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

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Abstract

Highly synchronized during the 2008-2009 recession, Euro area and US economies began to diverge when the former entered a double-dip recession, in the middle of 2011, while the latter pursued its expansion. To understand the divergence, we provide a structural interpretation of these episodes through the estimation of a business cycle model with financial frictions (Christiano et al., 2014b) for both economies. Our results show that risk shocks, measured as the volatility of idiosyncratic uncertainty, play a crucial 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 began to diverge when the former entered a double-dip recession, in the middle of 2011, while the latter pursued its expansion – Figure 1 compares the cumulated growth of real GDP per capita for the two economies. The divergence is particularly striking given the strong similarity of the timing[2] and the magnitude[3] of the 2008-2009 recessions. Today, the US economy has overtaken the pre-crisis level of output per capita, which is, in 2013Q4, 3 percent above the 2007Q4 level. This 3 percent growth over six years may appear disappointing, a "Modest Recovery" as qualified by

[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 differences 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.

the IMF (World Economic Outlook, October 2013), but it outweighs the 2 percent of negative cumulative growth in the Euro area. Actually, the renewed downturn before reaching prior peak in Europe corresponds to the pattern of a "double dip recession" identified by Reinhart and Rogoff (2014) as typical after historical systemic banking crises. We propose in this paper an interpretation of this divergence based on risk shocks in the financial sector.

Because of the 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: Is the Euro area hitten by specific shocks? Are the European economic structures so different from the US? Or is it due to different policies? It is an essential task to disentangle these factors to draw the lessons of these recent recessions. A way to perform this task is to estimate dynamic and stochastic general equilibrium (DSGE) models to measure the contribution of these factors (shocks, frictions and policies) to business cycles. Papers like Christiano et al. (2003) and Chari et al. (2007) have shown the relevance of such models to study Great Depressions. Furthermore, transatlantic comparison has existed since the development of DSGE estimation methodology, such as Danthine and Donaldson (1993) and more recently Smets and Wouters (2005).[4] Finally, various recent papers use the estimation of DSGE model to analyze the recent recessions (Sala et al., 2012; Galí et al., 2012; Coenen et al., 2013; Del Negro et al., 2013; Christiano et al., 2014a). Our paper is clearly related to this literature, but our conclusions differ in some important points as explained below.

The interest of estimation depends crucially on the ability of the DSGE model to fit observed data. The choice of the model is therefore essential to draw relevant insights from its estimation. For comparison purpose, the choice is even more delicate because the selected DSGE model should be mostly identical for two economies (otherwise estimation's results may be difficult to compare) while performing well for the two compared economies (whom historical data are however different by definition). To compare US and Euro area recent recessions, we choose the model of Christiano et al. (2014b) (CMR hereafter) for three reasons. First, CMR demonstrate the good empirical performances of this model for US business cycles, especially to account for the 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. Therefore, we presume (and will effectively demonstrate) that the CMR model can also be applied to the Euro area economy.[5] 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),

[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] In Christiano et al. (2010), the sample period does not cover the double-dip recession in Europe.

in shocks (associated with shifts in demand, technology, policy or financial risk), and in policies (fiscal or monetary).

Financial risks plays a key role in the US Great Recession according to CMR estimation and we want to know whether it is still the case for the US recovery and for the Euro area episodes. CMR gives a non-trivial macroeconomic role to the financial risk 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 (Townsend, 1979). 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. 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 the loan interest rate and the risk free rate. 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).[6]

The model in this paper is estimated 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 the risk shock 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 Gerali et al. (2010) who estimate DSGE models with an explicit imperfectly competitive banking sector. Our contribution to this literature is to show that risk shocks explain the recent divergence of 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 interesting 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 "modest" US recovery and (*ii*) the EA double-dip recession. In Galí et al. (2012), the US Great recession is explained by negative risk premium and investment shocks. However, contrary to us, the recovery is driven by productivity shocks without a risk reversal in the financial sector. In Sala et al. (2012) risk premium shocks explain the recession in US

[6]We have to mention that risk shocks can be interpreted as shocks on the riskiness of the business done by (non-financial) entrepreneurs or by financial firms. 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. This point will be of importance to discuss the potential role of the banking sector risk in the Euro area double-dip recession.

(but without risk reversal) and play no role in recessions for the UK, Sweden, and Germany. Importantly, these two contributions consider only equity shocks (that is shocks on the wealth of borrowers) as financial shocks and not risk shocks as suggested by CMR. Our results show that the US have succeeded in reducing (and even in inversing) the risk problem in the economy whereas the EA 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 (see Reichlin (2014) for a narrative of the banking crisis in Europe).

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.

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

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

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

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 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 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".

2.2. Estimation

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 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 a good proxy of credit spread where lending is mostly done by financial markets. 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. Inference about parameters

The model is estimated through Bayesian procedures surveyed by An and Schorfeide (2007).

The table 1 contains a brief description of the parameters that we fix during the estimation. Tables for estimated structural parameters and shock processes are detailed in Appendix B.

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	0.020	0.025
α	Power on capital in production function	0.34	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
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

[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, notable 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 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.

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%
π	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%
μ_z^*	GDP per capita growth (APR)	1.9%	1.9%	1.6%	1.9%
Υ	investment specific 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.

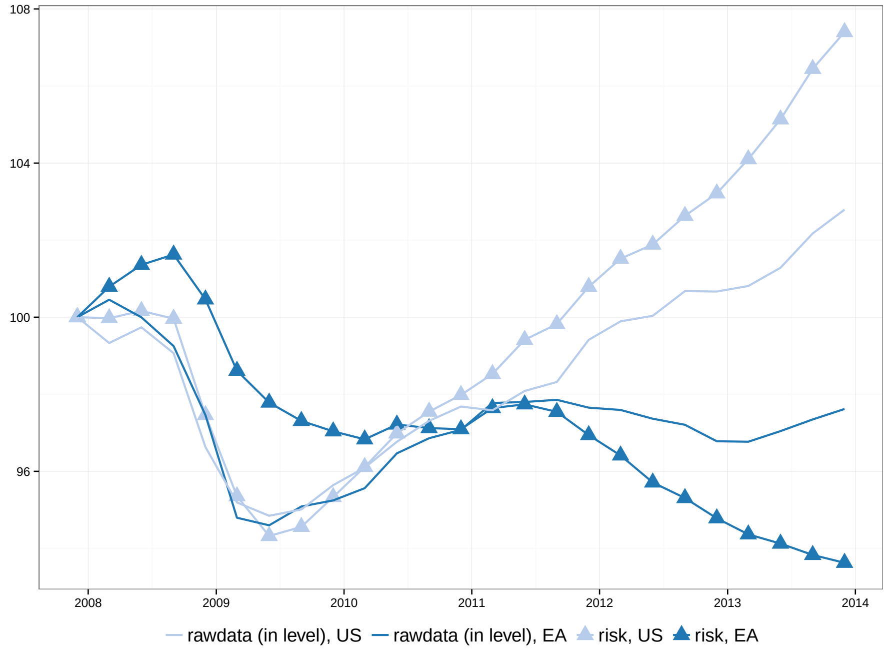
3. Explaining the divergence

3.1. The role of risk shocks in the divergence

The figure 1 shows risk shocks contribution to the divergence between the US and the Euro area. Risk shocks have negatively contributed to growth in the US between 2008Q3 and 2010Q1, with a trough in 2009Q2. These results are consistent with the common narrative of the crisis and the previous estimations done by CMR and others. 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. The real GDP per capita growth is 3 percent between 2007Q4 and 2013Q4 whereas it would have been 10 percent without any shocks (given the steady-state growth) and 7.5 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 EA. First, the deterioration of risk in the financial sector comes later with lesser impact on growth during the first recession than in the US. The first recession in the EA started in 2008Q1 but the negative contributions of risk shocks to growth started in 2008Q4 and account for half of the contraction between 2007Q4 and 2009Q3. However, the key difference between the two economies is the absence of risk reversal in the EA. Actually, it is even worse for the EA because the negative contribution of shocks increases after 2011Q1 giving rise to the double-dip recession. The real GDP per capita growth is -3 percent between 2007Q4 and 2013Q4 whereas it would have been 10 percent without any shocks (given the steady-state growth) and -6.8 percent with only risk shocks.

Figure 1 – Real GDP per capita and simulated with only risk shocks in the US and the EA (base 100 = 2007Q4)

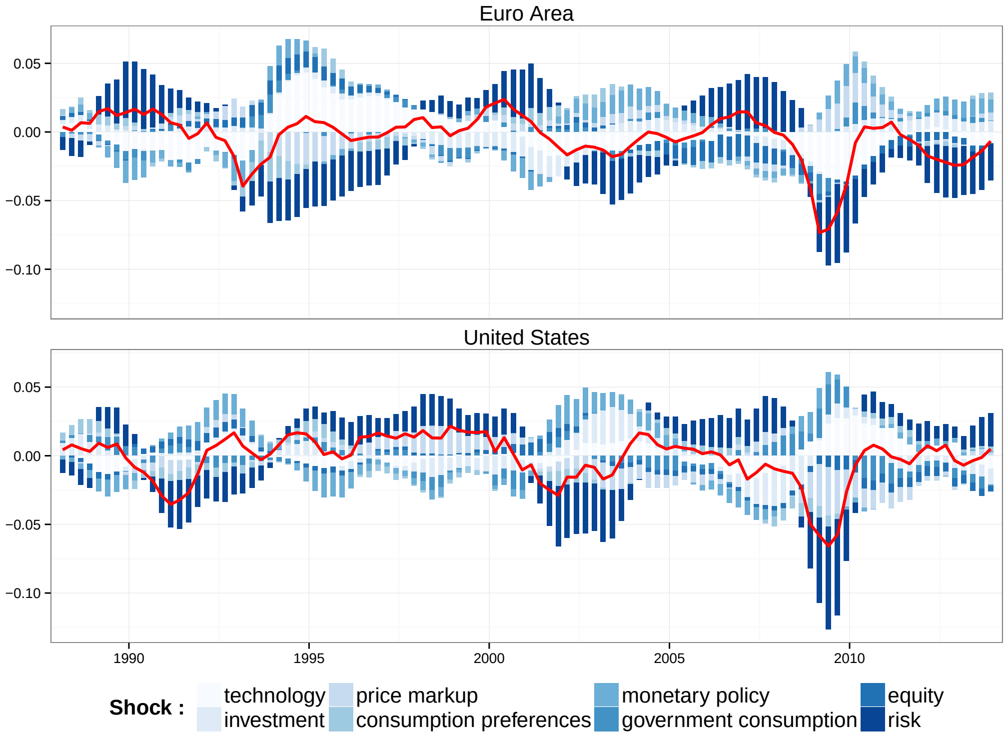


Note : The starred line is the simulated real GDP per capita, feeding only the estimated anticipated and unanticipated components of the risk shock to the model.

The fluctuation of risk 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 figures C.1 and C.2 provide a more detailed view of the role of risk shocks in the business cycles for the twelve variables used in the estimation since 1988Q1. 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: 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.

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. For the Euro area, we do not observe a substantial fall of the

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).

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 US than in the EA 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 Europe and decreased it in US in a way that dampens the divergence between the two economies.

3.2. The role of other shocks and structure

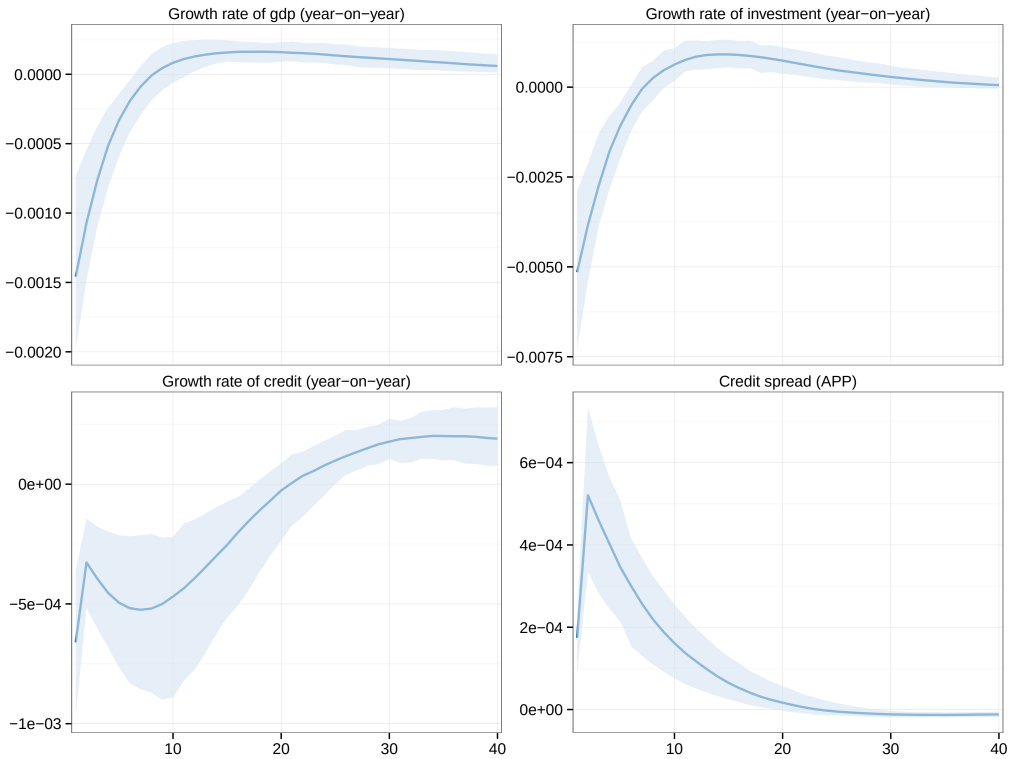
Risk shocks are not the only reason of the 2008-2009 Euro area recession. The second reason is a sequence of negative temporary productivity shocks between 2008Q3 and 2010Q3. However, their contribution to the first recession is inferior to that of risk shocks, which is twice higher, and there is no substantial productivity growth during the second recession. Actually, risk shocks are the single negative source of growth during the second recession. Three sources of shocks have helped to mitigate the effects of the rising risk: a temporary fall in price mark-up (only

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

	risk	equity	investment	technology	markup	cons. pref.	monetary	gov. exp.
United States								
gdp	55	0	6	7	8	3	2	13
consumption	10	0	8	2	14	41	3	1
investment	81	0	13	0	3	0	1	0
credit	50	30	10	0	6	1	1	0
networth	65	3	28	0	1	0	2	0
inflation	48	0	9	1	29	2	1	0
hours worked	62	0	10	2	11	3	2	3
wage	1	0	0	88	8	0	0	0
interest rate	65	0	11	1	10	2	6	0
slope	65	0	9	0	8	1	6	0
invest. price	0	0	100	0	0	0	0	0
Euro area								
gdp	49	1	2	3	8	12	4	11
consumption	3	0	10	1	9	54	4	2
investment	78	2	11	0	3	0	3	0
credit	14	65	7	0	8	1	2	0
networth	54	6	36	0	0	0	4	0
inflation	21	0	7	0	46	3	2	0
hours worked	48	1	7	2	14	10	4	3
wage	2	0	1	73	16	0	0	0
interest rate	41	1	12	0	19	3	15	0
slope	41	1	7	0	14	2	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.

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



Note :

during the first recession.), improvements in marginal efficiency of investment, and monetary policy shocks. We find no significant effects of government consumption shocks.

Risk shocks are not the sole reason of the first recession in the US. The second reason by order 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 show that differences in structure play a minor role when compared with the role of shocks – see C.3. Importantly, the US economy would have also experienced a double-dip recession assuming the European sequence of shocks and the American economic structure.

4. Conclusion

The recent divergence between the Euro Area and the US, abundantly commented in the press, will surely constitute an important field for future researches. 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. (2014b). 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 Europe 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 (below the steady-state level) after 2009 in the US is more puzzling and call for further researches.

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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, Quar-

terly, 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	0.744	0.0273	0.7000	0.7873
b_p	beta	0.500	0.1000	0.755	0.0386	0.6974	0.8177
Fomegabar_p	beta	0.007	0.0037	0.006	0.0017	0.0038	0.0088
mu_p	beta	0.275	0.1500	0.228	0.0531	0.1469	0.3089
sigmaa_p	norm	1.000	1.0000	2.947	0.7799	1.7437	4.1714
Sdoupr_p	norm	5.000	3.0000	8.929	0.9838	7.3718	10.5401
xip_p	beta	0.500	0.1000	0.808	0.0241	0.7710	0.8510
aptil_p	norm	1.500	0.2500	2.497	0.1445	2.2692	2.7425
rhotil_p	beta	0.750	0.1000	0.872	0.0116	0.8551	0.8924
iota_p	beta	0.500	0.1500	0.811	0.0546	0.7269	0.9010
iotaw_p	beta	0.500	0.1500	0.612	0.1139	0.4379	0.7908
iotamu_p	beta	0.500	0.1500	0.929	0.0276	0.8889	0.9757
adytil_p	norm	0.250	0.1000	0.381	0.0848	0.2523	0.5386
signal_corr_p	norm	0.000	0.5000	0.430	0.0934	0.2700	0.5666
rholambdaf_p	beta	0.500	0.2000	0.872	0.0308	0.8233	0.9226
rhomuup_p	beta	0.500	0.2000	0.965	0.0134	0.9462	0.9884
rhog_p	beta	0.500	0.2000	0.916	0.0271	0.8734	0.9577
rhomuzstar_p	beta	0.500	0.2000	0.059	0.0261	0.0147	0.0941
rhoepsil_p	beta	0.500	0.2000	0.952	0.0158	0.9240	0.9747
rhosigma_p	beta	0.500	0.2000	0.974	0.0072	0.9624	0.9860
rhozetac_p	beta	0.500	0.2000	0.904	0.0238	0.8672	0.9382
rhozetai_p	beta	0.500	0.2000	0.943	0.0117	0.9221	0.9608
rhoterm_p	beta	0.500	0.2000	0.936	0.0214	0.9012	0.9692
stdsigma2_p	invg2	0.001	0.0012	0.035	0.0032	0.0300	0.0404
stdsigma1_p	invg2	0.002	0.0033	0.006	0.0039	0.0013	0.0109

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	0.0035	0.0127	0.0243
e_muup	invg2	0.002	0.0033	0.004	0.0003	0.0035	0.0044
e_g	invg2	0.002	0.0033	0.019	0.0015	0.0168	0.0216
e_muzstar	invg2	0.002	0.0033	0.010	0.0008	0.0089	0.0114
e_gamma	invg2	0.002	0.0033	0.006	0.0008	0.0050	0.0076
e_epsil	invg2	0.002	0.0033	0.006	0.0005	0.0054	0.0070
e_xp	invg2	0.583	0.8250	0.423	0.0312	0.3707	0.4717
e_zetac	invg2	0.002	0.0033	0.023	0.0025	0.0193	0.0274
e_zetai	invg2	0.002	0.0033	0.086	0.0191	0.0563	0.1194
e_term	invg2	0.002	0.0033	0.003	0.0008	0.0015	0.0039

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	0.845	0.0276	0.7986	0.8872
b_p	beta	0.500	0.1000	0.678	0.0470	0.6029	0.7593

(Continued on next page)

Table B.4 – (continued)

	Prior distribution	Prior mean	Prior s.d.	Posterior mean	Posterior s.d.	HPD inf	HPD sup
Fomegabar_p	beta	0.007	0.0037	0.012	0.0024	0.0080	0.0156
mu_p	beta	0.275	0.1500	0.085	0.0151	0.0615	0.1084
sigmaa_p	norm	2.000	0.5000	2.345	0.4520	1.5952	3.0555
Sdoupr_p	norm	5.000	3.0000	10.016	1.7322	7.3496	12.9554
xip_p	beta	0.500	0.1000	0.756	0.0233	0.7175	0.7910
aptil_p	norm	1.500	0.2500	2.439	0.1502	2.2114	2.7046
rhotil_p	beta	0.750	0.1000	0.867	0.0137	0.8476	0.8912
iota_p	beta	0.500	0.1500	0.914	0.0386	0.8585	0.9730
iotaw_p	beta	0.500	0.1500	0.346	0.0908	0.2090	0.5023
iotamu_p	beta	0.500	0.1500	0.911	0.0321	0.8620	0.9632
adytil_p	norm	0.250	0.1000	0.397	0.1035	0.2102	0.5494
signal_corr_p	norm	0.000	0.5000	0.391	0.0726	0.2771	0.5134
rholambdaf_p	beta	0.500	0.2000	0.847	0.0378	0.7856	0.9175
rhomuup_p	beta	0.500	0.2000	0.957	0.0147	0.9344	0.9822
rhog_p	beta	0.500	0.2000	0.983	0.0131	0.9626	0.9988
rhomuzstar_p	beta	0.500	0.2000	0.147	0.0681	0.0347	0.2489
rhoepsil_p	beta	0.500	0.2000	0.934	0.0127	0.9135	0.9542
rhosigma_p	beta	0.500	0.2000	0.909	0.0251	0.8705	0.9502
rhozetac_p	beta	0.500	0.2000	0.830	0.0767	0.7039	0.9285
rhozetai_p	beta	0.500	0.2000	0.948	0.0161	0.9213	0.9696
rhoterm_p	beta	0.500	0.2000	0.952	0.0171	0.9256	0.9814
stdsigma2_p	invg2	0.001	0.0012	0.043	0.0050	0.0351	0.0507
stdsigma1_p	invg2	0.002	0.0033	0.072	0.0157	0.0429	0.0962

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

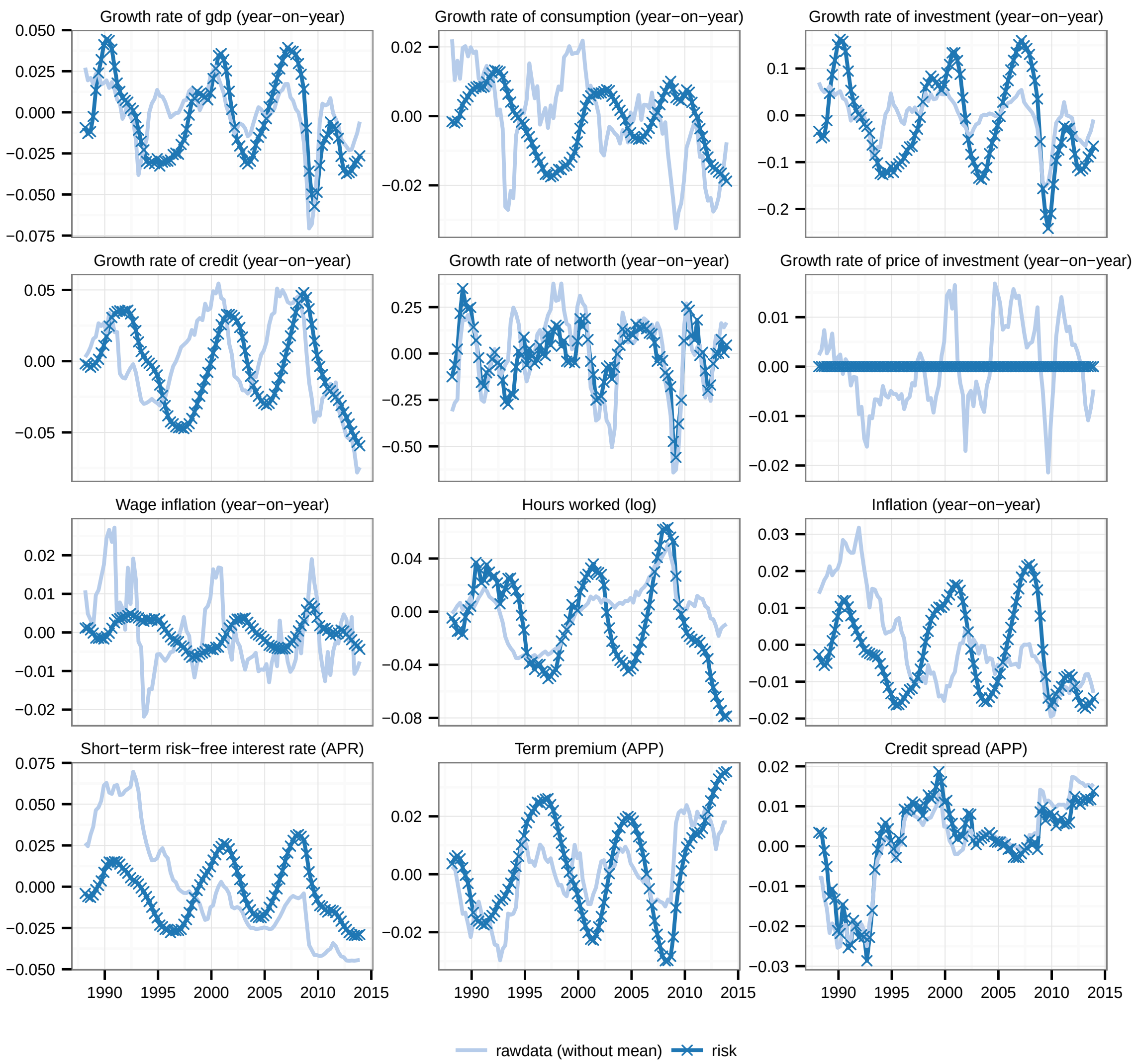
	Prior distribution	Prior mean	Prior s.d.	Posterior mean	Posterior s.d.	HPD inf	HPD sup
e_lambdaf	invg2	0.002	0.0033	0.011	0.0022	0.0076	0.0140
e_muup	invg2	0.002	0.0033	0.003	0.0003	0.0029	0.0039
e_g	invg2	0.002	0.0033	0.015	0.0012	0.0134	0.0171
e_muzstar	invg2	0.002	0.0033	0.005	0.0004	0.0046	0.0058
e_gamma	invg2	0.002	0.0033	0.015	0.0021	0.0114	0.0183
e_epsil	invg2	0.002	0.0033	0.005	0.0004	0.0042	0.0054
e_xp	invg2	0.583	0.8250	0.436	0.0369	0.3780	0.4986
e_zetac	invg2	0.002	0.0033	0.018	0.0019	0.0152	0.0215
e_zetai	invg2	0.002	0.0033	0.075	0.0213	0.0440	0.1104
e_term	invg2	0.002	0.0033	0.002	0.0007	0.0012	0.0033

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	0.0015	0.0117	0.0163

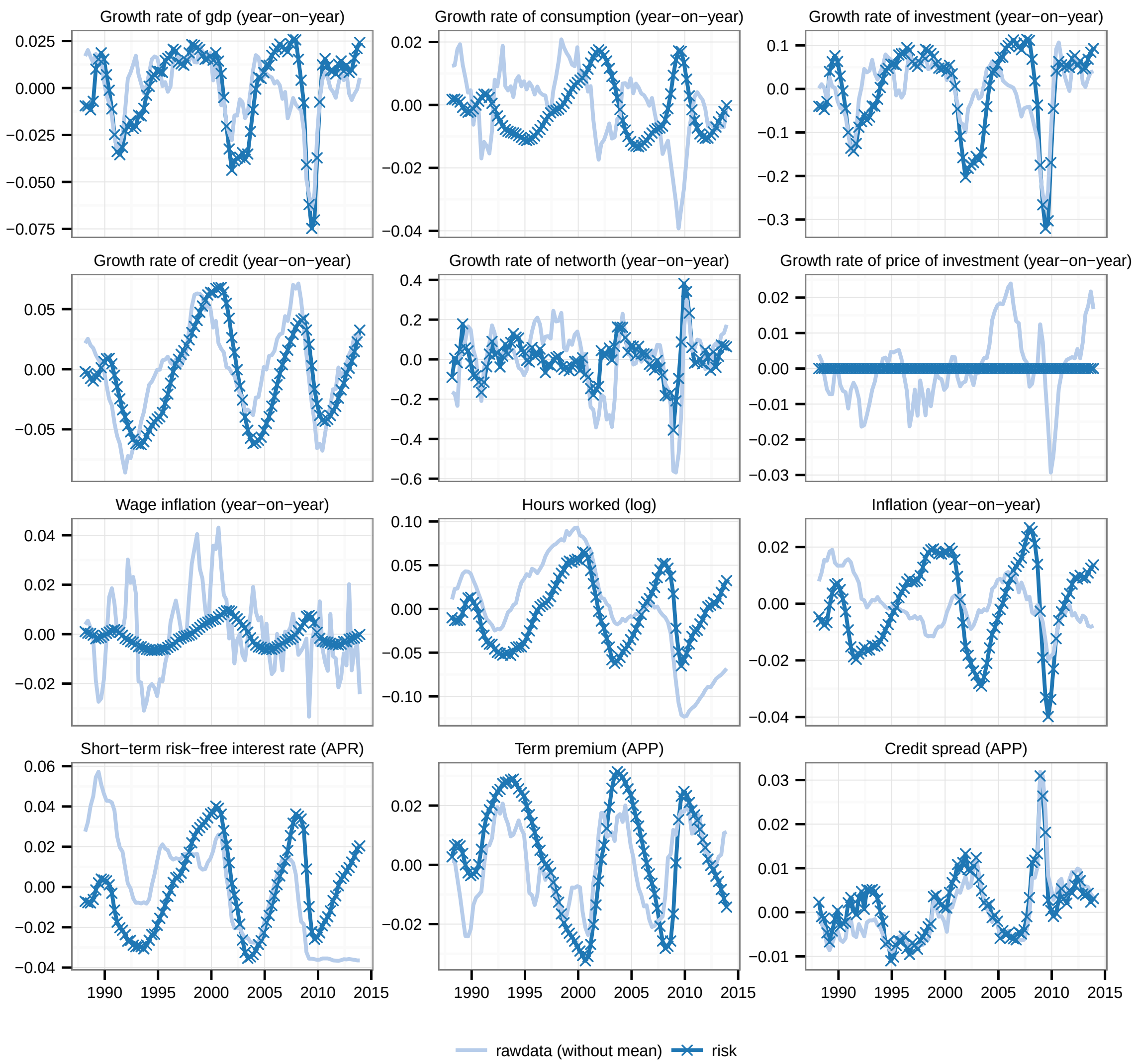
C. Other figures

Figure C.1 – The role of the risk shock in observed variables in the Euro area (1988Q1-2013Q4)



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

Figure C.2 – The role of the risk shock in observed variables in the United States (1988Q1-2013Q4)



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

Figure C.3 – EA and US specific economic structures hit by all EA shocks