financial sector. The monitoring cost is higher in the US than in the Euro area for a lower steady state probability of default whereas it is the opposite for the steady-state probability of default.

When it comes to the shock parameters, significant differences are observed only for the standard deviations of the unanticipated risk shock, which is higher in the Euro area than in the US, of the persistent technology shock, which is higher in the US than in the Euro area, of equity shock, which is higher in the Euro area than in the US, and of the measurement error on networth, which is higher in the US than in the Euro area. No significant difference is observed for the persistence of shocks.

Table 2 – Steady state properties : Model versus Data

		Model EA	Data EA	Model US	Data US
i/y	investment/GDP	0.22	0.21	0.27	0.24
c/y	private consumption/GDP	0.57	0.57	0.53	0.59
g/y	public consumption/GDP	0.21	0.21	0.20	0.16
k/y	capital/GDP	7	5	8	11
$n/(k-n)$	equity to debt	0.9	1.6	1.0	1.3-4.7
	transfer received by new entrepreneurs/GDP	0.22	not known	0.17	not known
	banks monitoring costs/GDP	0.53	not known	0.45	not known
	credit velocity	0.21	1.2	0.24	1.7
$R^k - R$	external finance premium (APP)	1.3	1.7	3.0	2.1

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 (data come from CMR). 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.

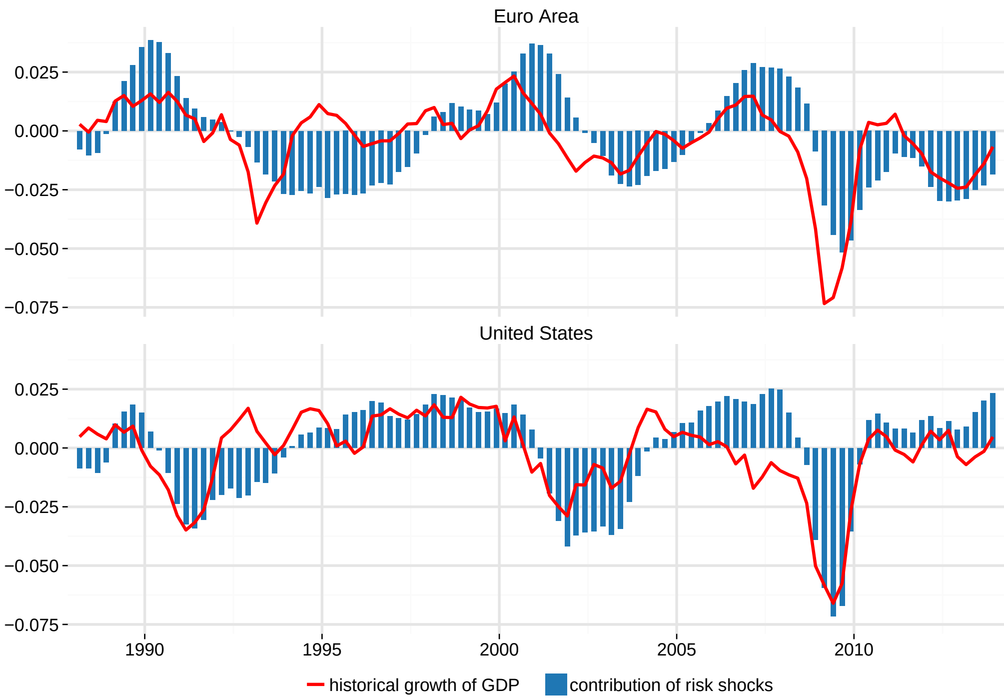
3. Explaining the divergence

3.1. The role of risk shocks in business cycles

The fluctuation of risk shocks is historically an important source of business cycles for both economies as shown in Figure 2 and Table 3, that is largely consistent with Christiano et al. (2010, 2014a). Around the half of the business cycle variance in output is accounted for by the risk shock in both economies (54 percent for the US and 41 percent for the Euro area), and more than three-quarters for the variance in investment (79 percent for the US and 74 percent for the Euro area).

It is necessary to explain the link between risk shocks and GDP growth. In CMR model, the fluctuations of risk are necessary to explain episodes of credit crunch and increase in the credit

Figure 2 – Historical contribution of risk shocks to the growth rate of real GDP per capita, year-on-year (1988Q1-2013Q4)



Note : The red line is the historical growth of real GDP per capita (year-on-year). The "contribution of risk shocks" is the sum of the contributions to GDP fluctuations explained by anticipated and unanticipated components of the risk shocks.

spread simultaneously. Consider the credit spread as 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, for a constant level of risk. Risk fluctuation implies negative co-movements between credit spread and the growth rate of credit: when risk is higher, lenders lent less and asked a greater premium. Figure 3 shows the bayesian impulse response functions of these variables to an unanticipated innovation in the risk shock.

Darracq Pariès et al. (2011) also conclude that roughly 50 percent of unconditional variance 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 3 – Variance decomposition at business cycle frequency (Percent)

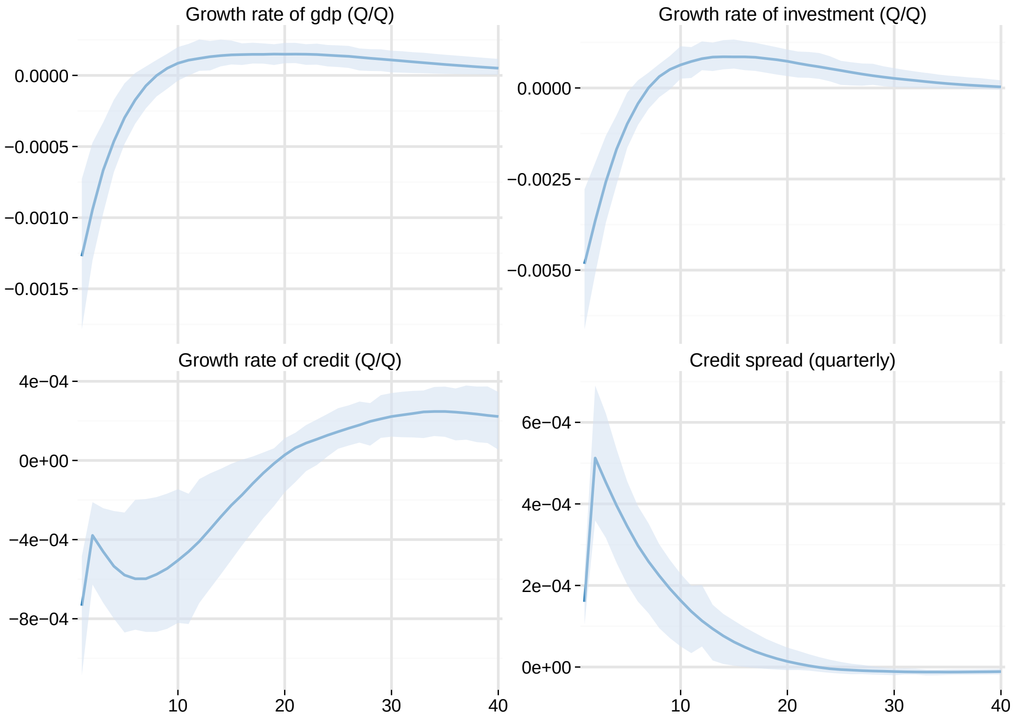
	risk	equity	investment	technology	markup	cons. pref.	mon. pol.	gov. cons.
United States								
gdp	54	0	7	14	8	3	2	13
consumption	11	0	9	26	14	36	3	1
investment	79	0	14	1	3	0	1	0
credit	48	29	11	3	7	1	1	0
networth	65	2	28	0	1	0	2	0
credit spread	93	1	5	0	0	0	0	0
inflation	47	0	10	10	30	2	1	0
hours worked	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
Euro Area								
gdp	41	1	2	16	11	14	4	12
consumption	0	0	8	18	11	56	3	2
investment	74	2	10	4	6	0	3	0
credit	15	64	6	5	7	0	1	0
networth	50	7	37	0	1	0	4	0
credit spread	90	2	7	0	0	0	1	0
inflation	18	0	5	28	45	2	2	0
hours worked	41	1	5	16	20	10	3	3
wage	0	0	1	80	17	0	0	0
interest rate	35	1	9	14	22	2	16	0
slope	38	1	5	7	15	1	14	0
invest. price	0	0	100	0	0	0	0	0

Note : For each observed 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. We omit the contributions of inflation target and term structure shocks. Numbers in each row may not add up to 100 as we ignore the correlation between the shocks when we add explained variances. Business cycle frequency is measured with HP filter ($\lambda = 1600$).

3.2. The role of risk shocks in the divergence

The role of risk shocks is central in explaining the divergence between Euro area and US economies during last recessions. Figure 4 compares actual real GDP per capita with its simulated values, feeding only risk shocks to the model, since 2007Q4. In the US , risk shocks have negatively contributed to growth 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. Actually, the US recovery would have been even weaker without this reversal in risk shocks. Real GDP per capita growth is 3.0 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

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



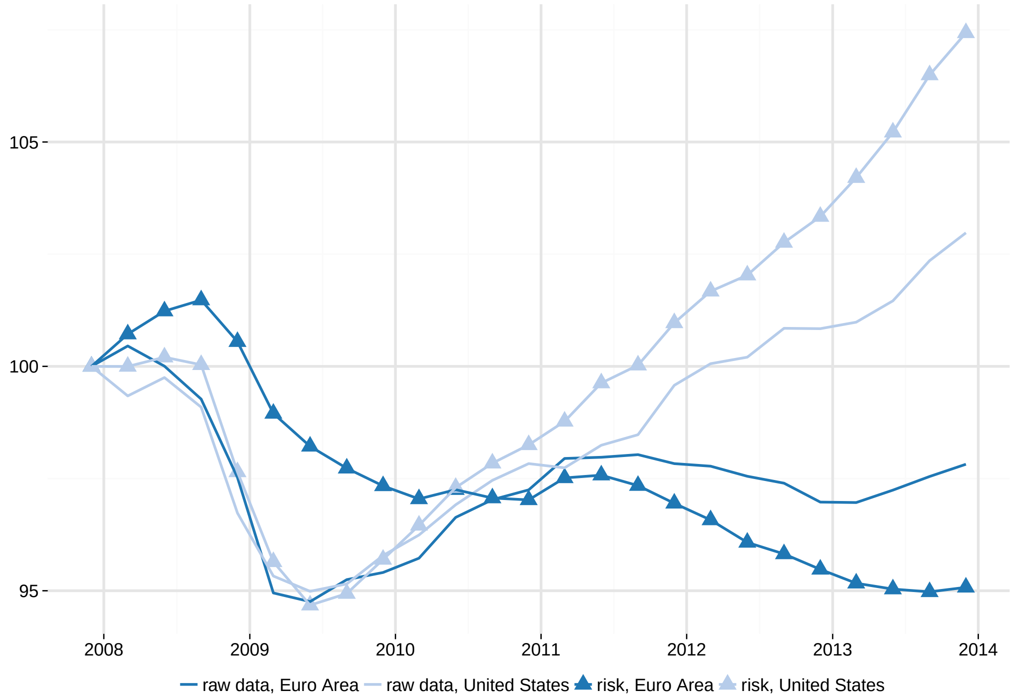
Note : The solid line is the mean of the Bayesian impulse response functions, i.e. the mean of the distribution of the IRFs generated when parameters are drawn from the posterior distribution. Shaded areas are between the lower and the upper bound of a 90% highest posterior density interval. Variables are in deviation from their steady-state values.

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. 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 -2.2 percent between 2007Q4 and 2013Q4 whereas it would have been more than 10 percent without any shocks (given the steady-state growth) and -4.9 percent with only risk shocks.

Figure 5 provides a detailed view of the role of risk shocks in the business cycles for four key variables: GDP, investment, credit and credit spread. Consistently with the previous analysis of the IRFs, 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

Figure 4 – Historical and simulated real GDP per capita in the US and the Euro area in level (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.

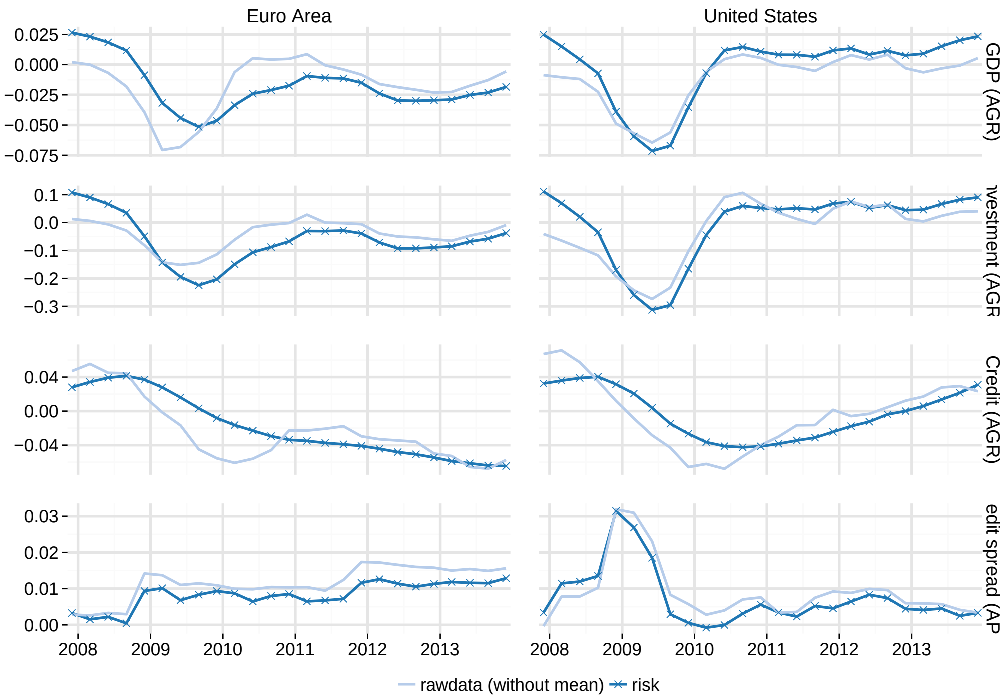
growth of investment and output. For the Euro area, we do not observe a substantial fall of the credit spread after first recession of 2008-2009, on the contrary it increases once again in 2011. Consequently, credit growth has continued to fall and the growth rates of investment and output are still below their steady-state value.

Cumulated growth since the beginning of the crisis is 5.2 percentage points higher in the US than in the Euro area nowadays, whereas it would have been more than twice higher if only risk shocks had occurred 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.

3.3. The role of other shocks and structure

Risk shocks are not the only reason of the 2008-2009 Euro area recession. Another reason is a sequence of negative temporary productivity shocks between 2008Q3 and 2010Q3. However, their contribution to the first recession is twice weaker than that of risk shocks. Actually, risk shocks are by far the most important negative source of growth during the second recession. Other sources of shocks have helped to mitigate the effects of the rising risks since 2007: a

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



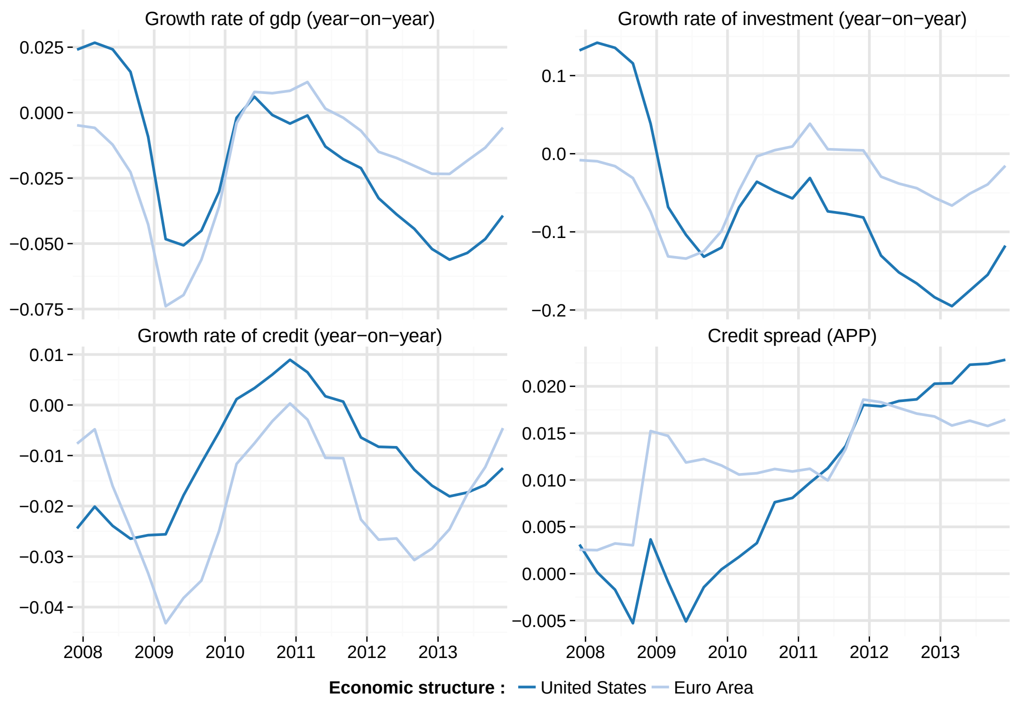
Note : Solid lines correspond to the annual growth rates (AGR) of real GDP, investment and credit per capita and annual percentage point (APP) of credit spread, without mean. Starred lines are the result of feeding only the estimated anticipated and unanticipated components of the risk shock to the model.

temporary fall in price mark-up and an expansion of government consumption (only during the first recession), improvements in marginal efficiency of investment, and monetary policy shocks.

As in the Euro area case, risk shocks are not the sole reason of the first recession in the US. In the US, the second reason of negative growth by order of importance is price markup shock. The rise of risk and of price markup are mitigated by a positive temporary productivity shocks (contrary to the Euro area) and positive government shocks (the last turned negative after the recession).

Euro area and US economies can also differ by their structures, and not only by the various shocks. The economic structure is characterized in our setup by the values of the structural parameters related with market frictions (such as wage/price rigidity) and policy (such as the coefficient of the Taylor rule). To assess the role of structure in the divergence between Euro area and US economies, we perform a counter-factual analysis that imposes in the US economy the estimated shocks of the 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.

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



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.

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 data sample 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, but 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), negative contributions of risk shocks are observed only during three quarters in 2009 and then turned positive in the subsequent quarters. Sala et al. (2013) and 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 as they do, and that contrary to Del Negro et al. (2013) we use also the loans to non-financial corporations 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 in our model.

This outcome of our estimation procedure is consistent with the recent analysis of the US credit market provided by the IMF (2013a) in the Global Financial Stability Report. Credit growth is qualified as weak in most advanced countries except for the non financial corporations in the US economy. Using an econometric model for the demand and the supply of credit demand and supply, IMF (2013a) concludes that both demand and supply factors are at the origin of the recent credit expansion in the US. The very low market interest rates are pointed out as the potential source of this credit expansion and recently, Stein (2013) and Rajan (2013) warn about the risk of this credit expansion for financial stability given the rising share of covenant-light loans. They suggest that this credit expansion may be the outcome of an excessive risk taking behavior similar to that observed before the 2008-2009 recession. According to our estimation results, the positive contribution of risk shocks in US growth is effectively close to that observed during the years before the crisis.

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 is consistent with 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 contributions 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. Moreover, they do not consider risk shocks as financial shocks but only equity

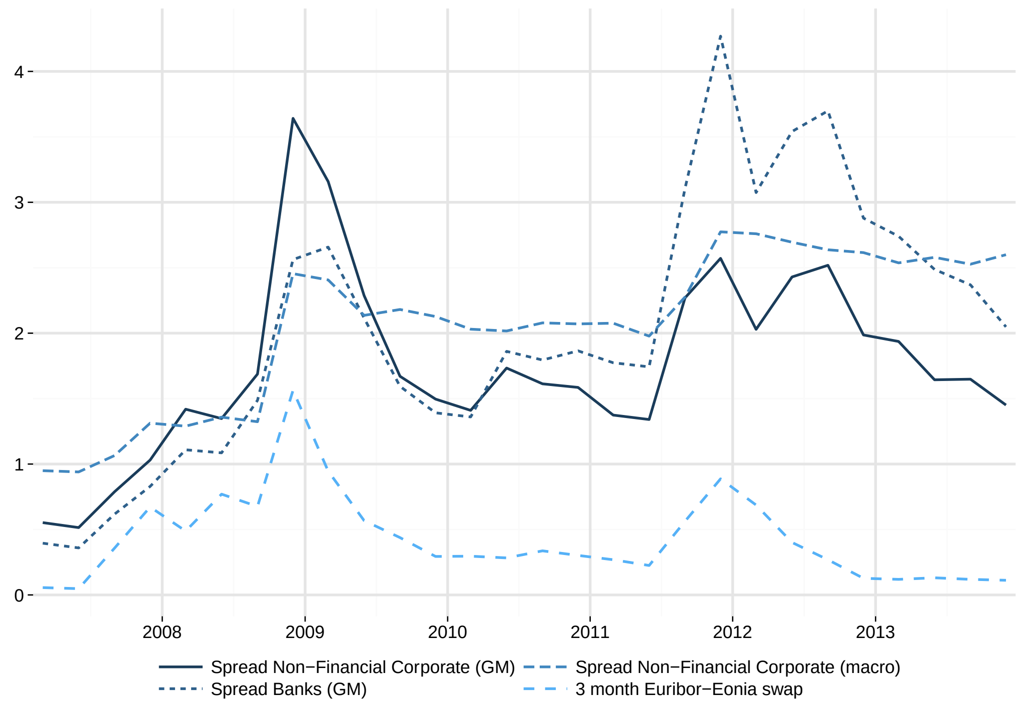
[11]In Lombardo and McAdam (2012), financial shocks contribute strongly to the fluctuations of house prices and to a lesser extent to those of output between 2008 and 2010.

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

premium shocks. Last, countries they have selected 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 financial sector. Since 2011, Euro area has been marked by the sovereign debt crisis in 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 sector whcih contaminates the real activity.[13] Corsetti et al. (2013) develop a New Keynesian DSGE model to show how the implementation of a procyclical fiscal policy during a sovereign debt crisis can lead to a belief-driven recession. Our model is not suitable to provide a full analysis of the sovereign debt crisis as done by Corsetti et al. (2013) given the absence of the public sector debt in the CMR model. Still, we can establish a link between the observed distress of banks during the sovereign debt crisis and the positive risk shocks that we estimated for this period.

Figure 7 – Spreads in percent (2007Q1-2013Q4)



[13]Shambaugh (2012), Lane (2012), and Reichlin (2014) are excellent narratives of the European debt crisis. Acharya et al. (2013) and IMF (2013b) studies the determinants of public debt costs and its interplay with the debt cost for banks. Neri (2013) and ECB (2012) attempt to quantify the transmission of these tensions to the bank lending rates for the non financial corporations in the Euro area.

CMR explain that risk shocks can be interpreted as shocks on the riskiness of the business done by entrepreneurs, i.e. non-financial corporations, or by financial firms, since we consider households as the ultimate lenders. In the former case, there is no agency problem between households and financial 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 the Euro area and the high contribution of risk shocks in the 2011 recession: the high level of idiosyncratic uncertainty estimated concern the risk of banks, which have been excessively exposed to the sovereign bond risk.

To develop this interpretation, the definition of the credit spread is essential. In our estimation, the credit spread used measures the cost of external finance for non-financial firms and not for banks. The two spreads for financial and non-financial firms have increased in 2011 as shown by Gilchrist and Mojon (2014) and reproduced in Figure 7. But they also show a divergence in the two spreads after 2012: it falls for banks whereas it remains high for non financial corporations. This high value of credit spreads explain the important role attributed to risk shocks in the persistence of low growth in the Euro area. It is worth mentioning that Gilchrist and Mojon (2014) report a fall in the credit spread for non financial corporations after 2012 when they consider the interest rate for corporate debt securities instead of the interest rate for bank loans. As discussed above, we choose the latter instead of the former given the high importance of bank credit when compared with debt securities in the external financing of non financial corporations – see ECB (2011). Further researches should be devoted to explain the recent divergence between these two spreads and why the loan interest rate does not fall after 2012, contrary to the yield of debt securities, given its strong macroeconomic consequences highlighted in this paper.

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 - 2013Q4 : 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 - 2013Q4 : 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 - 2013Q4 : 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 - 2013Q4 : 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 - 2013Q4 : 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 - 2013Q4 : 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 - 2013Q4 : 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 - 2013Q4 : 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 :
    * 1987Q1 - 1998Q4 : 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
    * 1999Q1 - 2013Q4 : Loans to Non-financial corporations, Closing balance sheet, Quarterly, 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 - 2013Q4 : 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 - 2013Q4 : 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 - 2013Q4 : 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	0.824	0.0294	0.7781	0.8768
b_p	beta	0.500	0.1000	0.724	0.0691	0.6198	0.8299
Fomegabar_p	beta	0.007	0.0037	0.012	0.0030	0.0078	0.0167
mu_p	beta	0.275	0.1500	0.080	0.0156	0.0569	0.1038
sigmaa_p	norm	1.000	1.0000	2.001	0.7163	0.9325	3.1599
Sdoupr_p	norm	5.000	3.0000	9.656	1.6887	7.2519	12.6991
xip_p	beta	0.500	0.1000	0.707	0.0394	0.6337	0.7663
aptil_p	norm	1.500	0.2500	2.516	0.1691	2.2369	2.7949
rhotil_p	beta	0.750	0.1000	0.865	0.0173	0.8362	0.8935
iota_p	beta	0.500	0.1500	0.904	0.0423	0.8442	0.9727
iotaw_p	beta	0.500	0.1500	0.337	0.0957	0.2059	0.5219
iotamu_p	beta	0.500	0.1500	0.909	0.0316	0.8548	0.9582
adytil_p	norm	0.250	0.1000	0.359	0.0802	0.2065	0.4684
signal_corr_p	norm	0.000	0.5000	0.423	0.1038	0.2572	0.5981
rholambdaf_p	beta	0.500	0.2000	0.891	0.0353	0.8375	0.9484
rhomuup_p	beta	0.500	0.2000	0.956	0.0152	0.9318	0.9805
rhog_p	beta	0.500	0.2000	0.976	0.0146	0.9551	0.9966
rhomuzstar_p	beta	0.500	0.2000	0.130	0.0555	0.0280	0.2102
rhoepsil_p	beta	0.500	0.2000	0.935	0.0125	0.9165	0.9553
rhosigma_p	beta	0.500	0.2000	0.901	0.0323	0.8651	0.9491
rhozetac_p	beta	0.500	0.2000	0.695	0.1160	0.5125	0.8590
rhozetai_p	beta	0.500	0.2000	0.958	0.0123	0.9393	0.9745
rhoterm_p	beta	0.500	0.2000	0.955	0.0173	0.9271	0.9831
stdsigma2_p	invg2	0.001	0.0012	0.044	0.0046	0.0362	0.0504
stdsigma1_p	invg2	0.002	0.0033	0.078	0.0151	0.0503	0.0988

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	0.008	0.0015	0.0056	0.0105
e_muup	invg2	0.002	0.0033	0.003	0.0003	0.0031	0.0039
e_g	invg2	0.002	0.0033	0.015	0.0012	0.0134	0.0174
e_muzstar	invg2	0.002	0.0033	0.005	0.0004	0.0046	0.0059
e_gamma	invg2	0.002	0.0033	0.016	0.0024	0.0126	0.0202
e_epsil	invg2	0.002	0.0033	0.005	0.0003	0.0043	0.0053
e_xp	invg2	0.583	0.8250	0.447	0.0435	0.3719	0.5149
e_zetac	invg2	0.002	0.0033	0.019	0.0035	0.0146	0.0256
e_zetai	invg2	0.002	0.0033	0.088	0.0191	0.0607	0.1262
e_term	invg2	0.002	0.0033	0.002	0.0006	0.0012	0.0030

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	0.0013	0.0116	0.0158