Does Risk Aversion Affect Bank Output Loss? The Case of the Eurozone

Mike G. Tsionas[a]
Emmanuel Mamatzakis[b]
Steven Ongena[c]

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Abstract

We propose a new model to infer the evolution of bank-specific output losses due to the uncertainty in bank output prices. Losses are based on bank risk aversion with micro foundations tethered to the uncertainty regarding prices. Our model allows us to measure time-varying bank-specific output losses and risk aversion while taking into account all bank cross-sectional heterogeneity. We employ a panel data set to estimate the input and output elasticities with both parametric and non-parametric techniques. We are the first to document that increasing risk aversion among Eurozone banks during the financial crisis resulted in sizable output losses. Although subdued thereafter, losses have been resurging in recent years. Both conventional and unconventional monetary policy responses by the ECB mitigated uncertainty in bank output prices, though unequally so across countries. Certain measures of unconventional monetary policy may have even enhanced bank risk aversion and thereby output losses, but mainly so for large countries. (153 words)

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[a]Department of Economics, Lancaster University Management School, LA1 4YX, UK and Athens University of Economics and Business. Email: m.tsionas@lancaster.ac.uk. [b]School of Business, Management and Economics, Jubilee Building, University of Sussex, Falmer, Brighton BN1 9SL, UK. Email: e.mamatzakis@sussex.ac.uk. [c] Department of Banking and Finance, University of Zurich, Zurich 8032, Switzerland, Swiss Finance Institute, KU Leuven; and CEPR. Email: steven.ongena@bf.uzh.ch.

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1. Introduction

Defining and measuring bank risk has been subject to much controversy, also because of the intrinsic difficulties in disentangling its underlying determinants. As is evident from a review of this literature (see below), and despite the plethora of studies that exist, there is a gap when it comes to the underlying bank risk based on micro foundations. Our paper aims to fill this gap.

We provide a structural model of bank output losses based on bank risk aversion with micro foundations tethered to the uncertainty regarding prices in the three broad categories of bank outputs, i.e., loans, other earning assets and off balance sheet items and fees.[1] Bank risk aversion is endogenous for bank managers, and their aim is to maximize expected profit without regarding its variability. To the best of our knowledge, we are the first to propose a bank risk aversion model based on individual bank optimization.

The model follows {Froot, 1998 #3407} who analyze the capital allocation and capital structure decisions facing financial institutions. Their model incorporates two key features: Value maximizing banks want to manage risks and not all the risks they face can be hedged frictionless in financial markets. Departing from their approach we develop a new model of bank level risk that factors in the pricing of those risks that cannot be easily hedged.

In our model risk is bank-specific and as such we are able to explicitly measure bank risk exposure as derived from a profit maximization process where uncertainty regarding input and output price elasticities determines the bank`s risk aversion which in turn is directly related to risk. In fact, standard micro foundations suggest that the expected utility under profit maximization relies on the entire distribution of risky activities. As in {Freixas, 1998 #1620} we build on the notion that the expected price of outputs is uncertain. And, as in {Appelbaum, 1997 #3414} bank risk aversion will be measured based on the first order conditions of a flexible indirect von Neumann-Morgenstern utility function with respect to outputs.[2]

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[1] The notion that banks might be risk averse is not new. {Stiglitz, 2003 #1802} for example argue that banks due to information asymmetry and competition imperfections may follow risk adverse practices. The degree of bank risk aversion may crucially depend upon a bank`s net worth (see also {Rajan, 2006 #1461}; {Borio, 2012 #1807}; {Delis, 2017 #3835} and {Quaranta, 2018 #3836}. Following from this idea, we explore whether uncertainty around these three bank output prices, that in turn would impact upon bank net worth, would also affect bank risk aversion. We follow {Santomero, 1997 #3402} in our categorization of risky financial assets. Of course, banks could also lend more or less depending on the uncertainty of the outcomes of doing so ({Akerlof, 1970 #3909} and {Stiglitz, 1981 #513}), a direction of estimation we leave open for future research.

[2] See also {Henderson, 2013 #3415} who model the behavior of a risk-averse agent who seeks to maximize expected utility. In general, there is some gap in the banking literature because the microeconomic foundations of banking may have been somewhat neglected when it comes to measuring bank risk. From a theoretical point of view a handful of general equilibrium models have been proposed (for example {Segoviano Basurto, 2009 #3419}; {Tarashev, 2010 #3089}; {Benchimol, 2014 #3489}).

Our model further builds on the concept that with more risk aversion each of the three outputs, i.e., loans, other earning assets and off balance sheet items and fees, will be lower, and that the converse would also be true. This is an effective way of measuring bank risk aversion due to uncertainty in expected output prices, as we clearly identify it for the case of loans, for other earning assets and for off balance sheet items and fees.[3] The simplicity of such identification lies in measuring bank output losses due to bank risk aversion, in terms of lower outputs.

Despite its conceptual simplicity, the estimation of our new measure of bank risk aversion is rather cumbersome. As such we contribute to the literature by providing both parametric and non-parametric estimations of bank risk aversion and thus bank output losses that are bank/country-specific but also time-varying. To this end, we employ a panel data set that contains banks operating in the Eurozone between 2001 and 2015 that gives an unbalanced panel of 39,681 observations, which comprises 5,017 different banks. In addition, we provide the framework for a second stage analysis based on GMM estimation of a panel Vector Autoregressive (VAR) where endogeneity is appropriately tackled, whilst we are able to estimate responses of bank risk aversion to covariates, notably ECB monetary policy, whether conventional or unconventional.

Moreover, in the empirical application we provide evidence on bank risk aversion in the Eurozone, a region that has been dealing with bank solvency issues for some years now. {Ivashina, 2010 #2001} and {De Haas, 2013 #2279} for example study the consequences on bank lending due to financial crisis. Findings from these studies show that there is variability in bank lending across banks and countries during the financial crisis, though overall there is a detrimental effect on bank lending ({Ivashina, 2010 #2001}). The case of Eurozone is of interest as it constitutes a currency zone where monetary policy has been very active with a remarkable focus on financial stability. {Jiménez, 2014 #1594} for example provide loan level evidence of the presence of a risk-taking channel of monetary policy in Spain. Our proposed framework allows us to disentangle the short from the long run impact of both conventional and unconventional monetary policies on bank risk aversion and thereby output losses.

Our estimates suggest that during the financial crisis sizeable bank output losses materialized due to increases in bank risk aversion, and that for some Member States of the

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Yet such models are hard to estimate. On the other hand, some applied models such as Value at Risk (VaR) ({Adrian, 2016 #3420}), or in general '*stress testing'* models, have been proposed to assess bank risk. In fact, there are a plethora of approaches, from financial contagion through interconnectedness ({Rochet, 1996 #1644}; {Billio, 2012 #3421}) to bank runs ({Diamond, 1983 #63}). In contrast to this literature, we simply revisit the bank fundamentals represented by an indirect utility function.

[3] {Daníelsson, 2002 #3424} argue against trying to model the preferences of bank regulators/supervisors, as there is much publicly disclosed information available and, in addition, such modelling would be challenging. We therefore take the preferences of regulators and supervisors as given.

Eurozone such losses persist until today. However, monetary policy, whether conventional or unconventional, reduces overall uncertainty and thereby bank risk aversion and bank output losses. As a result the ECB's monetary policy appears to have moderated the loss of output due to uncertainty after the financial crisis (as in, e.g., {Bekaert, 2013 #3490}). Unfortunately, for some Member States, notably France and Germany, we observe some asymmetry in the impact of selected measures of unconventional monetary policy, such as main refinancing operations, on bank output losses. In this instance, unconventional monetary policy may actually enhance bank output losses. These results reveal the complexities and thereby the challenges involved in setting monetary policy to fit all across a currency union.

The remainder of the paper is structured as follows: Section 2 provides a brief literature review on research of bank risk. Section 3 presents our theoretical model, and Section 4 discusses the Eurozone banking industry and the data set. Section 5 reports and discusses the estimations, and Section 6 offers some concluding observations.

2. Literature review on bank risk

To this date, there is no universally accepted way of conceptualizing bank risk ({Diamond, 1983 #63}; {Santomero, 1997 #3402}), let alone of measuring it ({Diamond, 2005 #3403}; {Brunnermeier, 2009 #3404}; {Acharya, 2013 #3405}; {Acharya, 2015 #3406}); {Dong, 2016 #3837}; {Delis, 2017 #3835}; {Quaranta, 2018 #3836} and {Badunenko, 2017 #3838}.[4] This lack of consensus and understanding may be further compounded because '*traditional approaches have difficulty analyzing how risks can accumulate gradually and then suddenly erupt in a full blown crisis*' ({Gray, 2007 #3423}).

There have been attempts of course to shed more light on bank risk. Going back to {Santomero, 1997 #3402} there is the argument that bank risk can either be related to financial assets that cannot be easily transferred to a third party − and due to this absence of secondary markets there is also no counterparty risk − or related to other assets and/or activities that are associated with high return (see also recent studies by {Dong, 2016 #3837} and {Delis, 2017 #3835}.[5]

[4] For measures of risk most often used in banking see {Szegö, 2002 #3408}, {Koutsomanoli-Filippaki, 2009 #3409}, {Delis, 2017 #3835} or {Quaranta, 2018 #3836}. {Lehmann, 2010 #3410} plead for '*a pronounced external and forward looking approach to supplement the traditional methodology, which tends to be more inward looking and ultimately backward oriented*' regarding risk. Others have argued that a forward-looking approach brings into the picture irrelevant issues of forecasting volatility for example. {Bauer, 2004 #3411} take a different approach as they focus on risk arising from deposits, which can lead to bank runs. In the event of such a run, liquidation costs arise.

[5] Following this argument, it is widely acknowledged that effective bank risk management to reduce risk exposure can be applied (see {Decamps, 2004 #3412}; {Acharya, 2013 #3405}; {Acharya, 2015 #3406}), though not always as effective as the circumstances would warrant ({Diamond, 2005 #3403}). Then bank regulation and supervision needs to audit (e.g., {Colliard, 2018 #3745}), sanction (e.g., {Delis, 2017 #3748}) and if needed complement risk management at the bank level ({Bernanke, 2006 #3413}). Bank ownership (e.g., {Mohsni, 2014 #3721}; {Allen, 2017 #3722}), governance (e.g., {Vallascas, 2017 #3723}), managerial compensation (e.g., {Fahlenbrach, 2011 #3205}) and the

To better understand systemic financial stability {Elsinger, 2006 #1723} for example develop a framework which relies mainly on easily observable market data and which provides an early warning system by computing the '*value at risk*' for a lender of last resort. They find that the funds necessary to prevent contagion are surprisingly small.[6] As in {Elsinger, 2006 #1723} other research on bank risk has evolved around the issues of early warning mechanisms and prediction of banking crises (e.g., {Lawrence, 2006 #3425}; {Barrell, 2010 #3426}; {Aebi, 2012 #3427}; {El-Shagi, 2013 #3428}). {Lehar, 2005 #1724} for example estimates the dynamics and correlations between bank asset portfolios. To obtain measures for the risk of a regulator's portfolio, the individual liabilities that the regulator has *vis-à-vis* each bank are modeled as contingent claims on each bank's assets. He finds that larger and more profitable banks have lower systemic risk and that additional equity capital reduces systemic risk but only for banks that are constrained by regulatory capital requirements.[7]

{Cornett, 2011 #2419} on the other hand emphasize the importance of liquidity as they report that it dried up during the financial crisis of 2007-2009. Banks that relied more heavily on core deposit and equity capital financing, which are stable sources of financing, continued to lend more relative to other banks. Banks that held more illiquid assets on their balance sheets, in contrast, increased asset liquidity and reduced lending. Off balance sheet liquidity risk materialized on the balance sheet and constrained new credit origination as increased takedown demand displaced lending capacity. They conclude that efforts to manage the liquidity crisis by banks led to a decline in credit supply.[8]

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internationalization of the bank (e.g., {Berger, 2017 #3746}; {Rajamani, 2017 #3747}) may also play role.

[6] This research follows {Basak, 2001 #3429} who analyze optimal, dynamic portfolio and wealth/consumption policies of utility maximizing investors who must also manage market risk exposure using Value at Risk (VaR). They find that VaR risk managers often optimally choose a larger exposure to risky assets than non-risk managers and consequently incur larger losses when losses actually occur. They suggest an alternative risk management model, based on the expectation of a loss, to remedy the shortcomings of VaR. A general equilibrium analysis reveals that the presence of VaR risk managers amplifies the stock market volatility at times of "down markets" and attenuates the volatility at times of "up markets".

[7] {Kim, 1988 #1357} argue that banks choose portfolios of higher risk because of inefficiently priced deposit insurance. Bank capital regulation is a way to redress this bias toward risk. Utilizing a mean variance model, the use of simple capital ratios in regulation is an ineffective means to limit the insolvency risk of banks. The authors suggest, instead, to explicitly derive the '*theoretically correct'* risk weights. In a recent paper, {Glasserman, 2014 #3418} propose an adaptive approach based upon the regulator would set weights as if he/she knew the true asset profitability of banks. Along similar lines, {Kuritzkes, 2005 #3416} consider the risk management problem faced by the Federal Deposit Insurance Corporation (FDIC) similarly to bank managing a loan portfolio, whilst in the FDIC's case the risk arises from losses in banks. {Stulz, 1996 #3417} proposes, instead, that risk management is not there to dampen swings in corporate cash flows or value, but rather to provide protection against the possibility of costly lower tail outcomes, for example situations that would cause financial distress or make a company unable to carry out its investment strategy.

[8] Another strand of the literature examines the relationship between bank risk, as measured by nonperforming loans, and bank performance (e.g., {Havrylchyk, 2006 #3430}; {Koutsomanoli-Filippaki, 2009 #3409}; {Mamatzakis, 2015 #3431}). {Atkinson, 2005 #3432} highlight the importance of including indicators of output quality, i.e., nonperforming loans, in the cost function suggesting that

As this review of the literature makes clear there are no (or few) structural models of bank risk based on micro foundations. In the next section we develop such a model.

3. The bank's indirect utility of profits

Our paper builds on the expected utility of profit maximization as in {Hughes, 2001 #2009}.[9] Whilst {Tsionas, 2016 #3422} proposes a theoretical model with a Taylor approximation, we extend this analysis beyond the Taylor approximation as we focus on bank output price uncertainty.

3.1. The general formulation

The production technology is described by a general transformation function $F(X,Y) \geq 1$, where $X \in \Re_+^K$ is a vector of inputs, $Y \in \Re_+^M$ is a vector of outputs. The transformation function describes how inputs are transformed into outputs. In the case of a single output, and a production function $Y = \varphi(X)$ (which is by definition, a frontier) one can write the transformation function as $F(X,Y) = \frac{\varphi(X)}{Y}$, and the bank`s technology as follows:[10]

$$T = \{(X,Y) \epsilon \Re^K \times \Re^M : X \text{ and } Y \text{ are technologically feasible}\} \quad (1)$$

Then, the bank would maximize the expected utility of profits:

$$E[U(\Pi] = E[U(PY - WX - C)] \quad (2)$$

where C represents fixed costs and *U(Π)* is a von Neumann-Morgenstern utility function of profit *Π*, with $U' > 0$. The input prices $W \in \Re_+^K$ are known to the bank, but output prices $P \in \Re_+^M$ are not known before decisions are made, so there is uncertainty around output prices.

Following {Appelbaum, 1997 #3414}, our basic stochastic assumption about bank output prices is:

$$P = m + e, \quad (3)$$

where μ represents expected prices, and ε is a vector random variable whose distribution

otherwise the bank performance estimates are likely to be biased (see also {Glass, 2018 #3839}). {Fiordelisi, 2011 #3433} assess the intertemporal relationship between bank efficiency, capital and risk in a sample of European commercial banks employing several definitions of efficiency, capital and risk and using the Granger causality methodology in a panel data framework. Their estimates suggest that lower bank efficiency with respect to costs and revenues Granger causes higher bank risk and that increases in bank capital precede cost efficiency improvements. They find that more efficient banks eventually become better capitalized and that higher capital levels have a positive effect on efficiency.

[9] {Hughes, 2001 #2009} show how to incorporate banks' capital structure and risk taking into a model of production. In doing so, they bridge the gap that exists between the banking literature that studies moral hazard effects of bank regulation without considering the underlying microeconomics of production and the literature that uses dual profit and cost functions to study the microeconomics of bank production without explicitly considering how banks' production decisions influence their riskiness.

[10] For simplicity of notation we shall not include indexes for time, bank and country. Please note that our model would fit a panel data analysis and as such there is both time and cross-sectional dimension.

is $\mathcal{F}_{\varepsilon}$, and has expectation a null vector.[11]

The model generalizes {Appelbaum, 1997 #3414} who considers the single output case in which there is only a single unknown output price. Using duality, the problem can be expressed in terms of indirect von Neumann-Morgenstern utility function as follows:

$$V(W,\mu,C;\mathcal{M}) = \max_{x\in\Re_+^K, y\in\Re_+^M} : E\left\{U\left((\mu+\varepsilon)'Y - W'X - C\right)\right\}, \text{s.t.} F(X,Y)\geq 1. \tag{4}$$

Here, $\mathcal{M}$ denotes higher order moments of the distribution $\mathcal{F}_{\varepsilon}$.

Note that the functional form of $F(X,Y)$ is not known. Our specification for the indirect utility function in (4) is a flexible, translog, functional form (where small letters w, p, c represents logs of W, P and C respectively):[12]

$$\begin{aligned}\log V(W,C;\mathcal{M}) = {} & \alpha_0 + \sum_{k=1}^{K}\alpha_k w_k + \tfrac{1}{2}\sum_{k=1}^{K}\sum_{k'=1}^{K}\alpha_{kk'}w_k w_{k'} + \\ & \sum_{j=1}^{J}[\sum_{m=1}^{K}\beta_m^{(j)}\mu_m^{(j)} + \tfrac{1}{2}\sum_{m=1}^{M}\sum_{m'=1}^{M}\beta_{mm'}^{(j)}\mu_m^{(j)}\mu_{m'}^{(j)} + \\ & \sum_{k=1}^{K}\sum_{m=1}^{M}\gamma_{km}^{(j)}w_k\mu_m^{(j)} + c\sum_{k=1}^{K}\delta_k^{(j)}w_k + \psi_1 c + \tfrac{1}{2}\psi_2 c^2 \\ & c\sum_{m=1}^{M}\zeta_m^{(j)}\mu_m^{(j)}] + \tfrac{1}{2}\sum_{j=1}^{J}\sum_{j'=1}^{J}\left\{\sum_{m=1}^{M}\sum_{m'=1}^{M}\eta_{mm'}^{(j,j')}\mu_m^{(j)}\mu_{m'}^{(j')}\right\}.\end{aligned} \tag{5}$$

where $\mu_m^{(j)} = E(p_m^j \mid z), j=1,...,J, m=1,...,M$ are moments. The moments are, in fact, conditional moments (viz. conditionally on z, that are weakly exogenous variables) whose construction is detailed below.[13]

The specification in (5) is different from {Appelbaum, 1997 #3414} who have used a restricted version of (5) in which maximization is performed under the assumption of cost minimization in which case the x_k`s appear as arguments in (5).

The bank`s risk aversion can be measured based on the notion that output prices are uncertain as in {Appelbaum, 1997 #3414} using a simple device. From the first order conditions with respect to outputs of the indirect utility function $V(W,\mu,C;M) = \max_{y\in\Re_+^M} : E\left\{U\left((\mu+\varepsilon)'Y - \mathcal{C}(W,Y) - C\right)\right\}$, where $\mathcal{C}(W,Y)$ is the usual (variable) cost function, we have:

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[11] Standard assumptions regarding the underlying data generating process of P are valid herein, regarding stationarity and existence of third and fourth moments.

[12] We drop μ as an argument of V as it is implicitly included in $\mathcal{M}$. Please also note that in Appendix I we discuss in detail the application of the envelope theorem on the indirect utility function in (4) that yields input demands and output supply functions.

[13] The first moment $\mu_m^{(1)}$ is included in logs as it is always positive. We do not follow this rule for moments higher than the first.

$$E\left[U'(\Pi)(\mu_m+\varepsilon_m)\right]=\frac{\partial C(W,Y)}{\partial Y_m},\ m=1,\ldots,M \tag{6}$$

and therefore the moments are:

$$\mu_m=\frac{\partial C(W,Y)/\partial Y_m}{E\left[U'(\Pi)\right]},\ m=1,\ldots,M.$$ [14]

This is equivalent to the condition:

$$\mu_m=\frac{\partial C(W,Y)}{\partial Y_m}+\lambda_m,\ \text{where}\ \ \lambda_m=-\frac{\operatorname{cov}(U',P_m)}{E(U')}>0$$

Therefore, under risk aversion output will be lower and the converse is also true. Setting $\mu_m^{(j)}=0,\ j=2,\ldots,M$ in (6) results in the case with no uncertainty. If output is higher in the no-uncertainty case, then risk aversion is present. This is broadly consistent with {Stiroh, 2006 #3434} who finds that banks most reliant on activities that generate noninterest income do not earn higher average equity returns, and are much riskier as measured by return volatility (both total and idiosyncratic) and market betas. It is also consistent with {Altunbas, 2000 #3435} who find that optimal bank size is considerably smaller when risk and quality factors are considered when modeling the cost characteristics of Japanese banks. This suggests that the pervasive shift towards noninterest income might not improve the risk/return outcomes ({Koutsomanoli-Filippaki, 2009 #3409}).

3.2. Parametric estimation

Following from the discussion of identifying shares of inputs and outputs, see equations (5) and the derivatives of (6), we estimate the following system of equations:

$$s_k=\frac{\alpha_k+\sum_{k'=1}^{K}\alpha_{kk'}w_{k'}+\sum_{j=1}^{J}\left\{\sum_{m=1}^{M}\gamma_{km}^{(j)}\mu_m^{(j)}+c\delta_k^{(j)}\right\}}{\sum_{j=1}^{J}\left\{\sum_{k=1}^{K}\delta_k^{(j)}w_k+\sum_{m=1}^{M}\zeta_m^{(j)}\mu_m^{(j)}+\psi_1+\psi_2 c+\xi_k\right\}},\ k=1,\ldots,K, \tag{7}$$

$$r_m=-\frac{\sum_{j=1}^{J}\left\{\beta_m^{(j)}+\sum_{m'=1}^{M}\beta_{mm'}^{(j)}\mu_{m'}^{(j)}+\sum_{k=1}^{K}\gamma_{km}^{(j)}w_k+c\zeta_m^{(j)}\right\}+\sum_{m'=1}^{M}\eta_{mm'}(j,j')\mu_m^{(j')}}{\sum_{j=1}^{J}\left\{\sum_{k=1}^{K}\delta_k^{(j)}w_k+\sum_{m=1}^{M}\zeta_m^{(j)}\mu_m^{(j)}\right\}+\psi_1+\psi_2 c}+\xi_{K+m},\ m=1,\ldots,M, \tag{8}$$

where ξ is a $(K+M)\times 1$ vector error term that we add for statistical purposes.[15]

For simplicity, we include four moments for each one of the M output prices. The very last term in (5) captures interactions between moments of order j and j' (

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[14] Also, it is worth noting that the output cost elasticity is $e_{cy}=\sum_{m=1}^{M}\frac{\partial \log C(W,Y)}{\partial \log Y_m}$, and therefore the expected marginal utility is $E\left[U'(\Pi)\right]=\frac{e_{cy}}{ER/C}$, the denominator in equation (6).

[15] As the system is homogeneous of degree one in the parameters we impose the identification constraint $\psi_1=-1$. Equations (7) and (8) are derived from application of the envelope theorem (see Appendix I) in (5).

$j, j' = 1,...,J$) for the various log output prices p_m and $p_{m'}$ ($m, m' = 1,...,M$).

Given data $\{p_{mi}, z_i, i = 1,...,n\}$ we can estimate:

$$\mu_m^{(1)} = \sum_{i=1}^{n} p_i \Omega_i(z), \tag{9}$$

where $\Omega_i(z) = \mathcal{K}\left(\frac{z_i - z}{h}\right) / \sum_{i=1}^{n} \mathcal{K}\left(\frac{z_i - z}{h}\right)$, $\mathcal{K}(\cdot)$ is a kernel function and h is the scalar bandwidth parameter and z are bank specific variables considered as weakly exogenous to the cost function (for example total loans, other earning assets and off balance sheet items and fees). Following standard practice, we take $h = n^{-(4+D)}$ when the data is normalized by their standard deviations. As z is a vector we use a product kernel, $\mathcal{K}_D(z) = \prod_{d=1}^{D} \mathcal{K}(z_d)$ where for $\mathcal{K}(\cdot)$ we use an Epanechnikov kernel. For $j > 1$, we use:

$$\mu_m^{(j)} = \sum_{i=1}^{n} p_i^j \Omega_i(z),\ j = 2,....,J. \tag{10}$$

The asymptotic correctness of these estimators is established in {Singh, 1970 #3459}.

Further, in a second stage we want to relate these moments to measures of conventional and unconventional monetary policy. As the moments are estimated non-parametrically, estimating a relation between moments and measures of monetary policy, in two stages, is known to yield biased and inconsistent results. To solve the problem we use a bootstrap. The bootstrap approach we use has been introduced, in a different setting, by {Simar, 2007 #3662}. The relationship of moments to measures of monetary policy is given by a panel VAR model which we detail in Part III of Appendix where we also detail our bootstrap technique.

Notice that we cannot drop an equation from this system as shares do not add up to unity. To simplify notation, we omit the observation index, which is, in fact, $i = 1,...,B$ for individual banks and $t = 1,...,T_i$ for time.

From duality theory it follows that the indirect utility function, V, must be non-decreasing in input prices and fixed costs (W, C) and non-increasing in expected output prices $\mu_m^{(1)}$. To comply with the theory the following specific constraints should be valid:

$$\alpha_k + \sum_{k'=1}^{K} \alpha_{kk'} w_{k'} + \sum_{j=1}^{J} \left\{ \sum_{m=1}^{M} \gamma_{km}^{(j)} \mu_m^{(j)} + c\delta_k^{(j)} \right\} \geq 0, k = 1,...,K, \tag{11}$$

$$\sum_{j=1}^{J} \left\{ \sum_{k=1}^{K} \delta_k^{(j)} w_k + \sum_{m=1}^{M} \zeta_m^{(j)} \mu_m^{(j)} \right\} + \psi_1 + \psi_2 C \geq 0, \tag{12}$$

$$\sum_{j=1}^{J} \left\{ \beta_m^{(j)} + \sum_{m'=1}^{M} \beta_{mm'}^{(j)} \mu_{m'}^{(j)} + \sum_{k=1}^{K} \gamma_{km}^{(j)} w_k + c\zeta_m^{(j)} \right\} + \sum_{m'=1}^{M} \eta_{mm'}(j, j') \mu_m^{(j')} \leq 0, m = 1,...,M. \tag{13}$$

We do not use maximum likelihood as this requires questionable normality and

homoskedasticity assumptions in (9) and (10). Instead, we opt for the Generalized Method of Moments (GMM), which, however, cannot be used under the observation-specific constraints (11) to (13). To address this, we impose, first, the restrictions (11) to (13) at the sample means $\bar{\mathbf{x}}$. For simplicity in presentation, let $\bar{\mathbf{x}}_{it} = [w_{it}, C_{it}, \mu_{m,it}^{(j)}]'$. We then apply the continuously updated estimator (CUE) version of GMM (see {Hansen, 1996 #3436}).[16] We refer to Part IV of the Appendix for more discussion of this issue.

We keep adding constraints at the points $\bar{\mathbf{x}} \pm \omega \cdot \mathbf{s}$ (where the vector of standard deviations is denoted by $\boldsymbol{s}$ for $\omega = 0.1, 0.2, \ldots$ until 99% of the data satisfy the constraints. Eventually, almost all data points satisfy the constraints for $\omega = 1.7$. Our instruments are input prices, all four observation specific moments of *P* and country, bank and time effects. In the list of instruments we include squares and cross products of all input prices, all four moments of *P* as well as all cross product terms along with cross product terms with bank-specific and time-specific effects. Time effects are introduced to account for other exogenous shifts in the demand functions. {Hansen, 1982 #3464}'s J statistic for testing the over identifying restrictions had a p-value no less than 0.30 in all cases for which we present empirical results. Moments are estimated using (9) where z includes total loans, other earning assets and off balance sheet items and fees, a measure of consumer's income (real GDP per capita), a measure of prices of other commodities (the GDP deflator), as well as country and time effects.

In Appendix II we present in detail the non-parametric approach to estimating bank risk aversion. In the empirical section, we shall present parametric and non-parametric estimations, whilst we also compare the fitness of the two estimations.

2.3. Bank risk aversion measure

Following {Gray, 2007 #3423} who consider the difficulties to account for bank risk in some detail, we propose herein to identify such risk through modeling bank risk aversion, opting for a micro foundation approach.

The starting point is to focus on demand and supply elasticities, with respect to output prices, that are given as follows:

$$E_{kmj}^{x} = \frac{\partial \log X_k}{\partial \log \mu_m^{(j)}} = \frac{\alpha_{kk'}}{\mathcal{D}_{w_k}} - \frac{\zeta_m^{(j)}}{\mathcal{D}_C}, k = 1, \ldots, K,\ j = 1, \ldots, J, \tag{14}$$

$$E_{mm'j}^{y} = \frac{\partial \log Y_m}{\partial \log \mu_{m'}^{(j)}} = \frac{\beta_{mm'}^{(j)}}{\mathcal{D}_{\mu_m}} - \frac{\zeta_m^{(j)}}{\mathcal{D}_C} - \Delta_{jj'}, m, m' = 1, \ldots, M,\ j, = 1, \ldots, J, \tag{15}$$

[16] We used the filterSD software which is written in Fortran77 and is released as open source code under the Eclipse Public License (EPL). It is available from the COINOR initiative. The code has been written by Roger Fletcher. The COIN project leader is Frank E. Curtis. For more details, see https://projects.coinor.org/filterSD.

where $\mathcal{D}_k = \frac{\partial \log V}{\partial \log W_k}, k = 1,...,K$, $\mathcal{D}_C = \frac{\partial \log V}{\partial \log C}$, $\mathcal{D}_{\mu_m} = \frac{\partial \log V}{\partial \log \mu_m^{(1)}}$, and $\Delta_{jj'} = 1$ if $m = m'$ and zero otherwise is Kronecker's *delta*.

These elasticities are meaningful empirical outcomes of the model. Equation (14) provides input demand elasticities with respect to moments of the bank output price distribution. More importantly, (15) provides elasticities of bank outputs Y_m with respect to the various moments $\mu_m^{(j)}$. These in the generalized sense are $\frac{\partial \log Y_m}{\partial \log \mu_{m'}^{(j)}} = \frac{\partial Y_m}{\partial \mu_m^{(j)}} \frac{\mu_m^{(j)}}{Y_m}$, implying a way of identifying uncertainty regarding bank output prices.

Moreover, bank input price elasticities can be computed easily:

$$E_{kk'}^{x} = \frac{\partial \log X_k}{\partial \log W_{k'}} = \frac{\alpha_{kk'}}{\mathcal{D}_k} - \frac{\delta_k^{(j)}}{\mathcal{D}_C} - \Delta_{kk'}, k, k' = 1,...,K, \tag{16}$$

$$E_{mm'}^{y} = \frac{\partial \log Y_m}{\partial \log \mu_{m'}^{(1)}} = \frac{\eta_{mm'}^{(j,1)}}{\mathcal{D}_{\mu_m}} - \frac{\delta_k^{(j)}}{\mathcal{D}_C}, m, m' = 1,...,M. \tag{17}$$

It must be noted that cross price elasticities of input demand are not symmetric and under uncertainty they may not have the same sign. Moreover, demand and supply functions that are upward sloping with respect to expected output prices but downward sloping with respect to second moments of prices, are consistent with risk averse banks with decreasing absolute risk aversion. That is to say that demand for bank inputs would increase as the expected bank output prices increase, and the same follows for bank supply, but on the other hand an increase in the volatility of bank output would result to a decline in both bank input demand and bank supply.

To compute output under the assumption of no uncertainty we use (10) and impose the restrictions that it is linearly homogeneous with respect to $w, \mu^{(1)}, c$. Note that $\frac{\partial V}{\partial C} = -1$ and moments of order $j = 2,...,J$ disappear from the model. Output '*shares*' can be computed from (17) and therefore expected or fitted outputs can be computed under the no-risk case, denoted as $\tilde{Y}_m$. Under risk (i.e., in output prices), then we could, also, compute from (17) expected or fitted outputs as $\hat{Y}_m$. Under bank risk aversion, we expect that $\tilde{Y}_m > \hat{Y}_m, m = 1,...,M$, or $\tilde{y}_m > \hat{y}_m, m = 1,...,M$ in log terms. To see by how much output would decrease we follow:

$$\overline{D}_m = (nT)^{-1} \sum_{i=1}^{n} \sum_{t=1}^{T} \left(\tilde{y}_{m,it} - \hat{y}_{m,it} \right), m = 1,...M, \tag{18}$$

which is the sample average percentage difference of outputs between the no uncertainty and uncertainty cases.

Equation (18) provides a measure of bank output loss due to uncertainty in output

prices. As we observe bank output with uncertainty and without the computation of bank output loss is straight forward. This measure provides an overall measure of the effects of uncertainty and thereby also an direct way of counting for the effects of bank risk aversion. In the empirical application, one could employ (18) so as to measure bank risk aversion as time-varying, bank-specific and/or country specific.[17] In Appendix II we present an extension to this measure based on a non-parametric estimation method.

Note that this is the first time that such a bank-specific risk aversion measure is proposed. In addition, by estimating equation (18) and thereby monitoring bank risk aversion and thus bank output loss based on micro foundations, we develop a novel early warning mechanism about possible financial crisis. Higher level of bank losses due to uncertainty in bank output prices would indicate that banks are facing high risk that they attempt to accommodate through higher risk aversion.

There is some discussion in the literature ({Koutsomanoli-Filippaki, 2009 #3409}; {Mamatzakis, 2015 #3431}) that bank managers, whether because of their own preferences or due to the enforcement of prudential regulation/supervision, would face large operating costs and as a result they would opt to settle for lower bank output, which can take the form of bank loans, other earning assets and off balance sheet items and fees. We build on this hypothesis and in particular we provide a framework where we estimate bank output (of the aforementioned three types) under risk and without risk. Moreover, in the current framework we provide a measure of bank risk aversion, based on the loss of bank output due to uncertainty in output prices. The higher the uncertainty of bank output prices of equation (18), the higher the loss of bank output.

4. The Eurozone financial crisis and the bank data set

4.1. The Eurozone financial crisis: An on-going saga

While the financial crisis started in the US in 2007, its impact was not felt in the Eurozone earlier than the end of 2008.[18] There were also significant lags in the Eurozone

[17] Most of the banking literature has focused on risk as the latter derives from one particular bank output, that is problem loans. There are several hypotheses regarding problem loans; if problem loans are exogenous then we have the '*bad luck'* hypothesis, if endogenous to bank management then the '*bad management'* or '*skimping'* ({Berger, 1997 #3437}). The aforementioned hypotheses have also led to '*moral hazard'* hypothesis ({Gorton, 1995 #91}), counting for the case that under-capitalized banks could issue further loans, some risky, so as to enhance counterparty risk. {Koutsomanoli-Filippaki, 2009 #3409} test for these hypotheses and find evidence for the *'moral hazard'* hypothesis in EU. To this day, no analysis has been proposed to deal with the micro foundations of bank output, and thereby bank loans. Our model shows that the bank output price uncertainty would lead to bank output losses.

[18] During 2007 it became clear that the financial industry in US was experiencing an unprecedented, crisis. Although there were few concerns in the Eurozone with respect to some banks in Belgium and the Netherlands, the market remained surprisingly resilient. However following, the Greek elections in October 2009 fiscal deficit figures were upwardly revised fourfold within a period of a quarter. Possible sovereign defaults within the Eurozone suddenly became a reality. The spread for the five-years Greek sovereign bonds rose from 215 basis points above the swap rate in December 2009 to almost 2,000 basis points in April 2010. Irish, Italian, Portuguese and Spanish spreads also rocketed with their banking industry being severely strained. The dramatic rises in sovereign bonds spreads in the Eurozone opened

response to the financial crisis. Some financial assistance was provided to entroubled Member States through the European Financial Stability Facility (EFSF) in 2010. A few years later in September 2012, the European Stability Mechanism (ESM) succeeded the EFSF with the ambition to provide financial assistance to Member States of the Eurozone.

With some considerable lags the ECB also applied quantitative and qualitative easing, along with conventional and unconventional monetary policy. It was only on July 26th, 2012, that Mario Draghi, President of the European Central Bank, in his now famous Speech at the Global Investment Conference in London stated that '*within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough*." Since then the ECB also announced a bond-buying operation, i.e., the Outright Monetary Transactions (OMT). Such transactions have not been entirely convincing as the state of the Eurozone banking is still raising serious concerns. For example, the Greek debt crisis continues to fester and Eurozone banks' exposures to risk taking, and more recently their bond borrowing, have raised doubts of how sound the financial markets in the Eurozone are.

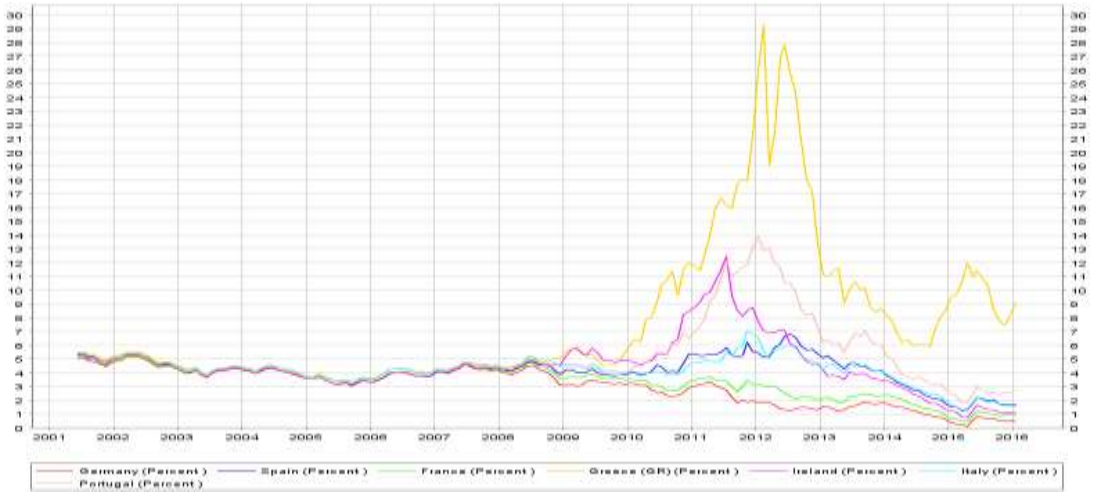
A simple way of depicting the state of financial instability in the Eurozone over the years is to look at the long-term interest rate for 10-year maturity sovereign bonds (see Figure 1). Interest rates converged prior to the launch of Euro in 2001 and remained at low levels for some considerable time until late in 2009. Since then we have witnessed some unprecedented hikes for some Member States of the Eurozone, notably in the periphery. These hikes appear to persist for some years, though with the exception of Greece there is some convergence since 2014. Note, that the financial crisis exposed a division between Member States of the Eurozone, despite some nominal convergence prior to the euro. There was clear evidence of a divergence in sovereign, but also corporate spreads across the Eurozone, with the periphery of the Eurozone reporting hikes in spreads in the period from 2010 to 2013, whilst the opposite is true for northern Member States (see Figure 1). Hikes in spreads in the periphery led to successive bank bail outs of large scale, and in one occasion bail in (see the case of Cyprus). In the following order, Greece, Ireland, and Portugal (and most recently Cyprus) did apply for financial assistance from EU Commission, and the International Monetary Fund, whereas the ECB provided technical support.[19] In addition, Spain have also benefited from financial assistance from the Eurozone. Overall, the Eurozone bank crisis proves to be very costly, ex post much more so when compared to the bailouts in US. So far more than 600 billion euros were allocated

the ongoing debate over the viability of the euro.

[19] Spain did not formally applied for financial assistance, yet its banking industry faced big losses due to the burst of the local property bubble. In Spain, only Bankia received funds in excess of 25 billion euros to stay afloat, with the total bill of the banking industry bail-out in the region is in excess of 100 billion euros. As a result Spain received 100 billion euros of financial assistance towards its banking industry from the EU. The case of Ireland is worth mentioning as its banking industry faced also with a loss of 100 billion euros, mostly related to defaulted mortgages. As a consequence the Irish banking industry had to be bailed out.

to bail out Eurozone banks.

Figure 1: Long-term interest rate, sovereign bonds of 10-year maturity in the Eurozone



Notes. The data are obtained from the ECB and are at a monthly frequency.

Alas, despite some considerable scale of financial assistance to the Eurozone banking industry, though not without significant lags compared to USA and UK, it is still uncertain whether there is firewall to safeguard the viability of the financial markets in the Eurozone and the banking industry in particular. The ECB program of monetary expansion since 2010 has progressively become more extensive and has involved mostly conventional, and in recent years unconventional monetary policy.[20] The ECB lowered interest rates across the board including the rate on the deposit facility, which banks may use to make overnight deposits with the Eurosystem, and the rate on the marginal lending facility, which offers overnight credit to banks from the Eurosystem. ECB also engaged in an unprecedented unconventional monetary policy program with the starting point being the Enhanced Credit Support in June 2009, and the Securities Markets Program in May 2010. Moreover, the Securities Markets Program (SMP), the Covered Bond Purchase Program 1 (CBPP1), and the Covered Bond Purchase Program 2 (CBPP2) were terminated in 2012.[21] The SMP amounted to € 240 billion and was designed as an intervention in the Eurozone public and private debt securities markets. Such interventions were assumed to be sterilised so as not to affect the monetary policy stance overall. The CBPP1 amounted to € 60 billion and reflected purchases in primary and secondary markets of covered bonds eligible for use as collateral for Eurozone credit operations. The

[20] In the Spring 2015 the ECB introduced as part of the so called '*expanded asset purchasing programme'* the third covered bond purchase programme (CBPP3), the asset-backed securities purchase programme (ABSPP), the public sector purchase programme (PSPP), and the corporate sector purchase programme (CSPP). Such ECB policies are officially designed to tackle low inflation. Yet, it is also the case that such policies would qualify as unconventional monetary policy. And this unconventional monetary policy came eight years later than in US and UK.

[21] The dates for the Securities Market Program were from 05/2010 to 06/9/2012, for the Covered Bond Purchase Program 1 from 06/2009 to 06/2010, and last for Covered Bond Purchase Program 2 from 11/2011 to 10/2012.

CBPP2 amounted to € 40 billion and focused on covered bonds with a residual maturity of 10.5 years. These programs were followed by the expanding Asset Purchase Program (APP), which up until May 2016 contained: The third Covered Bond Purchase Program (CBPP3), the Asset-Backed Securities Purchase Program (ABSPP), the Public Sector Purchase Program (PSPP), and the Corporate Sector Purchase Program (CSPP). As part of unconventional monetary policy we also take into account longer-term refinancing operations and marginal lending facility programmes.[22]

In addition, the Eurozone is focusing on enhancing the homogeneity and the integration of the banking industry by accelerating the process towards a Eurozone banking union. As part of this process a new institution, the Single Supervisory Mechanism (SSM) was established, aiming to provide unified bank supervision across Eurozone Member States. In parallel, failing banks will be managed by the Single Resolution Mechanism (SRM), which is yet to be activated as board selection is pending.[23] Following the above, it might not come as a surprise that we shall apply our bank risk aversion model to the Eurozone. That would be the first time that effects of uncertainty regarding output prices in the Eurozone banking industry would be revealed.

4.2. The Eurozone bank data set

Given these striking developments the Eurozone is a region of particular interest to examine bank risk-taking. In this study, we employ a comprehensive data set based on IBCA Bankscope and Orbis Bank Focus that contains all commercial, cooperative, savings, and investment banks operating in the Eurozone between 2001 and 2015. We examine the database for any reporting errors and other inconsistencies and end up with an unbalanced panel of 39,681 observations, which comprises 5,017 different banks. As a result our data set is a panel data set that has both time and cross section dimension. Also note, that the sample period is sufficiently long and covers also the aftermath of the financial crisis that would provide information on whether bank risk has been subdued since the financial meltdown in 2008 and following ECB's interventions.

Moreover, as we derive our bank risk measure based on the duality theory we employ − what is now standard in the literature − the "financial intermediation approach" (see {Sealey, 1977 #3438}) for determining bank inputs and outputs.[24] Based on this approach, banks act as

[22] Part of unconventional monetary policy could be the fine-tuning (structural) reverse operations. However, such operations have been rather limited.

[23] As part of SSM mandate an extensive exercise of bank '*stress tests*' were carried out in 2014. This exercise was rather comprehensive, covering 130 banks with €22.0 trillion of total assets, near to 82% of total assets in the SSM. It revealed that some 25 billion euros of additional capital should be raised. There has been some open criticism on the accuracy of such capital shortage. However, fact remains that the bank crisis has been lingering ever since, possible suggesting that previous recapitalisations did little to convince that the Eurozone banking industry is sound.

[24] For a review of the various approaches that have been proposed in the literature for the definition of

intermediates and thereby have deposits, by employing labor, physical and financial capital, and thereafter produce three bank outputs that cover the vast majority of banking activity: loans, other earning assets and off balance sheet items and fees.

Descriptive statistics of the data set are provided in Table 1. All figures are in Euro thousands. For this study we focus on Member States of the Eurozone (i.e., that were Members during the crisis), i.e., Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Italy, Ireland, Luxemburg, Malta, Netherlands, Portugal, Slovenia and Spain.

Table 1: Descriptive statistics for the bank balance sheet variables

	Mean	Std. Dev.	Min	Max
Total assets	9,314,117	75,600,000	28,300	2,250,000,000
Loans	4,585,979	32,400,000	9,000	1,190,000,000
Other earning assets	4,208,908	41,900,000	6,700	1,760,000,000
Overheads	126,647	974,880	700	29,800,000
Personnel expenses	68,812	537,141	5,000	16,100,000
Operational Expenses	58,020	447,720	6,000	15,100,000
Total interest expenses	214,017	1,776,076	8,000	99,500,000
Total interest income	327,101	2,476,853	1,100	103,000,000
Total non-interest income	73,623	628,892	3,000	21,500,000
Liquid assets	2,206,915	22,900,000	2,400	1,020,000,000
Total securities	3,059,906	35,100,000	4,900	1,700,000,000
Cash and claims on banks	197,011	2,299,746	5,731	118,000,000
Off balance sheet items	1,265,483	17,400,000	16,400	2,330,000,000
Total customer deposits	3,647,544	27,200,000	8,582	1,170,000,000
Other deposits	1,728,755	13,300,000	6,000	665,000,000
Total liabilities	8,857,807	72,400,000	22,900	2,160,000,000
Equity to total assets	8.17	6.60	1.95	100.00
Net interest revenue	120,818	940,665	1,400	32,500,000
Loan loss provisions	32,233	330,343	-15,500	18,500,000
Loan loss reserves	334,590	1,604,379	3,000	35,900,000
Nonperforming loans	560,443	3,016,797	14,100	77,400,000
Net interest margin	2.52	1.12	0.21	5.61
Operating profit	34,855	433,895	-69,000	12,500,000
Return to assets	0.33	1.43	-2.63	44.84
Return to equity	4.32	16.97	-1.96	775.51

Notes. The table reports descriptive statistics for all bank balance sheet variables. All amounts are in euros, except all ratios which are in percent. The sample covers the period 2001 to 2015 and contains 39,681 observations for 5,017 different banks from Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Italy, Ireland, Luxemburg, Malta, Netherlands, Portugal, Slovenia and Spain.

In our analysis we consider three different inputs, i.e., physical capital, labor and financial capital, and three outputs, i.e., loans, other earning assets (which include government securities, bonds, equity investments, CDs, T-bills, and equity investment), and off balance sheet items and fees. In line with previous studies ({Koutsomanoli-Filippaki, 2009 #3409}; {Mamatzakis, 2015 #3431}) we define the price of physical capital as other administrative expenses to fixed assets, of labor as personnel expenses to total assets, of financial capital as the total interest expenses over total interest bearing borrowed funds. Regarding bank output prices, the price of loans is the interest income from loans, the price of other earning assets is the income from other earning assets (i.e., government securities, bonds, equity investments, CDs, T-bills, and equity investment), and lastly for the price of off balance sheet items and fees we employ the non-interest income. We take as fixed cost the value of total fixed assets. We also include in our analysis variables such as loan loss provisions, loan loss reserves, and non-performing loans to directly take into account problem loans into our modeling. Other bank-specific variables that we consider are: Equity to total assets, bank size (see e.g. {Beccalli, 2015 #3908}), net interest revenue, and net interest margin.

In terms of monetary policy, we measure ECB's conventional monetary policy by the rate

bank inputs and outputs see {Berger, 1997 #1032}.

on the deposit facility at which banks may use to make overnight deposits with the Eurosystem (DEP) and the rate on the Marginal Lending Facility which offers overnight credit to banks from the Eurozone (MLFr). Unconventional monetary policy includes the Securities Markets Program (SMP) together with the Covered Bond Purchase Program 1 (CBPP1), and the Covered Bond Purchase Program 2 (CBPP2) (SEC). In addition, we include the main Refinancing operations (REFIN); Longer-term Refinancing operations (LTREFIN). Lastly, we take also into account the Marginal Lending Facility (MLF) Program.

5. Empirical results

5.1. Parametric and non-parametric input and output elasticities

First, we present our results on the various elasticities at the point of approximation, which is the sample mean of the data.[25] Table 2 presents the results. Elasticities E_{Ij} denote an elasticity of input $I \in \{K, L, F\}$ standing for physical capital, labor and financial capital with respect to the j^{th} moment ($j = 1, ..., 4$) in the output price.[26]

Results show that all input elasticities are positive with respect to the first moment, the expected output price, and turn negative with respect to the second moment, the volatility of the output price. This implies that for all inputs, that is physical capital, labor and financial capital, an increase in the expected output price would also increase the demand for inputs, but higher volatility in output price would lead to lower demand. Similarly, it is reported that the third and fourth moment is positive and negative, respectively. In Appendix II, we report also non-parametric estimation of input and output elasticities. Appendix's Table A.1 presents results on input elasticities at the point of approximation, which is the sample mean of the data using the non-parametric estimation as explained by the local log likelihood function (in equation (A.9) in Appendix II) for the linear local fit case.

[25] Note, that we take into account heterogeneity across various bank specifications in the indirect utility function *V* in (11), which is a flexible, translog functional form, by including dummies for commercial, cooperative, savings and investment banks. In addition, to capture heterogeneity across countries in the Eurozone, we also incorporate country dummies.

[26] To facilitate the presentation of results standard errors (which show that input elasticities are significant) are not tabulated, available upon request.

Table 2. Parametric input elasticities with respect to moments

Elasticity (E_{ij}) of Input (I)	Physical Capital (K)				Labor (L)				Financial Capital (F)			
With Respect To Moment (j)	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
2001-2007												
Austria	0.367	-0.439	0.543	-0.726	0.196	-0.476	2.100	-0.801	0.881	-0.183	0.539	-0.764
Belgium	0.630	-0.736	0.713	-0.756	0.120	-0.206	1.843	-0.649	0.709	-0.261	0.490	-1.314
Cyprus	1.271	-1.183	1.429	-2.171	-0.028	-0.170	0.920	-0.949	0.232	-0.103	0.130	0.347
Finland	0.757	-0.423	0.524	-0.673	0.191	-0.441	2.071	-1.786	0.836	-0.254	0.874	-0.771
France	0.593	-0.261	0.671	-0.726	0.115	-0.187	1.557	-0.556	0.670	-0.209	0.370	-0.806
Germany	0.484	-0.427	0.509	-0.767	0.249	-0.439	2.100	-0.806	0.879	-0.165	0.496	-0.813
Greece	1.171	-1.243	1.500	-2.786	0.075	-0.024	0.746	-1.243	0.213	0.003	0.197	0.369
Italy	1.130	-1.143	1.243	-1.857	0.019	-0.090	0.947	-1.243	0.253	-0.108	0.309	0.439
Ireland	1.143	-1.271	1.400	-2.100	0.089	-0.113	0.659	-1.300	0.333	-0.036	0.114	0.211
Luxembourg	1.091	-1.104	1.200	-1.843	0.017	-0.074	0.874	-1.300	0.371	-0.005	0.271	0.414
Malta	1.214	-1.143	1.371	-2.214	0.070	-0.101	0.811	-1.087	0.239	-0.020	0.199	0.440
the Netherlands	0.493	-0.537	0.557	-0.614	0.274	-0.132	1.157	-0.420	0.410	-0.519	0.454	-0.897
Portugal	1.051	-1.173	1.243	-2.729	0.087	-0.068	0.673	-1.214	0.155	-0.025	0.273	0.396
Slovenia	0.819	-0.477	1.329	-2.257	0.045	-0.107	0.667	-1.124	0.089	-0.004	0.197	0.429
Spain	1.186	-1.243	1.357	-2.229	0.043	-0.061	0.787	-1.171	0.270	-0.031	0.283	0.396
2008-2011												
Austria	0.188	-0.173	0.270	-0.228	0.210	-0.333	2.175	-0.900	0.790	-0.258	0.678	-0.870
Belgium	0.015	-0.138	0.660	-0.468	0.159	-0.253	1.875	-0.483	0.665	-0.368	0.840	-0.733
Cyprus	0.805	-0.718	1.575	-1.350	0.128	-0.149	0.353	-1.875	0.343	-0.333	0.243	-0.375
Finland	0.268	-0.263	0.335	-0.189	0.195	-0.368	1.040	-0.473	0.508	-0.003	0.530	-0.240
France	0.001	-0.155	0.440	-0.495	0.124	-0.234	1.750	-0.363	0.648	-0.433	0.623	-0.713
Germany	0.135	-0.090	0.355	-0.238	0.265	-0.370	2.175	-1.175	1.350	0.065	0.495	-0.500
Greece	0.983	-0.740	1.525	-1.850	0.026	-0.033	0.573	-2.350	0.253	-0.268	0.214	-0.263
Italy	0.725	-0.890	1.250	-1.425	0.076	-0.095	0.468	-1.250	0.240	-0.710	0.453	-0.533
Ireland	0.923	-0.800	1.300	-1.250	0.091	-0.100	0.253	-1.400	0.250	-0.358	0.159	-0.152
Luxembourg	0.460	-0.403	0.830	-1.350	0.073	-0.082	0.370	-1.400	0.155	-0.613	0.440	-0.493
Malta	0.720	-0.705	1.675	-1.400	0.051	-0.059	0.385	-1.875	0.385	-0.405	0.345	-0.290
the Netherlands	0.275	-0.218	0.305	-0.228	0.250	-0.378	1.125	-1.250	0.803	-0.195	0.163	-0.640
Portugal	0.930	-0.828	1.065	-1.350	-0.061	0.008	0.450	-2.025	0.425	-0.253	0.260	-0.433
Slovenia	0.555	-0.733	1.500	-1.300	-0.017	-0.016	0.403	-1.900	0.440	-0.335	0.186	-0.345
Spain	0.828	-0.693	1.525	-1.400	0.099	-0.087	0.315	-1.925	0.293	-0.280	0.167	-0.350
2012-2015												
Austria	0.088	-0.200	0.308	-0.190	0.208	-0.365	0.743	-0.615	0.695	-0.235	0.223	-0.473
Belgium	0.285	-0.230	0.190	-0.708	0.173	-0.528	1.325	-0.220	0.313	-0.240	0.340	-0.705
Cyprus	0.738	-0.738	1.258	-1.185	0.222	-0.021	0.395	-1.250	0.343	-0.185	0.310	0.420
Finland	0.410	-0.189	0.220	-0.720	0.193	-0.158	0.403	-0.385	0.435	-0.088	0.186	-0.218
France	0.633	-0.265	0.435	-0.658	0.044	-0.055	1.375	-0.475	0.668	-0.245	0.365	-0.663
Germany	0.320	-0.415	0.500	-0.695	0.263	-0.523	1.975	-0.630	0.943	-0.073	0.345	-0.648
Greece	0.825	-0.950	1.045	-1.350	-0.007	-0.085	0.335	-1.200	0.238	-0.005	0.123	0.176
Italy	0.668	-0.390	0.743	-0.990	0.094	-0.033	0.218	-0.778	0.280	-0.273	0.195	0.145
Ireland	0.323	-0.443	0.818	-0.748	0.051	-0.221	0.273	-0.883	0.173	-0.463	-0.030	0.003
Luxembourg	0.255	-0.370	0.588	-0.438	0.068	-0.061	0.398	-1.400	0.135	-0.493	0.353	0.490
Malta	0.625	-0.670	1.300	-1.150	0.103	0.015	0.488	-1.450	0.418	-0.228	0.207	0.345
the Netherlands	0.143	-0.155	0.245	-0.118	0.153	-0.092	0.533	-0.520	0.338	-0.137	0.078	-0.216
Portugal	0.685	-0.768	1.050	-1.053	0.012	0.003	0.230	-1.098	0.295	-0.158	0.106	0.200
Slovenia	0.423	-0.890	1.238	-1.018	0.052	-0.002	0.623	-1.450	0.390	-0.268	-0.039	0.120
Spain	0.605	-0.683	1.250	-1.250	0.062	0.012	0.373	-1.500	0.445	-0.285	0.223	0.385

Notes. The table reports the estimates of the elasticities of the input with respect to the jth moment

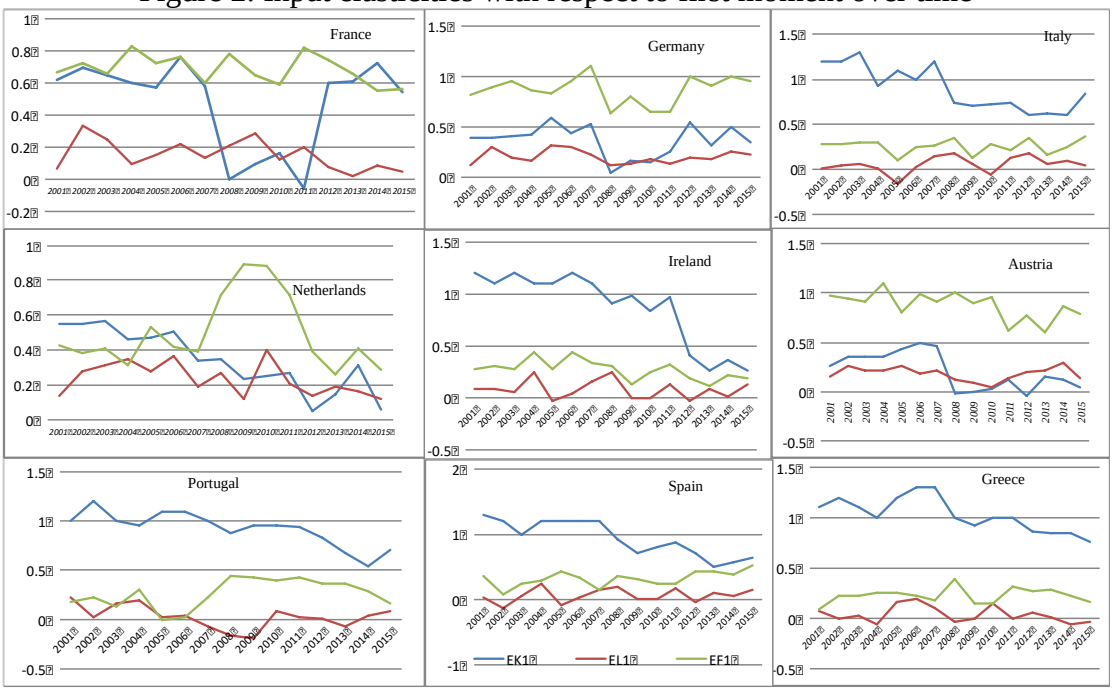
To assist the presentation we report herein results for the periphery that includes Ireland, Italy, Portugal and Spain, and separately for France, Germany and Greece. This grouping is simply for presentation purposes. All other results are available upon request. Input elasticities with respect to output prices are all positive and significant in line with the parametric estimations. Note that the higher the volatility of output prices, the lower the demand for bank inputs as the elasticity of inputs with respect to the second moment is negative. The elasticities with respect to the third and fourth moments are positive and negative, respectively. These elasticities are, generally, quite different across the three sub-periods. In line with the parametric estimations, demand for bank inputs during the credit crunch is significantly lower than prior to the crisis. These results reveal that during the crisis uncertainty regarding bank output prices has severe effects on bank inputs demand.

Given the underlying time dimension of our sample, Figure 2 shows the input elasticities with respect to the 1st moment of the output price over time. To facilitate the presentation we present figures for some selected Eurozone Member States, that is Member States in the periphery and some north/central Eurozone Member States. Clearly, there is variability across Member States regarding the demand for bank inputs during the credit crunch, though an overall decline is noted. There is a pronounced drop in the demand for physical capital (blue line), followed by financial capital (green line), in large Member States (see France, Germany and Italy). For Member States in the periphery, i.e. Portugal, Ireland, Spain and Greece, labour demand did also decline around financial crisis. Notice that demand for financial capital increase for Netherlands (and to less extent for Portugal) during the main

period of financial crisis, that is 2008 to 2011, yet it drops thereafter.[27] The decline in demand for labor, physical and financial capital is noticeable for all Member States in the Eurozone, but it is quite considerable for the periphery, i.e., Greece, Ireland, Italy, Portugal and Spain. One of the revelations of the financial crisis is related to the time horizon of the financial cycle. It is argued that the bust periods of a financial cycle last much longer, compared with those in a business cycle ({Aikman, 2015 #3440}; {Borio, 2017 #3439}).

Our results provide, for the first time, evidence of the prolonged bust period of financial cycle based on bank input demand. Certainly, there is some recovery in bank input demand over the period 2012-2015, but this is rather anemic, whereas for some Member States negative trends in bank input demand persist (see Austria, France, Germany, Greece, Ireland, Italy, the Netherlands and Portugal). Indeed, there is evidence of "multi-dipping" in the demand for bank inputs. Also it is worth noting that demand for labor is negative, in particular during and after the crisis for Greece, Ireland, Portugal and Spain. The value added of our results comes from the understanding that the financial crisis has shifted downwards bank input demand also in France and Germany, countries that are widely considered not to have been severely subjected to the effects of the crisis compared to the periphery. Yet, we reveal that based on micro foundations evidence that this is not the case. Eurozone banking industry is still facing the effects of uncertainty.

Figure 2: Input elasticities with respect to first moment over time



[27] Note that the Netherlands had to respond and bail out banks earlier than other Member States in the Eurozone, the elasticity of financial capital with respect to expected bank output price reflects this. Since 2011 a decline in demand for financial capital is recorded.

Notes. Elasticities are estimated for each of the inputs, K, L and F, with respect to 1st moment of output prices. These elasticities stand as EK1 for physical capital (blue line), EL1 for labor (red line) and EF1 for financial capital (green line).

In Table 3 we report output elasticities E_{Oj}, where $O \in \{Loans, OEA, OBS\}$ standing for loans, other earning assets (OEA) and off balance sheet items and fees (OBS), with respect to the j^{th} price moment ($j = 1,...,4$). Output elasticities are at the point of approximation, which is the sample mean of the data. Results show that higher expected output prices increase the supply of bank loans, bank other earning assets and off balance sheet items and fees, but that this effect is subdued during the credit crunch, whereas volatility in output prices has the opposite outcome. Output elasticities with respect to the 3rd and 4th moment are, as expected, positive and negative respectively. These output elasticities reveal similar patterns to input elasticities. Non-parametric estimations of output elasticities confirm the above and are available under request.

Table 3. Parametric output elasticities with respect to moments

Elasticity (E_{Oj}) of Output (O)	Loans (L)				Other Earning Assets (OEA)				Off Balance Sheet (OBS)			
With Respect To Moment (j)	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
2001-2007												
Austria	0.38	-0.59	0.19	-0.63	0.04	-0.27	-0.08	0.03	0.46	-0.38	0.31	-0.21
Belgium	1.00	-0.44	0.23	-0.17	0.25	-0.53	0.16	-0.18	0.44	-0.19	0.37	-0.17
Cyprus	0.48	-0.53	0.16	-0.32	-0.12	-0.27	0.09	-0.12	0.63	-0.45	0.40	-0.31
Finland	0.30	-0.62	0.32	-0.33	0.19	-0.40	0.32	-0.24	0.49	-0.19	0.30	-0.20
France	1.00	-0.67	0.30	-0.43	0.23	-0.34	0.26	0.11	0.56	-0.38	0.54	-0.18
Germany	0.82	-0.49	0.12	-0.13	0.25	-0.42	0.37	-0.28	0.48	-0.20	0.55	-0.40
Greece	2.10	-0.03	1.90	-0.20	-0.06	-0.35	0.25	-0.48	0.51	-0.43	0.33	-0.14
Italy	2.30	-0.29	1.50	-0.16	0.38	-0.39	-0.12	-0.40	0.49	-0.23	0.32	-0.13
Ireland	2.30	-0.36	1.80	-0.44	0.29	-0.05	0.25	-0.64	0.50	-0.23	0.47	-0.37
Luxembourg	0.88	-0.60	0.28	-0.29	-0.03	-0.71	0.53	0.02	0.74	-0.31	0.27	-0.15
Malta	0.58	-0.66	0.40	-0.43	0.02	-0.22	0.43	-0.06	0.53	-0.38	0.55	-0.15
the Netherlands	2.30	-0.33	1.70	-0.29	0.45	-0.57	0.01	-0.40	0.55	-0.51	0.33	-0.18
Portugal	2.20	-0.34	1.60	-0.38	0.17	-0.39	0.09	-0.35	0.58	-0.52	0.38	-0.30
Slovenia	0.58	-0.71	0.47	-0.39	0.25	-0.18	0.20	-0.29	0.48	-0.26	0.30	-0.26
Spain	1.90	-0.34	1.70	-0.37	0.20	-0.10	-0.04	-0.40	0.54	-0.44	0.33	-0.26
2008-2012												
Austria	0.61	-0.57	0.27	-0.62	0.61	-0.062	0.54	-0.28	0.34	-0.46	0.18	0.023
Belgium	0.82	-1	0.21	-0.63	0.18	-0.074	0.74	-0.14	0.44	-0.24	0.42	-0.23
Cyprus	0.66	-0.59	0.35	-0.46	0.57	-0.11	0.31	-0.37	0.71	-0.21	0.36	-0.025
Finland	0.47	-0.59	0.32	-0.098	0.17	-0.44	0.5	-0.27	0.22	-0.51	0.56	-0.09
France	0.86	-0.36	0.087	-0.69	0.17	-0.23	0.3	-0.36	0.34	-0.38	0.43	-0.25
Germany	0.57	-0.34	0.38	-0.19	0.11	-0.12	0.22	-0.63	0.42	-0.54	0.51	-0.29
Greece	1.1	-0.071	1.2	-0.37	0.31	-0.83	0.15	-0.65	0.64	-0.16	0.28	-0.09
Italy	1.2	-0.072	0.99	-0.15	-0.18	-0.36	0.78	-0.67	0.48	-0.29	0.32	-0.35
Ireland	1.5	-0.25	1	-0.12	0.18	-0.89	0.21	-1	0.44	-0.086	0.34	-0.23
Luxembourg	1	-0.82	0.28	-0.66	0.5	-0.12	0.32	-0.25	0.55	-0.32	0.49	-0.23
Malta	0.86	-0.66	0.32	-0.26	0.32	-0.19	0.13	-0.23	0.27	-0.28	0.52	-0.092
the Netherlands	0.82	-0.0094	1.3	-0.13	0.23	-0.81	0.35	-0.83	0.44	-0.4	0.46	-0.21
Portugal	1.3	-0.29	0.95	-0.31	0.073	-0.71	0.49	-0.72	0.6	-0.11	0.65	-0.33
Slovenia	0.81	-0.27	0.41	-0.56	0.19	-0.21	0.44	-0.48	0.56	-0.22	0.49	-0.33
Spain	1	-0.027	1.2	-0.2	0.18	-0.59	0.37	-0.43	0.44	-0.14	0.53	-0.3
2012-2015												
Austria	0.62	-0.55	0.18	-0.49	0.088	-0.15	0.16	-0.41	0.48	-0.34	0.54	-0.32
Belgium	0.94	-0.55	0.37	-0.35	0.06	-0.014	0.49	-0.063	0.64	-0.41	0.47	-0.073
Cyprus	0.64	-0.53	0.5	-0.46	0.39	-0.18	0.36	-0.14	0.49	-0.41	0.67	-0.24
Finland	0.78	-0.57	0.47	-0.41	0.083	-0.5	0.51	-0.32	0.33	-0.36	0.62	-0.048
France	1.1	-0.49	0.38	-0.67	0.28	-0.27	0.46	-0.22	0.43	-0.34	0.12	-0.21
Germany	0.63	-0.37	0.3	-0.51	0.24	-0.24	0.44	-0.22	0.51	-0.25	0.26	-0.17
Greece	1.8	-0.27	1.7	-0.32	0.35	-0.81	0.2	-0.38	0.4	-0.27	0.41	-0.3
Italy	1.9	-0.19	1.6	-0.14	0.23	-0.58	0.43	-0.6	0.64	-0.28	0.36	-0.34
Ireland	1.8	-0.39	1.2	-0.46	0.13	-0.56	0.2	-0.74	0.7	-0.31	0.49	-0.2
Luxembourg	1.7	-0.022	1.4	-0.21	0.31	-0.78	0.14	-0.5	0.47	-0.32	0.47	-0.2
Malta	0.78	-0.54	0.45	-0.6	0.21	-0.39	0.27	-0.21	0.61	-0.14	0.22	-0.32
the Netherlands	0.86	-0.52	0.41	-0.052	0.18	-0.53	0.36	-0.021	0.75	-0.47	0.65	-0.29
Portugal	1.7	-0.24	1.5	-0.23	0.2	-0.6	0.26	-0.46	0.51	-0.38	0.38	-0.11
Slovenia	0.55	-0.91	0.27	-0.54	0.17	-0.17	0.43	-0.062	0.4	-0.39	0.36	-0.27
Spain	1.6	-0.4	1.5	-0.25	0.3	-0.72	0.031	-0.39	0.46	-0.45	0.51	-0.29

Notes. The table reports the estimates of the elasticities of the output with respect to the j^{th} moment.

The reported findings suggest that the Eurozone banking industry has been subject to some severe head winds as both bank input demand and bank output supply have been distracted as a result of the financial crisis, and there is some persistence in recent years too. As this destruction was exacerbated by the credit crunch, the results show that the Eurozone banking industry has faced escalating uncertainties in bank output prices and that thereby bank risk aversion has been increasing. In addition, bank uncertainty regarding bank output prices has much more detrimental effects on bank input demand and bank outputs since the onset of the crisis.

5.2. Loss of bank output due to uncertainty in output prices

As we detect some variability over time and across Member States of the Eurozone in bank input demand and output supply since the financial crisis, we now turn to estimating any

loss of bank output due to changes in bank risk aversion triggered by the uncertainty in output prices. To this end, we employ equation (25). The results of bank loss of output are reported in Table 4 as D_m, where $m =$ loans, OEA (Other Earning Assets) or OBS (Off Balance Sheet items and fees). Since logs are used the measures are in percentage terms.[28] Any deviations from risk neutrality towards risk aversion due to uncertainty in output prices would lead to loss of output. Thus, bank outputs under certainty should be higher than under uncertainty. This implies that the larger the estimates of D_m the higher the loss of output due to uncertainty in output prices.

Table 4. Bank loss of output due to risk: parametric estimation

	2001-2007			2008-2011			2012-2015		
Loss in Output, in %	**Loans**	**OEA**	**OBS**	**Loans**	**OEA**	**OBS**	**Loans**	**OEA**	**OBS**
Austria	10.176	8.362	21.910	22.172	10.518	6.065	9.498	12.438	7.303
Belgium	14.465	9.266	21.562	21.602	10.546	6.567	9.318	12.398	7.441
Cyprus	11.982	7.792	21.925	22.345	11.856	7.313	9.328	12.180	7.197
Finland	14.359	9.515	21.351	21.143	10.627	6.637	9.399	12.473	7.220
France	10.974	7.407	19.857	19.753	12.022	6.477	9.399	12.529	7.393
Germany	12.322	3.216	23.471	23.508	12.177	6.542	9.370	12.407	7.278
Greece	10.593	11.700	22.871	22.945	24.871	28.029	9.473	12.446	7.419
Italy	12.156	16.279	21.368	21.085	11.280	13.868	9.537	12.233	7.423
Ireland	7.538	12.098	20.278	20.190	19.645	18.779	9.330	12.297	7.165
Luxembourg	13.947	6.850	22.427	22.357	11.259	6.354	9.493	12.487	7.632
Malta	11.540	7.851	22.233	22.577	10.734	5.667	9.518	12.362	7.421
the Netherlands	12.989	6.977	21.778	21.739	10.662	5.742	9.375	12.421	7.882
Portugal	8.777	12.834	20.966	21.193	16.885	22.572	9.438	12.287	7.341
Slovenia	13.306	8.051	18.996	19.127	9.950	11.719	9.427	12.300	7.499
Spain	8.093	14.165	28.305	28.400	13.615	16.740	9.198	12.373	7.634

Notes. The table reports the loss of output calculated with equation (25) which represents the difference of output between the no-uncertainty (full information) case and the uncertainty case, and which can be interpreted as the change in bank risk aversion. OEA are Other Earning Assets and OBS are Off Balance Sheet items and fees.

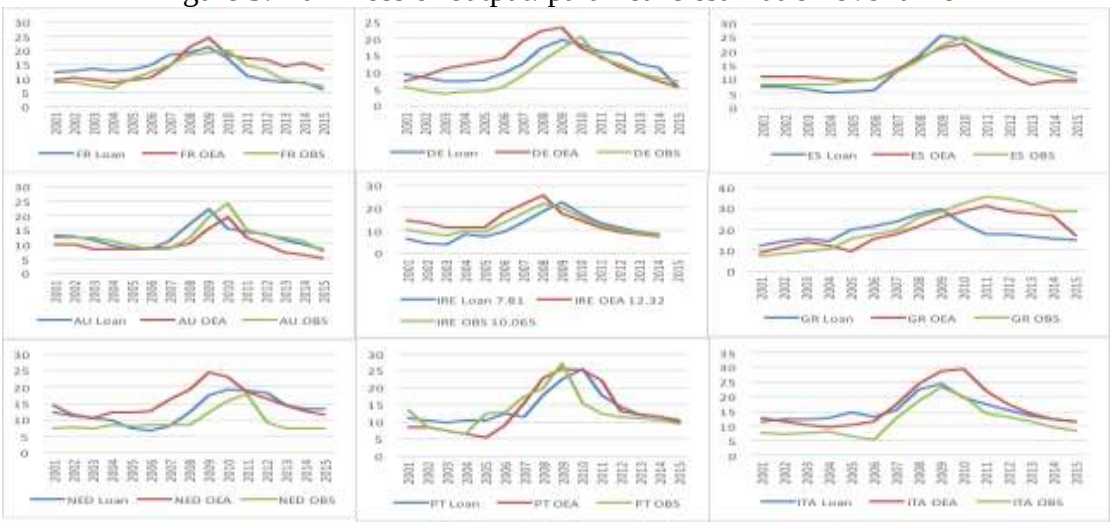
Table 4 shows that, indeed, in all sub-periods we have considerable loss of bank output, both in terms of bank loans, other earning assets and off balance sheet items and fees. This loss is aggravated during the 2008-2009 financial crisis period. The loss of bank output is quantitatively important, i.e., close to 20% for France and 24% for Germany (the largest Eurozone Member States) during the period 2008-2011. This is also the case for other Member States of the Eurozone, with that of Spain being rather striking as bank loans (but also other earning assets and off balance sheet items and fees) under certainty in Spain would have been around 28% higher during the crisis from 2008 to 2011. Note that bank loss of output for the Eurozone is also identified prior to the crisis, during the period 2001-2007, when the average loss of bank output during the bank risk aversion is around 11%. Alas, during the crisis period these losses doubled.

Worryingly, for some Member States in the Eurozone the output losses persist well after the crisis, that is from 2012 to 2015, notably in the case of Greece (and to a less extend for Ireland and Spain) for which the losses have been aggravated. For Greece there is a further loss of bank output of up to 25% (28%) for bank loans (other earning assets and off balance sheet items and fees) in the period 2012-2015. Also, not surprisingly the Spanish bank losses are the highest of all, i.e., 28% during the crisis, whilst there is some recovery of Spanish bank

[28] Standard errors are available upon request. All estimations of the loss of output are significant at the 5% level.

output losses in recent years.[29] The Irish banking industry is also of interest as the subprime crisis has revealed its dire state, that is proving hard to fix. Our results show that bank losses in Ireland persist also well after the financial crisis and despite the Irish banking industry have received unprecedented financial assistance (see also Figure 3).

Figure 3: Bank loss of output: parametric estimation over time



Notes. Bank risk aversion represents loss of output as derived from (25); the difference of output between the no-uncertainty case (full information) and the uncertainty case. FR is France, DE is Germany, ES is Spain, AU is Austria, IRE is Ireland, GR is Greece, ITA is Italy and PT is Portugal and NED is Netherlands. Loans is the loss of loans, OEA is the loss in other earning assets, whilst OBS is off balance sheet items and fees, all in % terms.

Figure 3 reveals that bank losses of output as a result of higher uncertainty in prices peaked during the crisis but they subdued thereafter somewhat. In recent years, there is a resurgence of bank output losses in most Member States. This roller coaster type of movement in bank output losses is very alarming. Some heterogeneity across Member States is observed, notably for France for which losses in other earning assets fall below 5% in recent years, though bank output losses is a serious concern for all.

These findings reveal an unpleasant reality as the Eurozone banking industry is facing large output losses as a result of uncertainty in bank output prices in recent years. It is true that output losses were high during the crisis across all Eurozone Member States (including the large Member States such as France and Germany that were supposed to weather the crisis well), yet their persistence thereafter is troublesome.

What we observe is evidence of bank '*risk averse management*', that is bank managers in the face of uncertainty in bank output prices opt for lower bank output, whether as bank loans or other earning assets. This attitude towards lower bank output has been emerging since the financial crisis, and we do not detect a reversion, suggesting that the financial cycle has been prolonged in the Eurozone. Some significant bank output loss is reported prior to the crisis as

[29] Greece still faces strong conditionality and non-access to financial markets, while Spanish banking industry was severely rocked by scandals but now seems on the road to recovery.

the average bank loss in loans (other earning assets) is 12% (10%) in the period 2001 to 2007. And despite the fact that bank output loss increased up to 22% during the crisis, it is worrying that since the crisis bank out loss remains at higher levels than before the crisis (see Table 4). This persistence in bank output loss is potentially alarming. One might raise the question whether intervention is warranted to mitigate the effects of persistence in bank risk aversion. It could be the case that ECB's monetary policy could come to aid.

Clearly though, since 2007 there is an escalation of bank risk aversion in the Eurozone, casting doubts over the soundness of the industry.[30] {Acharya, 2015 #3406} demonstrate that insolvent banks resort to raising rates as a way to attract deposits, and thereby enhance their capitalization, in the event losses occur in banks outputs. As the solvency risk of a bank increases, its realized rates of return decrease and despite the fact that weak institutions may offer substantially higher rates in the run up to failure, the realized rates of return will not be recovered. From this point of view, we provide evidence herein that uncertainty in output prices or uncertainty in rates of return on bank outputs, such as bank loans, other earning assets and off balance sheet items and fees, would be considered as the main drivers of bank risk aversion and bank risk therefore in the Eurozone. We also reveal, rather alarmingly, that persistence of bank output losses is widely spread across all of the Eurozone in recent years, and not confined just in the periphery.

As we provide a measure of bank output loss using non-parametric estimations we present in Table 5 this non-parametric measure of bank output loss while in parentheses we report standard deviations. Results show, once more, that during the crisis we have significant bank losses in output, whether on loans or other earning assets or off balance sheet items and fees. For example, note that due to the uncertainty bank loans (bank other earning assets) are 21% (27%) in the Eurozone periphery during the crisis, whilst losses remain high thereafter though there is some correction to 19% (18%) in 2012 to 2015. Bank output losses remain at high levels over the whole sample. For France and Germany there is a significant, from a statistical and economic point of view, higher loss in bank loans and other earning assets during the crisis, though in recent years it appears that some recovery in loss of output is in place. Yet, even for large Eurozone Member States bank risk aversion plays an important role, in line with parametric estimations.

[30] {Acharya, 2015 #3406} report that '*toxic*' financial assets, such as subprime loans, were a major part of commercial and investment bank balance sheets in US, and EU in general, undermining bank solvency. When risks escalated banks had little room to maneuver other than as a first reaction seek to raise their deposits by offering higher rates. In fact, non-solvent banks were the ones that offered higher interest rates. This effect has been magnified somewhat by quantitative and qualitative easing of monetary policy at the global level. Our results pick up such effects in terms of higher risk aversion during and after the crisis.

Table 5. Bank loss of output due to risk without ECB policy actions: Non-parametric estimates

	2001-2007			2008-2011			2012-2015		
Loss in Output, in %	Loans	OEA	OBS	Loans	OEA	OBS	Loans	OEA	OBS
France	13.12%	7.45%	9.44	19.45%	16.65%	13.20	12.45%	6.32%	9.44
	(3.44)	(2.61)	(2.71)	(3.45)	(2.76)	(4.15)	(3.25)	(3.45)	(1.55)
Germany	12.43%	5.52%	7.32	22.34%	12.35%	11.15	10.24%	5.21%	8.12
	(3.71)	(3.07)	(2.55)	(2.40)	(5.22)	(5.45)	(3.28)	(2.87)	(2.30)
Greece	9.76%	12.36%	9.43	25.12%	31.14%	13.20	24.33%	30.25%	9.44
	(2.22)	(4.17)	(1.87)	(5.44)	(3.16)	(4.67)	(5.57)	(4.65)	(3.13)
Ireland, Italy, Portugal, Spain	18.16%	21.32%	14.12	21.36%	27.34%	19.15	19.25%	18.25%	11.20
	(2.72)	(5.44)	(4.11)	(4.06)	(6.22)	(7.12)	(3.15)	(4.32)	(4.41)

Notes. The table reports the loss of output calculated with equation (25) which represents the difference of output between the no-uncertainty (full information) case and the uncertainty case, and which can be interpreted as the change in bank risk aversion.Output loss is calculated without ECB policy actions. OEA are Other Earning Assets and OBS are Off Balance Sheet items and fees.

Characteristically, for Greece, although in the early sub-period the loans (other earning assets) under certainty would have been 10% (12%), that is much lower loss compared to the loss of the Eurozone periphery, but also if compared to output loss in France and Germany, thereafter Greek bank loans (other earning assets) losses rocketed to 25% (31%) during the crisis. Since the crisis, Greek bank output losses show very strong persistence. This, clearly, illustrates that risk due to uncertainties in output prices in Greece has increased dramatically, during and after the crisis, as consolidation in banking (and fiscal) balance sheets is still pending. Uncertainties in output prices have severely distorted bank behavior as revealed by hikes in bank risk aversion that leads to bank output losses.

5.3. The long run impact of conventional and unconventional monetary policy

Against a disturbing backdrop of Eurozone bank output losses during the crisis and thereafter, it is of interest to assess whether ECB's intervention has been effective to moderate these losses. So here we provide evidence of second stage analysis based on GMM estimation of a panel VAR (see Appendix III for the GMM estimator of a panel VAR). This analysis takes into account of the impact of the combined conventional and unconventional monetary policy on bank risk aversion. By doing so, we can reveal bank output losses due to uncertainty in output prices in the presence of ECB's interventions.

In Table 6 we report the bank output losses due to uncertainty in output prices taking into account the impact of ECB's monetary policies.[31] A comparison with results in Table 5 reveals that indeed ECB's monetary policy, overall, mitigates the bank output loss due to uncertainty in output prices. Over the whole period the average bank loss of output is close to 2% less than it would have been without the intervention of the ECB. These results show that ECB's interventions have been effective on average to curb bank output loss. Note, though, that there is some variability across Member States of the Eurozone, as the periphery benefits most from the ECB's monetary policy actions. Over the whole period the average bank output loss in the periphery (Greece) is reported to be 3% (4%) less because of the intervention of the ECB. This is particularly evident for bank loans, that are higher by 8% due to ECB intervention in the periphery (9% in Greece) during the period 2012 to 2015. For France there are also some

[31] We report the non-parametric estimations. Parametric estimations are similar and available upon request.

gains as the loss of bank output is by 0.6% less due to ECB's monetary policy. This is, though, rather low if compared to the periphery. Interestingly, for the case of Germany our results reveal that the bank output loss is slightly higher by 0.2% because of the ECB intervention. This higher bank output loss in the case of Germany is mostly on other earning assets and it is particularly noticeable during the third period of our sample, that is 2012-2015.

Table 6. Bank loss of output due to risk taking into account ECB interventions: Non-parametric estimates

	2001-2007			2008-2011			2012-2015		
	Loans	**OEA**	**OBS**	**Loans**	**OEA**	**OBS**	**Loans**	**OEA**	**OBS**
France	14.44	9.81	11.13	19.32	12.30	8.33	12.21	8.44	6.13
	(4.12]	(4.34]	(3,81]	(5.12]	(5.81]	(3.15]	(4.22]	(2.14]	(1.45]
Germany	13,15	8.23	9.47	15.21	12.40	7.81	10.15	8.12	9.51
	(3.81]	(2.50]	(3.12]	(5.12]	(5.12]	(3.20]	(2,51]	(2.10]	(2.51]
Greece	8.22	18.20	11.51	12.33	25.12	20.17	17.44	14.21	15.45
	(2.28]	(3.81]	(3.44]	(3,44]	(6.22]	(8.81]	(5.10]	(6.15]	(4.55]
Ireland, Italy, Portugal, Spain	11.30	17.21	15.22	16.21	21.30	9.13	9.33	8.44	7.33
	(2.81]	(4.32]	(4.20]	(4,48]	(6.45]	(2.53]	(1.88]	(2.07]	(2.64]

Notes. The table reports the loss of output calculated with equation (25) which represents the difference of output between the no-uncertainty (full information) case and the uncertainty case, and which can be interpreted as the change in bank risk aversion.This output loss is calculated with ECB policy actions. OEA are Other Earning Assets and OBS are Off Balance Sheet items and fees.

Our findings reveal that the ECB's interventions appear to have an asymmetric effect across Member States with Germany facing challenges because of such interventions. This asymmetry highlights the complexities involved in a currency zone with considerable heterogeneity in the way that uncertainty and thereby bank risk aversion affects the banking industry. Yet, we demonstrate that there have been some changes in bank behavior over time, as picked by our bank risk aversion measure due to ECB policy. Such changes in bank behavior are also varying across Eurozone with large Member States exhibiting a higher bank risk aversion in response to ECB monetary policy.

In addition to the above evidence, Table 7 reports the long run effect of monetary policy on bank risk aversion. Note that we report results for all the underlying components of monetary policy.

Table 7. Effect of monetary policy on bank risk aversion: the long run effect

		Eurozone	Spain, Greece, Portugal, Italy, Ireland	France	Germany
Rate on deposit facility	**DEP**	-0.155	-0.33	-0.23	-0.13
		(0.02)	(0.01)	(0.03)	(0.03)
Rate on marginal lending facility	**MLFr**	-0.143	-0.232	-0.43	-0.055
		(0.03)	(0.03)	(0.02)	(0.02)
SMP/CBPP1/CBPP2	**SEC**	-0.028	-0.125	-0.032	-0.035
		(0.02)	(0.02)	(0.03)	(0.04)
Main refinancing operations	**REFIN**	0.032	0.071	0.022	0.019
		(0.02)	(0.02)	(0.02)	(0.03)
Longer-term refinancing operations	**LTREFIN**	0.012	-0.085	0.022	0.012
		(0.02)	(0.02)	(0.03)	(0.02)
Marginal lending facility	**MLF**	-0.013	-0.028	-0.024	-0.01
		(0.02)	(0.01)	(0.01)	(0.02)

Notes. GMM estimation of the panel VAR in equation A.12 in Appendix. The components of monetary policy comprise: the rate on the deposit facility at which banks may use to make overnight deposits with the Eurosystem (DEP); the rate on the marginal lending facility which offers overnight credit to banks from the Eurosystem (MLFr); Securities Markets Programme (SMP) together with the Covered Bond Purchase Programme 1 (CBPP1), and the Covered Bond Purchase Programme 2 (CBPP2) (SEC); Main refinancing operations (REFIN); Longer-term refinancing operations (LTREFIN); and, the marginal lending facility (MLF).

The impact of conventional monetary policy, that is the rate on the deposit facility (DEP) and the rate on the marginal lending facility (MLFr), on bank risk aversion is negative across Member States and the Eurozone as a whole. Interestingly, the impact of unconventional monetary policy varies. On the one hand, the impact of the securities markets program together with the covered bond purchase program (SEC) and the marginal lending facility (MLF) is clearly negative, suggesting that unconventional monetary policy subdues bank risk aversion.

On the other hand, the impact of the longer-term refinancing operations (LTREFIN) on bank risk aversion is positive for France and Germany and the Eurozone overall. So once more, we reveal the complexities involved in monetary policy as some interventions appear to enhance uncertainty. Therefore, caution in what monetary policy can achieve across the Eurozone is warranted.

5.4. The generalised measure of bank risk

In addition, we report a generalized measure bank risk (GMR thereafter) as $GMR = \log|S_*|$.[32] This measure of bank risk is generalized as we define risk in the context of a system. To be more precise, suppose we have random variables $\xi = [\xi_1, \ldots, \xi_N]' \sim N(\mu, \Sigma)$. To define an overall measure of risk, it is customary to use the log determinant of Σ. The reason is that the density of ξ evaluated at the mean, is proportional to the negative log determinant of Σ. The generalized risk measure comes from local likelihood estimation which is bank-year specific.[33]

The generalized risk measure comes from local likelihood estimation which is bank-year specific. Table 8 reports the long run impact of conventional and unconventional monetary policy on the generalized measure of bank risk, which is reported to carry a negative sign in most of the cases. Results seem to provide further evidence of earlier results in Table 7. Overall, ECB's interventions assist to subdue the general level of bank risk and as such it provides reassurance for banks in the Eurozone to expand bank output. However, when it comes to monetary policy no one size fits all, notably for Germany.

Table 8. Effect of monetary policy on GMR: Eurozone (2001-2015), total long run effect.

		Eurozone	Spain, Greece, Portugal, Italy, Ireland	France	Germany
Rate on deposit facility	**DEP**	-0.081 (0.02)	-0.073 (0.01)	-0.085 (0.00)	-0.077 (0.01)
Rate on marginal lending facility	**MLFr**	-0.052 (0.02)	-0.044 (0.00)	-0.044 (0.01)	-0.04 (0.02)
SMP/CBPP1/CBPP2	**SEC**	-0.033 (0.02)	-0.017 (0.02)	-0.021 (0.02)	-0.025 (0.01)
Main refinancing operations	**REFIN**	0.014 (0.02)	0.022 (0.02)	0.019 (0.01)	0.022 (0.01)
Longer-term refinancing operations	**LTREFIN**	-0.019 (0.02)	-0.036 (0.02)	-0.025 (0.02)	-0.013 (0.01)
Marginal lending facility	**MLF**	0.021 (0.01)	0.021 (0.01)	0.032 (0.01)	0.02 (0.01)

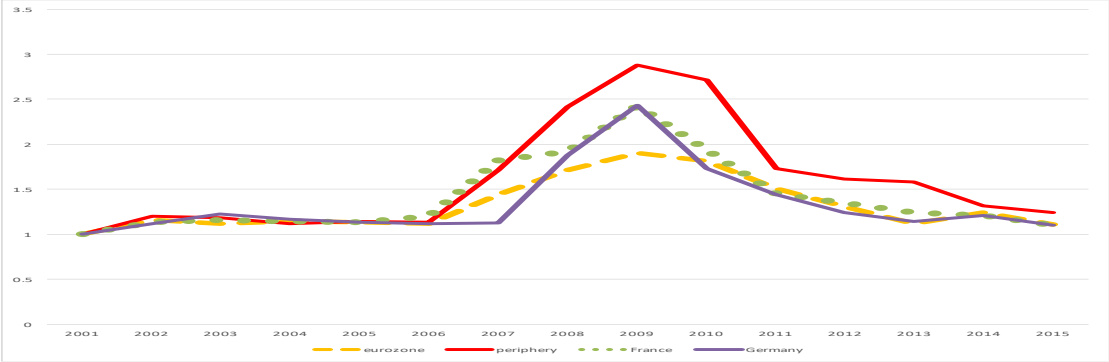
Notes. GMM estimation of the panel VAR in equation A.12 in Appendix.The components of monetary policy comprise: the rate on the deposit facility at which banks may use to make overnight deposits with the Eurosystem (DEP); the rate on the marginal lending facility which offers overnight credit to banks from the Eurosystem (MLFr); Securities Markets Programme (SMP) together with the Covered Bond Purchase Programme 1 (CBPP1), and the Covered Bond Purchase Programme 2 (CBPP2) (SEC); Main refinancing operations (REFIN); Longer-term refinancing operations (LTREFIN); and, the marginal lending facility (MLF).

Figure 4 draws the GMR over time, reporting the underlying shape of the financial cycle of the Eurozone. In recent years, uncertainty is subdued, providing evidence that ECB's monetary policy is on the right track regarding safeguarding financial stability on average.

[32] GMR is derived from the share equations (14) and (15) as we take the sub-matrix, which corresponds to the covariance matrix of loans, other earning assets and off balance sheet items and fees.

[33] Please note that in Appendix (II) we provide details of the local log likelihood function (see equation (A.9) for the non-parametric estimation method.

Figure 4: Generalized measure of risk



Note: Authors' local likelihood estimations of generalized measure of risk, $GMR = \log|S_*|$.

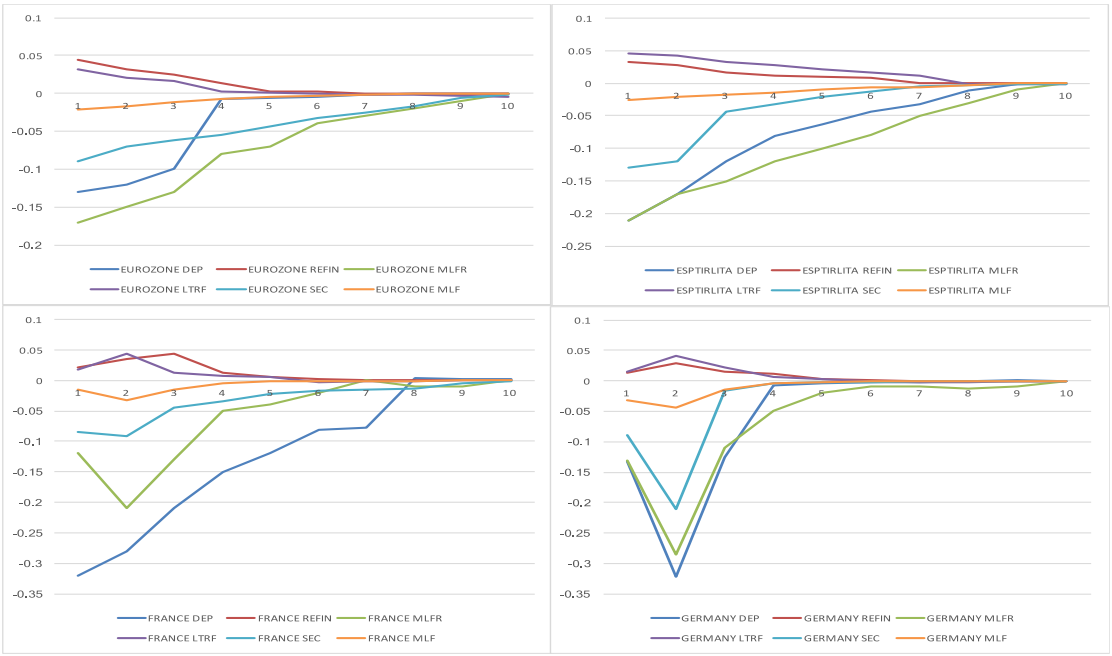
However, leaving aside the effect of monetary policy on the periphery, our bank risk analysis reveals that the Eurozone banking industry, despite recent strong monetary policy interventions whether conventional or nonconventional, is far from being on solid ground. Clearly, monetary policy has been supportive, yet Eurozone bank output losses due to rising bank risk aversion and rising uncertainty regarding output prices remain rather pertinent. In a sense, the present results highlight that further action is warranted to reduce bank output prices uncertainty and thereby reduce bank output losses. Along these lines, our methodology could offer a novel early warning mechanism of monitoring bank risk and thus bank output loss based on micro foundations.

5.5. The short run impact of conventional and unconventional monetary policy: Generalised Impulse Response Functions (GIRFs)

Following from the long run effect of monetary policy on bank risk aversion, we report next the underlying short run dynamics by applying a panel VAR as presented in Appendix III. This panel VAR model lessens *a priori* assumptions about the underlying relationships between bank risk aversion and monetary policy. All variables enter panel VAR as endogenous within a system of equations. Figure 5 draws the Generalized Impulse Response Functions (GIRFs) over ten periods ahead, reporting the response of the bank risk aversion to a one standard deviation shock in the conventional or unconventional monetary policy.[34]

Figure 5: Generalised impulse response functions of bank risk aversion to monetary policy

[34] The panel VAR is of order one as indicated by the {Schwarz, 1978 #1820} information criterion. Unobserved cross country heterogeneity is taken into account by specifying country specific fixed terms. To facilitate the presentation we do not report GIRFs for the response of bank risk aversion to its own shocks. Standard errors are found to be low, suggesting that GIRFs are significant at 5%.



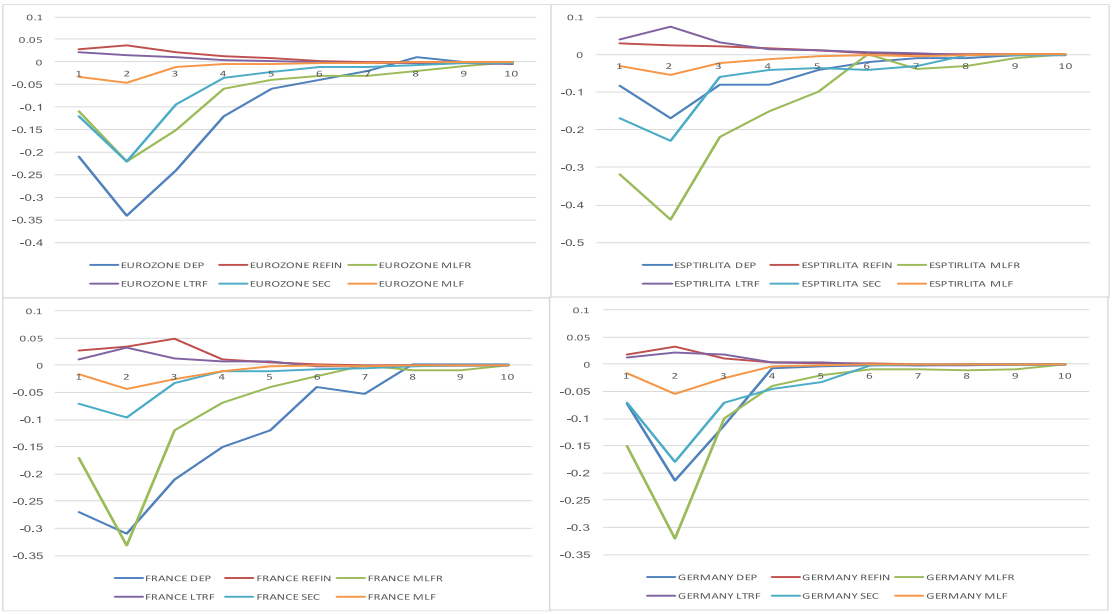
Notes. The components of monetary policy comprise: the rate on the deposit facility at which banks may use to make overnight deposits with the Eurosystem (DEP); the rate on the marginal lending facility which offers overnight credit to banks from the Eurosystem (MLFr); Securities Markets Programme (SMP) together with the Covered Bond Purchase Programme 1 (CBPP1), and the Covered Bond Purchase Programme 2 (CBPP2) (SEC); Main refinancing operations (REFIN); Longer-term refinancing operations (LTREFIN); and, the marginal lending facility (MLF). ESPTIRLITA notes Spain, Portugal, Ireland and Italy.

The GIRFs show that the response of the bank risk aversion, and thus of the bank output losses, to a shock in conventional monetary policy, whether it is the rate on the deposit facility (DEP) or the rate on the marginal lending facility (MLFr), is negative across Member States and the Eurozone as a whole. So conventional monetary policy assists to mitigate uncertainty in the banking industry in the short run. The same is true for the response to the unconventional monetary policy as defined by the securities markets program together with the covered bond purchase programs (SEC) and by the marginal lending facility (MLF). However, the response to the main refinancing operations (REFIN) and the longer-term refinancing operations (LTREFIN) on the bank risk aversion is positive across the Eurozone. This asymmetry in the response of the banking industry to the monetary policy is present in the short run as identified earlier in the long run.

We also report the GIRFs for the generalized risk measure, $GMR = \log|S_*|$.

Figure 6 reports the GIRFs. Once more, overall ECB's interventions assist to subdue the general level of bank risk, though certain unconventional monetary policy actions (see the main refinancing operations REFIN and the longer-term refinancing operations LTREFIN) have positively affected the bank risk in the short run.

Figure 6: Generalised impulse response functions of generalised bank risk to monetary policy



Notes. The components of monetary policy comprise: the rate on the deposit facility at which banks may use to make overnight deposits with the Eurosystem (DEP); the rate on the marginal lending facility which offers overnight credit to banks from the Eurosystem (MLFr); Securities Markets Programme (SMP) together with the Covered Bond Purchase Programme 1 (CBPP1), and the Covered Bond Purchase Programme 2 (CBPP2) (SEC); Main refinancing operations (REFIN); Longer-term refinancing operations (LTREFIN); and, the marginal lending facility (MLF). ESPTIRLITA notes Spain, Portugal, Ireland and Italy.

{Jiménez, 2014 #1594} for Spain and {Ioannidou, 2015 #1958} for Bolivia for example show that expansionary conventional monetary policy may amplify bank risk taking that may result in both an increase in bank loans and in higher default rates. Our results show that aggressive unconventional monetary policy may have a corresponding impact on bank risk, implying "moral hazard". Indeed we find that the unconventional monetary easing lowers bank risk and as such it could increase the volume of bank loans, other earning assets and off balance sheet items and fees in the periphery of the Eurozone, but also that some measures of unconventional monetary policy may have the opposite effect. In effect, our findings complement the literature on the risk-taking channel by documenting a heterogeneous response depending on policy measure and country in the Eurozone.

6. Conclusion

This paper formulates an indirect utility function to estimate the first four moments of the output prices' distribution parametrically and non-parametrically. Our new estimation techniques are then applied to Eurozone banking, where the degree of financial integration among Members States has been, supposedly, quite advanced.

The results indicate that input and output elasticities differ widely before and after the subprime crisis making it possible to use the model routinely to provide early warning signals about possible crises. Rising uncertainties in bank output prices lead to an increasing bank risk aversion and, in turn, to increases in bank output losses during the crisis. This effect is persistent thereafter across most Member States of the Eurozone. Policy interventions ought to look at

financial stability, but not only focus on capital requirements. It may be necessary to reduce uncertainty regarding bank output return/prices, and this might involve some restructuring of the Eurozone banking industry.

On a positive note, we show that the ECB's monetary policy in recent years subdues bank output losses on average. However, there is some variability of the impact of ECB's interventions, mainly on the refinancing operations, on bank uncertainty across Member States of the Eurozone. For Germany, in particular, ECB's interventions might have enhance the bank risk aversion and as result the output losses might also have increased in recent years. Accelerating the process towards a Eurozone banking union could ease the heterogeneity across Member States and a unifying banking market could foster the necessary restructuring of the sector that would reduce uncertainty.

References