Essays on Uncertainty, Monetary Policy and Financial Stability

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Abstract

In the first chapter, I examine both theoretically and empirically how income uncertainty affects the effectiveness of monetary policy. I consider income risk from potential unemployment, and find that monetary policy has a smaller influence on aggregate demand when unemployment risk is high. I build on the fact that saving arising from a precautionary motive has a smaller interest elasticity. As a consequence, aggregate demand reacts less to the interest rate when uncertainty is high. The second chapter links the build-up of financial risk that led to the recent financial crisis to the preceding period of exceptionally low macroeconomic volatility. The degree of stability that a country has enjoyed before 2007 predicts robustly how much it suffered from the crisis, a result that also holds for individual firms. In the final chapter, I connect this period of low volatility to the conduct of monetary policy. Building on a stylized model, I show empirically that monetary policy may have been 'too successful' in stabilizing inflation, as this has contributed to excessive financial risk taking.

Resum

En el primer capítol, aquesta Tesi Doctoral estudia com la incertesa en els ingressos afecta l'eficàcia de les polítiques monetàries. Considerant el risc en els ingressos de la desocupació potencial, la investigació conclou que les polítiques monetàries tenen una influència menor en la demanda agregada quan el risc de desocupació és elevat. Parteixo del fet que l'estalvi sorgit de motius preventius té una menor elasticitat respecte el tipus d'interès. Com a conseqüència, la demanda agregada reacciona menys als tipus d'interès quan la incertesa és alta. En el segon capítol s'enllaça el risc financer que va precedir la crisi financera recent amb el període precedent caracteritzat per una volatilitat macroeconòmica baixa. El grau d'estabilitat que un país va gaudir abans del 2007 prediu de forma robusta el grau en què va patir durant la crisi econòmica, un resultat que també es manté quan s'analitzen les empreses. En l'últim capítol de la Tesi, connecto aquest període de volatilitat baixa amb la manera en què s'han desenvolupat les polítiques monetàries. A través d'un model, mostro com les polítiques monetàries han estat massa"exitose" en estabilitzar la inflació, la qual cosa ha contribuït en una excessiva aversió al risc financer.

Preface

This dissertation has in many ways been influenced by the economic environment during which it was written. I started my research at Pompeu Fabra in the aftermath of the Great Recession, the deep global economic downturn that followed the financial crisis of 2007-08. Soon after, a debt crisis took hold of Europe, which until now, while I am finishing my thesis, is far from being resolved. Many things that have happened were almost unimaginable as little as ten year ago: the financial sector as we know it would have been wiped out if it was not for an unprecedented intervention by central governments across the globe, several member countries of the European Union found themselves at the brink of defaulting and leaving the common currency, experiencing deep slumps in output and unemployment rate surges of up to 30%. This profound economic disturbances came after a period of relative calm and optimism. The new millennium started with the widespread believe that the problem of large economic fluctuations had essentially been solved, that central banks could focus on the task of 'fine tuning', and that the European unification and the introduction of the Euro would lead to prolonged growth and to convergence of standards of living across members countries. This relative calm was swept away, with economies around the globe experiencing large increases in uncertainty, and central banks undertaking unconventional policy measures in huge scales, while still struggling to prevent economic collapse. Intrigued by these events, I made uncertainty the central focus of my dissertation research. Much of this dissertation deals with how uncertainty affects the behavior of individuals and of firms, and how, as a consequence, it changes the impact of policy measures on macroeconomic outcomes.

In the first chapter of this thesis, I consider how uncertainty affects the saving behavior of households, focusing on uncertainty that stems from unemployment risk. I suggest that if unemployment uncertainty is high, monetary policy has a smaller effect on aggregate demand. The mechanism combines three elements, which individually are well established in the literature: First, if unemployment risk is high, households engage in precautionary saving to protect themselves against potential income shocks. Second, saving that is done for a precautionary motive responds little to changes in the interest rate, *i.e.* the interest elasticity of precautionary saving is near zero. Thirdly, a low interest elasticity of saving, and hence also of demand, implies that conventional monetary policy struggles in stimulating the economy through changes in the real rate. To illustrate this mechanism, I construct a stylized New Keynesian model with heterogeneous households, which allows for comparing responses to monetary policy shocks across economies with different unemployment risk. My empirical results support the finding that income risk from unemployment limits the effectiveness of monetary policy. Using household level data from the US, I find that consumption responses to changes in the real rate are smalll for households that have a high risk of becoming unemployed, and for households that live in states with low unemployment insurance benefits. These results also hold on an aggregate level: both within US states and within Euro Area countries, I find that regions with high unemployment or low insurance benefits are less affected by monetary policy.

The relationship between uncertainty and financial stability is the topic of the second and third chapter. In particular, I investigate how periods of low macroeconomic volatility give agents an incentive to increase financial risk taking. This in turn can make the effects of large adverse shocks more devastating, if these agents compose a systemic feedback loop that amplifies negative shocks. This gives rise to a trade-off between short run stability and resilience to large shocks, as more stability during normal times can imply more dramatic crisis events, leading potentially to a higher total volatility. I describe this mechanism in detail in the second chapter, and extend the analysis in the third chapter, by considering monetary policy explicitly as a potential stabilizing mechanism during normal times. I find that if monetary policy reduces fluctuations during normal times, the economy may become more vulnerable to financial shocks. I then use the the recent financial crisis as an event study to test the model, and find that most theoretical predictions are confirmed by the data. A more volatile economic environment in the years before the crisis robustly predicts a better performance during the crisis years. This result is true for both individual firms and for countries. I also find that the independence of central banks, which serves as a proxy for the capacity of monetary policy to stabilize inflation, predicts worse crisis outcomes.

Contents

Chapter 1

UNEMPLOYMENT RISK, PRECAUTIONARY SAVINGS, AND THE EFFECTS OF MONETARY POLICY

1.1 Introduction

When facing a recession, central banks aim at stimulating demand through cuts in nominal interest rates. Such adjustments can only succeed if the interest elasticity of demand is sufficiently negative. A crucial determinant of the interest rate elasticity is the relative importance of precautionary saving, a motive which arises in response to uncertainty about future income. This paper argues that unemployment risk, which constitutes a main component of individual income uncertainty, plays a significant role in the effectiveness of monetary policy. In particular, when job loss risk is high and unemployment protection low, a monetary stimulus in the form of a cut in nominal interest rates will fail to spur economic activity.

A change in the interest rate has two opposing effects on household consumption and saving rates. Consider a reduction in the real interest rate. The substitution effect, due to changes in intertemporal prices of consumption, gives households incentives to reduce savings and increase current consumption. On the other hand, a lower interest rate reduces the future value of savings, a negative wealth effect to which households react by cutting current spending. In a standard New Keynesian model, the substitution effect dominates, implying a negative interest elasticity of savings. But the presence of precautionary savings alters this picture. Large uncertainty about future income means that there may exist low income states in which a potentially lower consumption level is mainly financed out of savings, implying high marginal utilities derived out of savings. Consequently, the wealth effect of a reduction in the real interest rate is larger than the substitution effect, driving the interest elasticity of savings towards zero or even turning it negative. In such a situation, a central bank policy which lowers interest rates in order to stimulate demand will not be successful.

I illustrate this mechanism using an otherwise parsimonious New Keynesian model, extended with heterogeneous households. Employed households face an exogenous risk of becoming unemployed, a state in which they receive no labor income. Due to the income shock and credit constraint, unemployed households must rely on accumulated savings and potential government transfers in the form of unemployment benefits to finance consumption. To shield themselves against this income uncertainty, prudent households accumulate precautionary savings, with the size of the desired saving buffer being increasing in the probability of a job loss and decreasing in the unemployment benefit. The effectiveness of central bank policy is then compared across economies that differ in their levels of precautionary saving. Impulse responses show that monetary policy shocks have a substantially smaller effect in economies with high job loss risk and low unemployment insurance. This relationship continues to hold after taking the endogenous response of unemployment risk to monetary policy into account.

I then proceed to provide empirical support for the suggested relationship between unemployment risk and the effectiveness of monetary policy. Using the US Consumption Expenditure Survey, I document that consumption reacts less to changes in the interest rate if the household faces a high risk of losing a job, or if it resides in a state with low unemployment benefits. I then use aggregate data from US states and Euro area countries and show that the negative association between the real interest rates and economic performance goes towards zero in regions with higher unemployment rates as well as in regions with lower unemployment benefits, as measured by replacement rates. Taken together, the data provides strong support for the the notion that unemployment risk dampens the response to monetary policy shocks.

There are few existing papers that investigate how monetary policy effectiveness depends on uncertainty. Bloom et al. (2013) show that in a model with partial irreversibility of investments, a fiscal policy consisting of a wage bill subsidy is less effective if aggregate uncertainty is high. Vavra (2014) finds that monetary policy shocks have less impact on output if aggregate uncertainty is high, since prices adjust more frequently in such an environment. This paper proposes a different channel, in which uncertainty reduces monetary policy effectiveness through a precautionary savings motive. Aastveit et al. (2013) find empirical support for the hypothesis that monetary policy affects output less if uncertainty is high, without identifying a specific channel. Guerrieri and Lorenzoni (2011) show that after a negative shock to borrowing capacities, households increase precautionary savings which, assuming nominal rigidities and a zero lower bound, can lead to a large output drop. A similar approach is taken in Bayer et al. (2015). In their model, a shock to uncertainty and a binding zero lower bound have adverse effects on output, since households increase precautionary saving and hence reduce demand. This paper adds to the previous two by showing that the effectiveness of monetary policy is already reduced before the zero lower bound is reached. Leduc and Liu (2015) investigate a mechanism in the opposite direction, finding that uncertainty has large effects on unemployment, which they explain with the interaction of search frictions and nominal rigidities. The relevance of the feedback loop between unemployment risk and precautionary savings during the Great Recession is documented in Challe et al. (2015). Finally, and probably most similar in spirit to this paper, Paoli and Zabczyk (2013) focus on cyclical fluctuations of precautionary savings, showing that policy responses need to be stronger when accounting for an increase in uncertainty during a downturn.

The relevance of precautionary savings is empirically well documented (see *e.g* Carroll (1994), Cagetti (2003), Lusardi (1998), Carroll et al. (2012)). Gourinchas and Parker (2001) point out the importance of precautionary savings with respect to aggregate fluctuations. Similar to this paper, Engen and Gruber (2001) use differences in unemployment insurance replacement rates across US states to identify a motive for precautionary saving. Similarly, there is a large body of literature, starting with the seminal paper of Hall (1978), aiming at estimating interest elasticities. Gruber (2013) provides an excellent review. Contributions that link the level of precautionary savings to interest elasticities include Carroll (1992), who notes that interest rates have little effect on wealth accumulation, if the latter is a buffer stock against negative shocks. Bernheim (2002) concludes that the interest elasticity of savings can fall considerably after accounting for precautionary savings, while Engen and Gale (1997) find that savings are relatively insensitive to the rate of return if done for precautionary reasons. Cagetti (2001) confirms these findings of a low interest elasticity in the presence of precautionary savings.

Taken at face value, the findings of this paper have several relevant implications. First, in a monetary union, monetary policy will be least effective in regions with high unemployment risk. This is particularly troubling when considering an economic downturn. A monetary stimulus in the form of a reduction in the nominal interest rate will fail exactly in the regions that might need it most. Second, economies might fall into traps with high unemployment and low growth, during which monetary policy will not be effective in stimulating aggregate demand. Third, a fiscal policy that protects households from income shocks, in particular unemployment and other forms of social insurance, as well as potentially public employment programs, can help to avoid reaching such a state. And finally, an increase in inequality, as long as it goes in hand with increases in individual income fluctuations, can reduce the effectiveness of monetary policy.

The remainder of this paper is structured as follows. Section 1.2 provides a theoretical discussion of how uncertainty affects the interest elasticity of saving. The baseline New Keynesian model with unemployment risk is presented in section 1.3. Section 1.4 describes the calibration and solution method, as well as results and predictions from model simulations. Section 1.5 discusses extensions of the model, and shows that predictions continue to hold after accounting for endogenous government debt and the effects of monetary policy on unemployment risk. Section 1.6 provides empirical support for the theory, and finally, section 1.7 concludes.

1.2 Precautionary saving and interest elasticity

In this section, I investigate theoretically how the interest elasticity of savings depends on uncertainty. I show that under relatively general assumptions, the interest elasticity is smaller if savings arise from a precautionary motive. I analyze the saving decision in a two-period endowment economy with additively separable utility $U = u(c_1) + \beta E\{u(c_2)\}$, where u is twice differentiable and strictly concave. The utility function is assumed to exhibit decreasing absolute prudence, so that $\overline{c} > c > \underline{c}$ implies

$$-\frac{u''(c) - u''(\underline{c})}{u'(c) - u'(\underline{c})} > -\frac{u''(\overline{c}) - u''(c)}{u'(\overline{c}) - u'(c)}$$

so that prudence, *i.e.* the tendency to save more when future income is uncertain, decreases with income. Note that most generally used utility functions exhibit decreasing absolute prudence, in particular the Constant

Relative Risk Aversion function. For a good discussion of why decreasing absolute prudence is a natural condition to require of utility functions, see Kimball (1990).

Consider two individuals, x and y, who face budget constraints of the form

$$c_1^i = I - b^i$$
$$c_2^i = I_2^i + Rb^i$$

for $i \in \{x, y\}$. Note that income in the first period is the same for both individuals. Second period income of individual x is given by $I_2^x = I - \phi$, $0 < \phi < 1$, while $I_2^y = I - \xi$ with probability p and $I_2^y = I + \xi$ with probability $1 - p$, $0 < \xi < 1$. Optimal saving is given by the first order condition

$$1 = \beta RE \left\{ \frac{u'\left(c_2^{i*}\right)}{u'\left(c_1^{i*}\right)} \right\} \tag{1.1}$$

We focus on the case where $\xi(\phi)$ is defined such that for given parameter values, $b^{x*} = b^{y*}$. Note that then the two individuals are observationally equivalent in the first period, as they have identical income, consumption and saving. But the motive for saving varies: individual x saves because of a certain reduction of income in period 2. Expected income is the same in period 2 as in period 1 for individual y, but uncertainty about period 2 income gives rise to a precautionary motive. Individual y saves because there is a possibility of a large reduction in future income. The intuition for why this matters for interest elasticities can be gained from (1.1). Consider an increase in the interest rate R. As a direct effect, the RHS goes up, requiring an upward adjustment in $u'(c_1)$ (and downward in $u'(c_2)$), *i.e.* a decrease in c_1 (and increase in c_2), which is achieved through an increase in saving. This is the substitution effect. The indirect wealth effect works through the fact that with an higher interest rate, available resources in period 2 increase, so c_2 increases for a given b, thus c_1 goes up and b goes down, partially offsetting the substitution effect. For a prudent individual, this channel is stronger at states where c_2 is small and thus the slope of marginal utility particularly steep. The wealth effect is larger for individual y who faces a higher potential loss in future income, reducing the interest elasticity of saving.

To formally derive this result, I first state the interest elasticity as

$$\begin{aligned}\frac{\partial b^{i*}}{\partial R}\left(\frac{R}{b^{i*}}\right) &= -\frac{\beta[E\{u'\left(c_2^{i*}\right)\} + RbE\{u''\left(c_2^{i*}\right)\}]}{\beta * R^2 E\{u''\left(c_2^{i*}\right)\} + u''(c_1)}\left(\frac{R}{b^{i*}}\right)\\ &= \frac{A + C\,E\{u''\left(c_2^{i*}\right)\}}{B - C\,E\{u''\left(c_2^{i*}\right)\}}\end{aligned}$$

where I made use of the first order condition (1.1) and defined $A = u'(c_1)$, $B = -bu''(c_1)$, and $C = \beta R^2 b$. A, B and C are all strictly positive and constant across individuals. Thus, the last expression is strictly increasing in $E\{u''\left(c_2^{i*}\right)\}$, and to show that a precautionary saving motive reduces the interest elasticity, it is sufficient to show that $u''\left(c_2^{x*}\right) > E\{u''\left(c_2^{y*}\right)\}$.

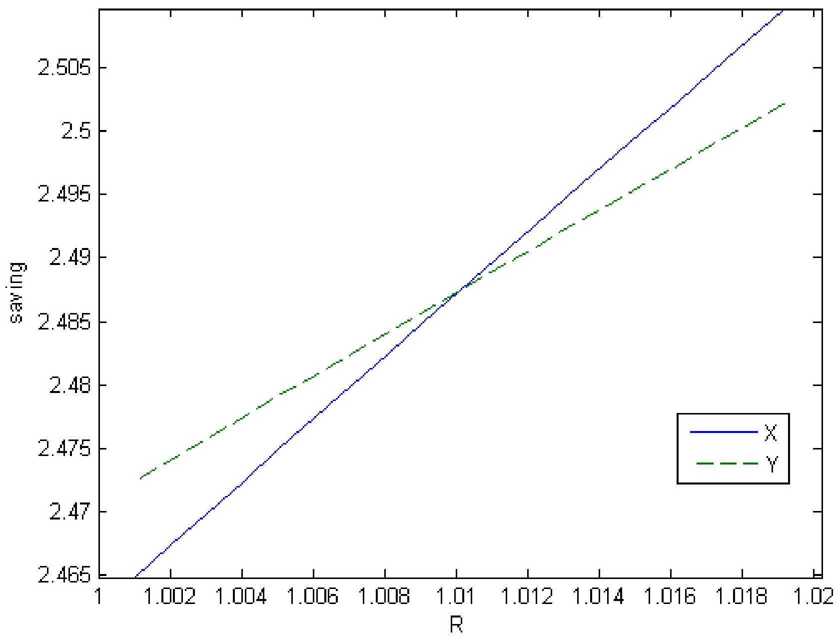
Condition (1.1) together with $c_1^{x*} = c_1^{y*}$ implies that $u'\left(c_2^{x*}\right) = pu'\left(\underline{c_2}^{y*}\right) + (1-p)u'\left(\overline{c_2}^{y*}\right)$, where $\underline{c_2}^{y*} = I - \xi + Rb^*$ and $\overline{c_2}^{y*} = I + \xi + Rb^*$, with $\overline{c_2}^{y*} > c_2^{x*} > \underline{c_2}^{y*}$. Using decreasing absolute prudence we can write

$$\begin{aligned}u'\left(c_2^{x*}\right) &= pu'\left(\underline{c_2}^{y*}\right) + (1-p)u'\left(\overline{c_2}^{y*}\right)\\ p\frac{u'\left(c_2^{x*}\right) - u'\left(\underline{c_2}^{y*}\right)}{u'\left(\overline{c_2}^{y*}\right) - u'\left(c_2^{x*}\right)} &= (1-p)\\ p\frac{u''\left(c_2^{x*}\right) - u''\left(\underline{c_2}^{y*}\right)}{u''\left(\overline{c_2}^{y*}\right) - u''\left(c_2^{x*}\right)} &> (1-p)\\ u''\left(c_2^{x*}\right) &> pu''\left(\underline{c_2}^{y*}\right) + (1-p)u''\left(\overline{c_2}^{y*}\right)\\ u''\left(c_2^{x*}\right) &> E\left\{u''\left(c_2^{y*}\right)\right\}\end{aligned}$$

which proves that the interest elasticity of saving that arises from a precautionary motive is indeed smaller.

To provide a numerical illustration, I consider the case of log utility, with parameter values $\beta = 0.99$, $I = 10$, initial interest rate $R = 1/\beta$ and $\phi = 5$. I set $p = 0.5$ and $\xi = 7.909$, which imply that $b^x = b^y = 2.487$ at the current interest rate. Figure 1.1 shows saving for different levels of the interest rate. The solid blue line represents individual x, characterized by a lower but certain second period income, while the dashed green line represents the individual with uncertain income. Saving behavior is significantly less sensitive to changes in the interest rate if the saving motive results from uncertainty over future income. In fact, at $R = 1/\beta$, the interest elasticity of individual x is equal to 1, while equaling only 0.67 for individual y.

Figure 1.1. Savings of individual with certain future income (solid blue line) and uncertain income (dashed green line)



1.3 A New Keynesian model with precautionary saving

The model presented in this section builds on Galí (2015), and extends the textbook New Keynesian model with heterogeneous agents. All components are kept as simple as possible, in order to highlight the suggested relationship between unemployment risk and the effects of monetary policy. As in the standard model, nominal rigidities allow firms to only readjust their prices periodically, giving rise to monetary non-neutrality. Agents are heterogeneous with respect to their labor market status. Employed households face an exogenous probability of losing their job each period. Unemployed households do not work and hence receive no labor income, but a (smaller) payment from unemployment benefits. This risk of a future state with lower income gives employed agents an incentive to accumulate precautionary savings. In line with the goal to keep the model simple, there is no capital in this economy. Instead, agents save using government bonds.

1.3.1 Households

The economy has a population of size one. A share ν_t of households are employed, and face the risk of getting unemployed the next period with probability ρ_{t+1}. The unemployed, constituting a share of $1 - \nu_t$ of the population, receive unemployment benefits of real value s from the government, which together with past savings are used to finance consumption. Agents are credit constrained, as financial wealth is restricted to be non-negative. An employed household uses income from work and savings to consume and to buy government bonds. The government taxes employed workers lump-sum to finance unemployment benefits and bond returns.

An employed household's budget constraint is thus given by

$$\int P_t(i)c_t(i)\,di + b_t = w_t h_t + (1 + i_{t-1})b_{t-1} - T_t + D_t \tag{1.2}$$

where i_t is the nominal interest rate, h_t denotes hours worked, w_t is the hourly wage rate and D_t are dividend payments. Households maximize expected lifetime utility of the form

$$\sum_{t=0}^{\infty} \beta^t E_0 \left\{ \left(\frac{{c_t}^{1-\sigma} - 1}{1 - \sigma} - \psi \frac{h_t^{1+\varphi}}{1 + \varphi} \right) exp(x_t) \right\} \tag{1.3}$$

subject to (1.2), where c_t is a consumption index given by

$$c_t \equiv \left(\int_0^1 c_t(i)^{1-\frac{1}{\epsilon}}\, di.\right)^{\frac{\epsilon}{\epsilon-1}}$$

The preference shifter x_t is assumed to follow an AR(1) with mean zero and lag-term coefficient $\rho_x \in [0,1)$. As usual, demand for variety i is given by

$$c_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon}$$

where the price index is defined as $P_t \equiv \left(\int_0^1 P_t(i)^{1-\epsilon}\, di.\right)^{\frac{1}{1-\epsilon}}$.

The first order conditions can then be written as

$$\frac{w_t}{P_t} = \psi {c_t}^{\sigma} h_t^{\varphi} \tag{1.4}$$

$$1 = \beta(1+i_t)E_t\left\{\left(\frac{c_t}{c_{t+1}}\right)^{\sigma}\frac{1}{\Pi_{t+1}} exp(x_{t+1}-x_t)\right\} \tag{1.5}$$

Denoting consumption of an employed and an unemployed household with c^e and c^u, respectively, (1.5) becomes

$$1 = \beta(1+i_t)E_t\left\{\left(\rho_{t+1}\left(\frac{c_t^e}{c_{t+1}^u}\right)^{\sigma} + (1-\rho_{t+1})\left(\frac{c_t^e}{c_{t+1}^e}\right)^{\sigma}\right)\frac{1}{\Pi_{t+1}} exp(x_{t+1}-x_t)\right\} \tag{1.6}$$

Unemployed households do not work and consume all available income. Thus we have

$$c_t^u = (1+i_{t-1})b_{t-1}/P_t + s \tag{1.7}$$

To keep the model tractable, it is assumed that once a household gets unemployed, it lives for one more period and then dies, ensuring that all available resources are consumed in the last period. The household gets replaced with a newborn, which is employed with probability ζ_t and unemployed with probability $1-\zeta_t$. A newborn household receives an initial transfer from the government, of an amount equal to the average wealth of households with the same employment status. This assumption ensures that there is no wealth dispersion within household types, and thus considerably simplifies the model. ζ_t is determined by the separation rate ρ_t and employment rate ν_t.

1.3.2 Firms

Firms use labor as the only input to produce a differentiated good indexed by $i \in [0,1]$. Technology is identical across firms and represented by the production function

$$Y_t(i) = A_t(h_t^d(i))^{1-\alpha} \tag{1.8}$$

where $a_t \equiv log(A_t)$ follows an AR(1) process with mean zero and lag-term coefficient $\rho_a \in [0,1)$. Price stickiness is modeled following Calvo (1983), assuming that only a fraction θ of firms can adjust prices in any period.

The firm side is identical to Galí (2015), where a careful derivation can be found. It is shown that the production structure leads to an inflation equation of the form

$$\pi_t = \beta E_t\{\pi_{t+1}\} - \lambda(\mu_t - \mu) \tag{1.9}$$

where π_t is the log of gross inflation, $\mu = log(\frac{\epsilon}{\epsilon-1})$ is the desired log mark-up over marginal costs and $\lambda = \frac{(1-\theta)(1-\beta\theta)(1-\alpha)}{\theta(1-\alpha+\alpha\epsilon)}$. The average log mark-up is approximated with

$$\mu_t = log(\frac{P_t(1-\alpha)A_t}{w_t(h_t^d)^\alpha}) \tag{1.10}$$

1.3.3 Monetary and fiscal policy

The central bank sets the nominal interest rate following a Taylor-type rule of the form

$$(1+i_t) = \frac{1}{r}\left(\frac{\Pi_t}{\Pi}\right)^\phi exp(u_t) \tag{1.11}$$

where the monetary policy shock u_t follows an AR(1) process with mean zero and lag-term coefficient $\rho_u \in [0,1)$. The target gross inflation rate of the central bank is denoted by Π.

The government issues bonds and collects taxes from employed workers to finance unemployment benefit transfers and for the repayment of maturing bonds. It is assumed that the government issues a constant real quantity of one-period bonds, *i.e.* $b_t/P_t = \bar{b}$. Taxes are collected lump-sum from employed households and are adjusted to balance the budget period-by-period, so that

$$T_t = \frac{1}{\nu_t}\left(\left(\frac{(1+i_{t-1})}{\Pi_t} - 1\right)\bar{b} + (1-\nu_t)s\right)$$

1.3.4 Equilibrium

After imposing the market clearing conditions for the markets for goods and labor, given by

$$\begin{aligned} Y_t(i) &= \nu_t c_t^e(i) + (1-\nu_t)c_t^u(i) \\ h_t^d &= \nu_t h_t \end{aligned}$$

the equilibrium dynamics are defined by combining the labor supply (1.4), the Euler equation for employed households (1.6) and unemployed consumption (1.7), with the production function (1.8) and the equations determining marginal costs (1.10) and inflation dynamics (1.9), as well as the monetary policy rule (1.11) and three processes for the exogenous shocks.

1.4 Calibration and Results

To account for risk, I use a global solution algorithm to solve for the full dynamics of the model. There are four state variables: outstanding government debt and the lagged values of the three exogenous shock processes. As policy variables I choose hours worked and the nominal interest rate. I first log-linearize the model around the risk-less steady state, and use the resulting linear dynamics to compute an initial guess for the policy functions over the state grid. Given the initial guess, I then solve the model at each grid point, using linear interpolation for future values, and the Trapezoid rule to approximate integrals in the expectation terms. I then use the Euler equation (1.6) and inflation dynamics (1.9) to update the guess. Iterating on this step until the guesses converge then yields the solution for the policy functions, from which both the risky steady state and the full dynamics of the model can be computed.

To illustrate the suggested mechanism, the model is first solved for three different economies that are identical except for differences in the separation rate (and corresponding differences in the labor market status of newborns), which itself remains constant over time. The employment parameter ν is fixed at 0.92, corresponding to an unemployment rate of 8%. The economies studied differ only in their separation rates, which are 1%, 4% and 7%, respectively.[1] While the assumption of an unemployment rate that is independent of the separation rate is unrealistic, it is very useful as a first exercise for illustrative purposes. Unemployed consumption is by assumption independent of future interest rates, hence the elasticity of aggregate consumption with respect to the interest rate depends on the size of the pool of unemployed workers. To control for this channel, the unemployment rate is set to a constant value across economies. All remaining differences are then due to the precautionary saving motive of employed workers, induced by the separation rates. In the next section, I will consider the case were both the separation rate and unemployment react endogenously to labor market conditions.

All parameter values are reported in Table 1.1. The remaining values are standard in the literature and are not crucial for the qualitative results of the exercise. The central bank is assumed to follow an annualized inflation target of 2%, while the coefficient on inflation in the Taylor rule is set at 2. Fiscal policy is chosen such that in the steady state, the ratio of debt to annualized GDP equals 0.5.

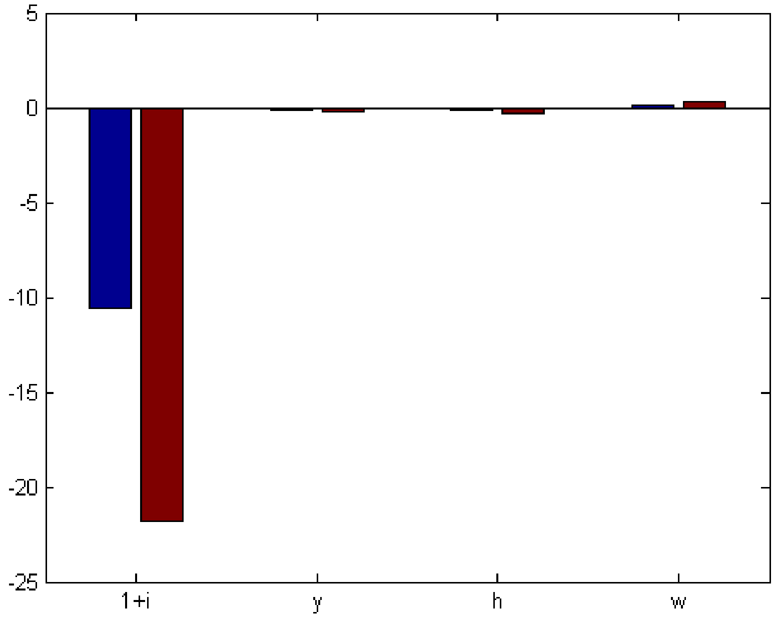
[1]The corresponding values of ζ are 11.5%, 46% and 80.5%, respectively.

Table 1.1. Parameter values

Parameter	Value	Parameter	Value
β	0.99	Π	1.005
σ	1.5	ϕ	1.5
φ	1		
ψ	1	$\bar{b}/y^{ss}$	2
ϵ	6		
		ρ_a	0.95
α	0.33	σ_a	1
θ	0.75	ρ_u	0.5
		σ_u	1
ν	0.92	ρ_x	0.5
ρ	0.01, 0.04, 0.07	σ_x	1
s	0		

Table 1.2 compares steady state values for the nominal interest rate, output, hours and the real wage across the three economies. The bars represent differences (in percentage terms) for the steady state values in economies with $\rho = 0.04$ and $\rho = 0.07$, respectively, relative to the benchmark economy with $\rho = 0.01$. Most notably, gross nominal interest rates are substantially lower in economies with higher separation rates, as can be seen in the top left panel. Steady state interest rates are 10.5% lower when $\rho = 0.04$ and 21.8% lower when $\rho = 0.07$. This is a direct consequence of the increased desire for precautionary savings. Recall that the real amount of government debt, and hence the real amount of savings, is exogenously given and constant. Hence, in economies with higher demand for savings, in this case due to a precautionary motive, the real interest rate must be lower in equilibrium. Since steady state inflation rates are fixed by the central bank objective, this difference is also reflected in the nominal rates.

Figure 1.2. Steady state values for economies with $\rho = 0.04$ (blue) and $\rho = 0.07$ (red), in percentage difference to benchmark economy with $\rho = 0.01$.



While the interest rates vary wildly across economies, differences are close to zero for all other steady state values. Hours are slightly lower if the separation rate is high, amounting to a decrease of steady state output of 0.09% if $\rho = 0.04$ and of 0.18% if $\rho = 0.07$. In accordance with the lower hours and decreasing returns, real wages are higher, but also this difference is very small.

We now turn to a comparison of the effects of monetary policy in the three cases. The economies are simulated for 10000 periods, from which impulse responses to a monetary shock are computed. Figure 1.3 depicts the reactions of the nominal rate, inflation, output, hours and consumption of employed and unemployed households, in response to a contractionary monetary policy shock of one standard deviation. The respective responses to an expansionary shock are shown in Figure 1.4.

Figure 1.3. Impulse responses to contractionary monetary policy shock, separation rates set at $\rho = 0.01$ (blue), $\rho = 0.04$ (green), and $\rho = 0.07$ (red).

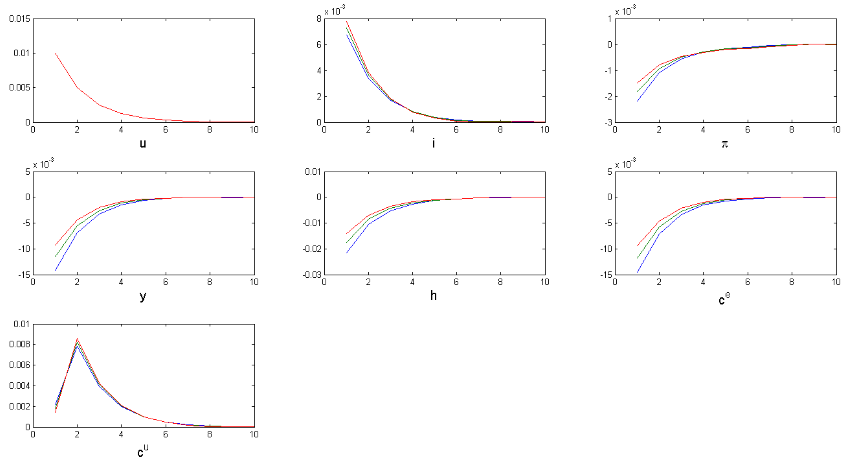
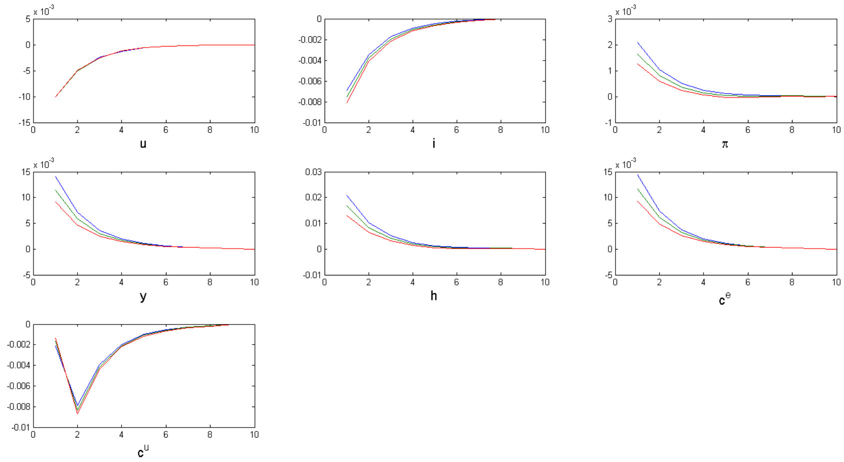


Figure 1.4. Impulse responses to expansionary monetary policy shock, separation rates set at $\rho = 0.01$ (blue), $\rho = 0.04$ (green), and $\rho = 0.07$ (red).



For both types of shocks, a consistent picture emerges. Economies with lower separation rates react more strongly to monetary policy. A contractionary shock of one standard deviation reduces output on impact by 1.42%

in the economy with the lowest unemployment risk, while output drops of 1.16% and 0.92% are observed in the other two cases. Economies with a higher separation rate also experience a smaller reduction in consumption of employed households, hours and inflation. Equivalent differences emerge when looking at an expansionary shock. The key to understanding the mechanism lies in observing the reaction of consumption of the unemployed. Consider an expansionary monetary policy shock. This is reflected in a drop in the nominal rate and and an accompanying increase in the inflation rate, both leading to a decline in the real interest rate. With returns to savings going down, the consumption of unemployed households has to go down as well, since they finance consumption out of savings. As shown in the figures, unemployed consumption drops by a similar amount in all three economies. This in turn directly strengthens the precautionary saving motive of employed households, particularly so in economies with a high transition probability to unemployment, *i.e.* a large ρ. In consequence, we observe a smaller increase in employed consumption and hence in employment when the separation rate is higher.

Finally, note that the smallest response in the interest rate is observed in the economy with low unemployment risk. This is simply due to the endogenous reaction of the central bank to the drop in inflation, as implied by the assumed Taylor rule. Nevertheless, this reaction is not sufficient to offset the effects of the precautionary saving motive. In conclusion, the model predicts a stronger effect of monetary policy in economies with low unemployment risk.

1.5 Model extensions

In this section, two alternative cases to the previous model are analyzed. First, I introduce differences in the generosity of unemployment benefits, and second, I study the case of endogenous unemployment. The first exercise changes two modeling assumptions compared to the previous section. For one, it is no longer assumed that the real amount of government debt issued is constant across economies (while the interest rates are allowed to vary). Instead, I assume that fiscal policy targets a steady state nominal rate that is equal in all economies, and adjusts debt issuance accordingly. In the previous exercise, a precautionary saving motive was reflected in lower real rates, while actual levels of savings were exogenously given. Now, savings levels are allowed to vary across economies. In all economies, it is assumed that the government targets a gross nominal rate of 1.02%. As a second change, economies will no longer differ with respect to their separation rates, which is now set at 4% for all economies. Instead, the generosity of unemployment insurance benefits will determine variations in income risk across economies. In particular, it is assumed that unemployment benefits s are equal to 0.05, 0.15, and 0.25, respectively, where higher values imply a lower income risk due to unemployment and hence a less strong precautionary savings motive.

Steady states values are again very similar across economies, with the exceptions of debt levels, where large differences prevail. Compared to the low risk benchmark economy with $s = 0.25$, steady state levels of government debt are 71% and 143% higher in the economies with lower unemployment insurance parameters of 0.15 and 0.05, respectively. Looking again at impulse responses to a monetary shock reveals that also under the new assumptions, the suggested relationship between unemployment risk and monetary policy effects still holds[2]. Responses to a contractionary and an expansionary monetary shock, each of one standard deviation size, are shown in Figures 1.5 and 1.6, respectively.

[2]It is important to point out that there is no necessity for the two changes in assumptions, *varying unemployment benefits and endogenous government debt* to be implemented jointly, yet also when considering them individually, all qualitative results hold. For convenience, only results when both assumptions are changed at once are presented here.

Figure 1.5. Impulse responses to contractionary monetary policy shock, unemployment benefits set at $s = 0.25$ (blue), $s = 0.15$ (green), and $s = 0.05$ (red).

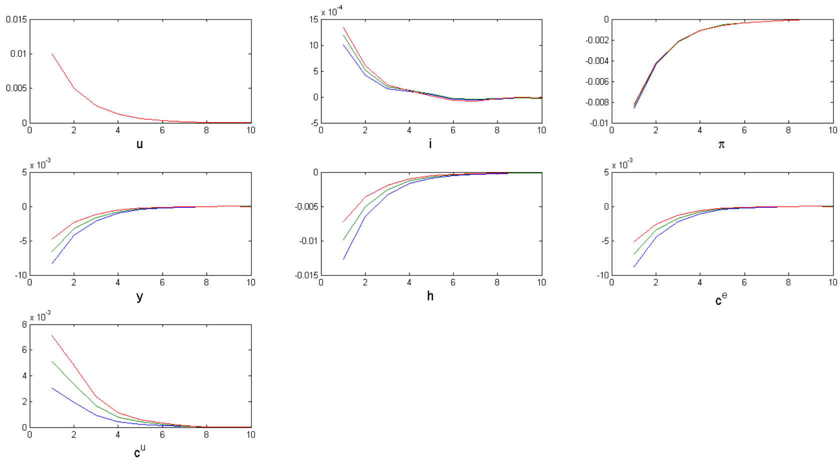
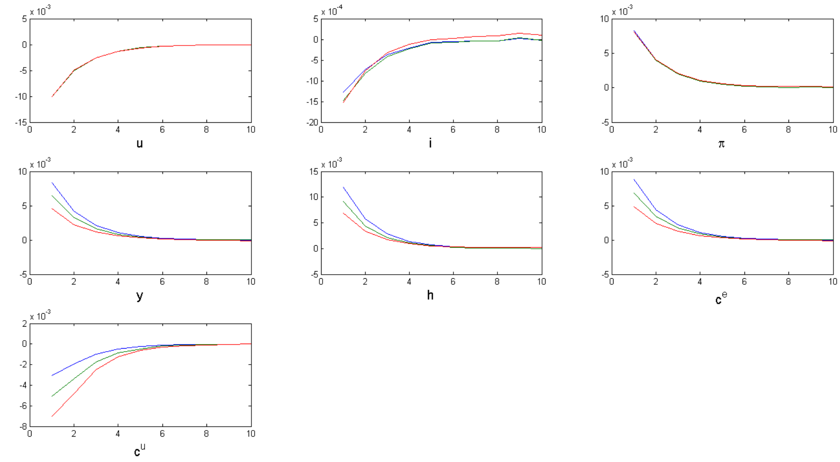


Figure 1.6. Impulse responses to expansionary monetary policy shock, unemployment benefits set at $s = 0.25$ (blue), $s = 0.15$ (green), and $s = 0.05$ (red).



Once again, the interest elasticity, and hence the degree to which a monetary shock affects consumption, depends crucially on the strength of a precautionary saving motive in the economy. If unemployment protection is high and income risk relatively small, this motive is weak and we see a large reaction of output. In the economy with $s = 0.25$, on impact output is reduced by 0.84% after a contractionary shock. When unemployment insurance benefits are decreased to $s = 0.15$ and $s = 0.05$, this response is reduced to 0.65% and 0.48%, respectively. An equivalent picture emerges after an expansionary shock: a central bank is more successful in stimulating demand if unemployment protection is relatively strong.

Unemployment so far was treated as exogenous and constant, but it is important to consider that monetary policy itself affects unemployment risk and hence the precautionary savings motive. To do so, the original model is extended with employment and separation rates that react endogenously to labor demand. To keep things simple, I postulate a proportional relationship between employment and labor demand of the form

$$\nu_t = \overline{\nu} \left(\frac{h_t}{\overline{h}} \right)^{\chi}$$

where $\overline{\nu}$ is chosen so that steady state employment is again at 0.92 as in the previous section, and χ is set at 0.5. The latter implies that half of the changes in total hours occur through adjustments at the extensive margin.

I further assume that separation rates move one to one with unemployment by specifying

$$\rho_t = \overline{\rho} \frac{1 - \nu_t}{1 - \overline{\nu}}$$

where $\overline{\rho}$ corresponds to the steady state value of ρ_t. All other parameter are equal to their original values as reported in Table 1.1. We look again at responses to a monetary shock, as computed from simulated data for three economies with varying steady state separation rates $\overline{\rho}$, as shown in Figures 1.7 and 1.8. The main mechanism still carries through. In the case of an expansionary shock, interest rates go down, increasing inflation and stimulating demand, leading to an increase in output. But since consumption of the unemployed is reduced, the precautionary savings motive is strengthened, particularly in economies with high separation rates. We again see that countries with high unemployment risk react less to a monetary impulse.

Taking endogenous employment into account offers to two additional observations. First, effects of a monetary policy shock are bigger across the board. This is due to the fact that *e.g* in the case of a contractionary shock, on top of the immediate impact on demand, there is a feedback loop that works through the reduction in output and hours worked. As unemployment and separation rates go up, the desire for precautionary savings is strengthened, depressing demand even further. This feedback increases the effect on impact by about 20% in all economies. Second, it can be observed that the differences across economies prevail, and that they are now slightly asymmetric. The difference in responses between a low risk and a high risk economy is bigger than in the original model when looking at an expansionary shock, and smaller in the case of a contractionary shock. The explanation for this is straightforward, and can be seen when looking at the responses of the separation rates. Given that output reacts more in the low risk economy, we also observe a larger response in the separation rate, and hence a larger feedback effect. In the case of an expansionary shock, this implies that the difference between economies in terms of their separation rates becomes larger, since it falls more in an economy which already has an initially low rate. The opposite is true for a contractionary shock, where the difference in separation rates gets compressed.

Figure 1.7. Impulse responses to contractionary monetary policy shock, unemployment benefits set at $\overline{\rho} = 0.01$ (blue), $\overline{\rho} = 0.04$ (green), and $\overline{\rho} = 0.07$ (red).

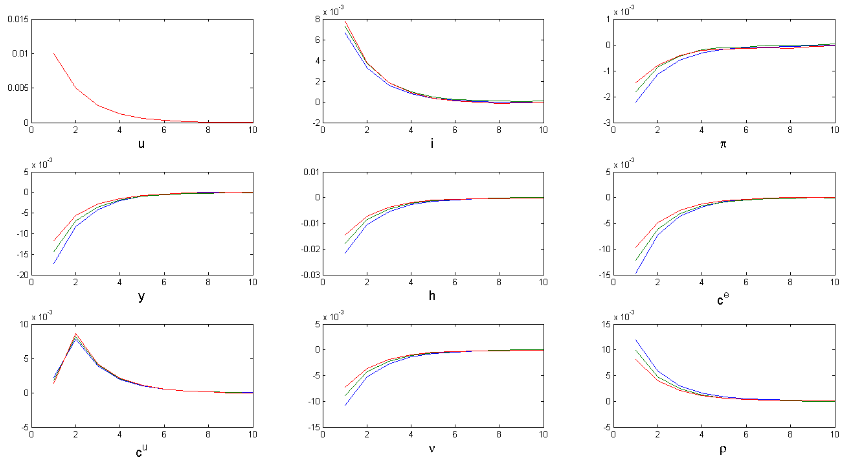
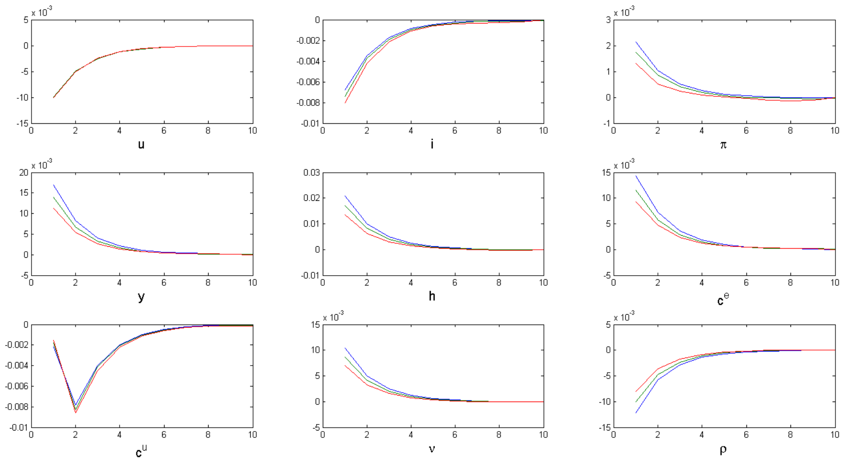


Figure 1.8. Impulse responses to expansionary monetary policy shock, unemployment benefits set at $\overline{\rho} = 0.01$ (blue), $\overline{\rho} = 0.04$ (green), and $\overline{\rho} = 0.07$ (red).



1.6 Empirical analysis

This section turns to an empirical investigation of the suggested link between effectiveness of monetary policy and unemployment risk. The theory in the previous chapter predicts that with increasing unemployment risk, either through higher transition rates into unemployment or lower benefits, there is a smaller effect of changes in the interest rate on economic activity, due to a reduced response of households. I present support for these predictions in two steps. First, using household level data on consumption expenditure, section 1.6.1 shows that households' consumption reacts more strongly to changes in the interest rate if unemployment risk is low. In section 1.6.2, I show that this carries over to the macro level, by examining the performance of US states in response to the federal funds rate, and the effect of the ECB policy rate on activity in Euro area countries. All these cases have the advantage that monetary policy is (approximately) independent of idiosyncratic household or regional shocks, which allows for relating differences in regional responses to interest rate changes with differences in their region specific characteristics. This strategy is particularly promising, since we are not interested in the average response to an interest rate change, but in how this response differs depending on unemployment risk.

1.6.1 Consumption expenditure at the household level

How do consumption expenditures respond to the interest rate? And how does this response depend on unemployment risk? To answer this question, I combine household level data from the US Consumption Expenditure Survey conducted by the Bureau of Labor Statistics with information on the federal funds rate and state level unemployment benefits. In the spirit of Rudebusch and Svensson (1999), I relate current (log) consumption expenditures to the lagged four period average of the federal funds rate, adjusted for inflation. If a reduction (increase) in the interest rate has a stimulating (dampening) effect, the causal relationship will be negative, yet since the interest rate is adjusted by the central bank given expectations about future economic development, this causal effect is typically difficult to identify. For this reason, I do not consider the average effect of the interest rate on consumption. Instead, I look at how this effect differs across households and regions. If the stimulating effect of an interest rate reduction is lower when unemployment insurance benefits are smaller, we would expect the interaction coefficient of the interest rate with the loss of income in case of unemployment should to be positive. Similarly, we would expect a positive interaction coefficient between the job loss risk faced by a household and the interest rate.

To test the first prediction, I construct the average loss rate UI which is equal to one minus the average statewide unemployment benefit replacement rate, *i.e.* the average income loss in case of unemployment. I then estimate regression equations of the form

$$\begin{aligned} y_{i,c,t} =& c + \beta\bar{r}_{t-1} + \gamma\bar{r}_{t-1} * UI_c + [\delta_1 + \delta_2\bar{r}_{t-1}] * X_{i,c} \\ &+ \delta_3\bar{r}_{t-1} * Z_c + m_c + n_t + \epsilon_{i,c,t} \end{aligned} \tag{1.12}$$

where $y_{i,c,t}$ are log consumption expenditures of household i in state c at time t. Data is of quarterly frequency and spans 1996 to 2014, and the sample contains all households where at least one member is employed at the time of the interview. As described above, $\bar{r}_{t-1}$ is the four quarter average of the real interest rate. The coefficient of interest is γ, which measures how the effect of the interest rate depends on unemployment risk. $X_{i,c}$ and Z_c are household and state level controls, respectively. I interact this controls with the interest rate measure to capture their potential effect on the elasticity of consumption. At the households level, these controls include various socio-economic characteristics such the main earner's education, occupation, race, gender, marital status, age and age squared, as well as the size of the household. At the state level, additional controls on the size of the financial sector are included. Finally, m_c and n_t are state and period fixed effects.

Estimated coefficients are reported in table 1.2. Across all specifications, the interaction coefficient γ is positive and significant, indicating that households who are better protected from unemployment more strongly to the interest rate. As can be seen in column (1) the effect is relatively small, yet clearly not negligible: moving from the highest loss rate (0.54) to the lowest (0.31) increases the effect of interest rate changes on consumption by 1.75%. The coefficient is remarkably constant across specification with additional controls.

Table 1.2. Unemployment insurance

Dep. variable:	Log Total Expenditures			
	[1]	[2]	[3]	[4]
$\bar{r}_{t-1}$	-8.837***			
	(2.084)			
$\bar{r}_{t-1} * UI$	0.0760*	0.0828**	0.0942**	0.0869**
	(0.0403)	(0.0392)	(0.0428)	(0.0400)
State FE	Yes	Yes	Yes	Yes
Period FE	No	Yes	Yes	Yes
HH Demographic controls	No	No	Yes	Yes
Economic controls	No	No	No	Yes
N	131260	131260	131260	127568
r2	0.0406	0.0607	0.181	0.184

Notes: Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. All regressions estimated by OLS. $\bar{r}$ is the four quarter average of the federal funds rate, adjusted for inflation. UI is one minus the state level average unemployment benefit replacement rate. Household demographic controls include the main earners age, age squared, race, gender, marital status, education level, occupation, as well as household size. Economic controls include the state level share of the financial sector. All regressions include interactions of the controls with the interest rate. Standard errors are clustered at the state level.

The risk of losing one's job should similarly affect the reaction of consumption expenditures to the interest rate. To test for this, I construct a household level measure of job loss risk in the following four quarters.[3] I estimate a model with transition to unemployment as dependent variable, using household level characteristics, including education and age of the main earner and the type of employment. This allows me to predict each employed

[3] The Consumption Expenditure Survey follows households for up to five quarters.

household's risk of job loss in the following year. I use this measure of job loss risk interacted with the interest rate in regression equations equivalent to (1.12), where the income loss variable UI_c is now replaced with the job loss risk $U_{i,c}$. The coefficient of interest is again γ, which is expected to be positive. The fact that the risk of job loss is measured at the household level allows me to estimate within state effects of unemployment risk, by including in the specification state fixed effects interacted with the interest rate. Table 1.3 reports interaction coefficients of job loss risk with the interest rate. While insignificant in the specification without fixed effects, the estimates of γ are large and significant in all other models, indicating that a one percentage point increase in the risk of job loss reduces the stimulating effect of an interest rate reduction by up to 0.86%. The effect increases in size with the addition of controls and gains significance at the 95% confidence level. Standard errors are bootstrapped to take into account that the regressor of interest is a predicted variable.

1.6.2 Evidence from US states and Euro zone countries

In this section, I investigate how interest rate changes affect aggregate economic outcomes differentially depending on unemployment risk. I examine two different monetary unions: the United States (using states as the unit of observation) and the Euro area. Economic performance is measured by log real income in US states and log real GDP in Euro area countries. I consider both deviations from long run trends as well as growth rates. The sample examined includes the periods of 1976q1-2014q4 and 2002q1-2014q4, respectively, with the latter corresponding to the period where the Euro existed as a physical currency. Building on Rudebusch and Svensson (1999) and Estrella (2002), economic performance is regressed on the average of the relevant real interest rate, where the average is taken over the previous four quarters. I use two proxies of region specific risk arising due to unemployment: the average regional unemployment rate in the five years before the beginning of the sample, and the average replacement rate, which is meant to capture unemployment insurance benefits.

Table 1.3. Unemployment risk

Dep. variable:	Log Total Expenditures			
	[1]	[2]	[3]	[4]
$\bar{r}_{t-1}$	-4.389***			
	(0.205)			
$\bar{r}_{t-1} * U$	0.4581	0.7068*	0.7887**	0.8648**
	(0.403)	(0.383)	(0.378)	(0.393)
State FE	No	Yes	Yes	Yes
Period FE	No	Yes	Yes	Yes
State FE interactions	No	No	Yes	Yes
HH Demographic controls	No	No	No	Yes
N	101018	101018	101018	101018
r2	0.189	0.260	0.285	0.380

Notes: Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. All regressions estimated by OLS. $\bar{r}$ is the four quarter average of the federal funds rate, adjusted for inflation. U is the predicted probability of household job loss within the next year. Household demographic controls include the main earners age, age squared, race, gender, marital status, education level, occupation, as well as household size. All regressions include interactions of the controls with the interest rate. Bootstrapped standard errors (for predicted regressors) in parenthesis.

I estimate equations of the form

$$y_{c,t} = const + \sum_{\tau=1}^{2} \alpha^{\tau} y_{c,t-\tau} + \beta \bar{r}_{t-1} + \gamma \bar{r}_{t-1} * U_c + \delta U_c + \epsilon_{c,t} \tag{1.13}$$

where the dependent variable $y_{c,t}$ is real income in the case of US states and real GDP for Euro countries, both measured as their log deviation from the long run trend. The monetary policy term $\bar{r}$ represents the four period average of the real relevant interest rate, *i.e.* the federal funds rate and the main refinancing rate, respectively, adjusted for inflation. U_c is a region's unemployment rate at the beginning of the sample. The coefficient of interest is γ, which measures how the effect of monetary policy depends on the unemployment rate. So failure of a decrease in the interest rate to stimulate economic activity implies $\gamma > 0$ (together with $\beta < 0$). In extended specifications, I add region and period fixed effects, as well as additional interactions of $\bar{r}_{t-1}$. The latter include interactions with initial level, per capita measures and growth rates of income or GDP. Controlling for these additional interaction terms strengthens the confidence that γ is indeed capturing the effect of increased unemployment risk, and not additional channels such as the general economic situation in a region.

Table 1.4 reports results for US states (columns 1-3) and Euro area countries (columns 4-6). For US states, and as shown in column 1, the estimated coefficient β is negative, implying that an increase in the (four quarter average) federal funds rate of 100 basis points is followed by a reduction of real income by 0.94%, relative to trend income, for a state with a zero percent unemployment rate. Note that these estimates do not have a causal interpretation, since interest rate changes should be correlated with expected mean income growth. Of more interest is the coefficient γ, which shows how the response of each state depends on unemployment risk. As suggested by the theory, γ is estimated to be positive, indicating that a reduction in the interest rate will not lead to increased income growth if unemployment risk is sufficiently large. For every one percentage point increase in the unemployment rate, the effect of the interest rate on income is reduced by 0.37 percentage points. The coefficient on the interaction term is significant at the 95% confidence level. The estimate is robust both in terms of size and of significance to the inclusion of further independent variables. In fact, both the inclusion of state and period fixed effects in column 2 and additional interactions of the interest rate with initial conditions (column 3) tend to increase both the magnitude and the significance of the estimate of γ.

Table 1.4. Deviation from trend

Sample:	US states			Euro area countries		
	[1]	[2]	[3]	[4]	[5]	[6]
y_{t-1}	1.054***	1.004***	1.002***	1.107***	1.005***	0.977***
	(0.0327)	(0.0389)	(0.0392)	(0.0687)	(0.132)	(0.122)
y_{t-2}	-0.0681**	-0.0181	-0.0172	-0.135*	-0.00698	0.00981
	(0.0314)	(0.0385)	(0.0384)	(0.0644)	(0.130)	(0.122)
$\bar{r}_{t-1}$	-0.0168			-0.0322		
	(0.0105)			(0.0192)		
$\bar{r}_{t-1} * U$	0.371**	0.387**	0.425**	0.780**	0.580***	0.613*
	(0.153)	(0.160)	(0.159)	(0.305)	(0.161)	(0.319)
U	-1.511**			-3.130**		
	(0.626)			(1.235)		
$\bar{r}_{t-1} * y$			0.315			-4.336
			(0.563)			(4.658)
$\bar{r}_{t-1} * Y$			0.00288			-0.179**
			(0.00178)			(0.0584)
$\bar{r}_{t-1} * Y^{pc}$			-2.230			-0.215***
			(2.316)			(0.0540)
Region FE	No	Yes	Yes	No	Yes	Yes
Period FE	No	Yes	Yes	No	Yes	Yes
N	6732	6732	6732	572	572	572
r2	0.960	0.976	0.976	0.968	0.986	0.987

Notes: Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. All regressions estimated by OLS. The dependent variable is the deviation from trend of log real income of US states in columns (1)-(3), and of log real output of Euro area countries in columns (4)-(6). $\bar{r}$ is the four quarter average of the federal funds rate, adjusted for inflation. U is the average regional level unemployment rate in the five years before sample start. y, Y, and Y^{pc} are average regional level output growth, log output and log output per capita, respectively, in the five years before sample start. Standard errors are clustered at the regional level.

A similar picture emerges when looking at Euro area countries. The estimated interaction coefficients in columns 4-6 tend to be larger in size. One percent increase in initial unemployment leads to a reduction in the effect of interest rates on output of 0.78 percentage points. Despite the smaller sample size, the estimated interaction coefficient is significant at the 95% confidence level, and relatively robust to the inclusion of country and period fixed effects, as well as of additional interaction terms. Confidence is reduced to 90% in the latter case, but the size of the coefficients remains large.

Results are robust to using the growth rate of outcomes as a dependent variable. Results are reported in Table 1.5. Remarkably, all main results carry through: in regions with low unemployment risk, a reduction in the interest rate is followed by an increase in economic activity (and vice versa), which does not hold as unemployment risk increases. Interestingly, the size of the interaction term coefficient is very much comparable to the results obtained using deviations from trend. In all specifications, the interaction coefficient is statistically significant at least at the 95% level.

Table 1.5. Growth rates

Sample:	US states			Euro area countries		
	[1]	[2]	[3]	[4]	[5]	[6]
y_{t-1}	0.0606**	0.00780	0.00654	0.258***	0.0324	0.0164
	(0.0270)	(0.0333)	(0.0334)	(0.0686)	(0.106)	(0.106)
y_{t-2}	0.178***	0.142***	0.140***	0.222***	0.235**	0.217**
	(0.0217)	(0.0223)	(0.0223)	(0.0653)	(0.0889)	(0.0891)
$\bar{r}_{t-1}$	-0.0155*			-0.00929		
	(0.00832)			(0.00775)		
$\bar{r}_{t-1} * U$	0.305**	0.334**	0.353***	0.318**	0.427**	0.397**
	(0.120)	(0.131)	(0.129)	(0.114)	(0.139)	(0.160)
U	-1.260**			-1.288**		
	(0.488)			(0.466)		
$\bar{r}_{t-1} * y$			0.0601			-1.577
			(0.496)			(1.692)
$\bar{r}_{t-1} * Y$			0.00203			-0.0999***
			(0.00144)			(0.0281)
$\bar{r}_{t-1} * Y^{pc}$			-1.729			-0.108***
			(1.840)			(0.0321)
Region FE	No	Yes	Yes	No	Yes	Yes
Period FE	No	Yes	Yes	No	Yes	Yes
N	6732	6732	6732	572	572	572
r2	0.0433	0.421	0.422	0.179	0.516	0.520

Notes: Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. All regressions estimated by OLS. The dependent variable is the growth rate of log real income of US states in columns (1)-(3), and of log real output of Euro area countries in columns (4)-(6). $\bar{r}$ is the four quarter average of the federal funds rate, adjusted for inflation. U is the average regional level unemployment rate in the five years before sample start. y, Y, and Y^{pc} are average regional level output growth, log output and log output per capita, respectively, in the five years before sample start. Standard errors are clustered at the regional level.

I then use the average replacement rate of unemployment insurance as an alternative measure for region specific unemployment risk. More precisely, instead of the unemployment rate as a proxy for job loss probability, the following part makes use of $UI = 1 - rr$, where rr is the average replacement rate, and UI thus a measure of the average income loss in case of a job loss. Note that the two measures are very complementary in nature, since the total risk of unemployment can be characterized as the probability of a job loss multiplied with the income loss. Table 1.6 reports results for regressions using the deviation from trend as dependent variable and UI as the risk proxy, while Table 1.7 shows estimations with growth rates as dependent variable. The results consistently confirm the previous findings. As indicated by the positive estimate of the coefficient of $\bar{r}_{t-1} * UI$, in regions with low replacement rates (and hence a high UI), economic activity reacts less positively (or not at all) to a reduction in the interest rate. This result is once again very significant and robust across various specifications. As before, the interaction coefficient tends to be larger for Euro area countries than for US states.

Table 1.6. Deviation from trend

Sample:	US states			Euro area countries		
	[1]	[2]	[3]	[4]	[5]	[6]
y_{t-1}	1.055***	1.006***	1.004***	1.082***	0.983***	0.965***
	(0.0327)	(0.0392)	(0.0395)	(0.0483)	(0.0691)	(0.0709)
y_{t-2}	-0.0693**	-0.0203	-0.0191	0.000889	0.214**	0.208**
	(0.0315)	(0.0389)	(0.0387)	(0.0590)	(0.0682)	(0.0691)
$\bar{r}_{t-1}$	-0.0311			-0.0373		
	(0.0195)			(0.0341)		
$\bar{r}_{t-1} * UI$	0.0657**	0.0691**	0.0618	0.162	0.111*	0.108***
	(0.0327)	(0.0343)	(0.0373)	(0.0923)	(0.0546)	(0.0284)
UI	-0.268*			-0.654		
	(0.134)			(0.370)		
$\bar{r}_{t-1} * y$			0.115			2.352
			(0.694)			(1.787)
$\bar{r}_{t-1} * Y$			0.00376*			-0.0851*
			(0.00220)			(0.0435)
$\bar{r}_{t-1} * Y^{pc}$			-0.00102			-0.143**
			(0.00259)			(0.0456)
Region FE	No	Yes	Yes	No	Yes	Yes
Period FE	No	Yes	Yes	No	Yes	Yes
N	6732	6732	6732	572	572	572
r2	0.960	0.976	0.976	0.969	0.987	0.987

Notes: Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. All regressions estimated by OLS. The dependent variable is the deviation from trend of log real income of US states in columns (1)-(3), and of log real output of Euro area countries in columns (4)-(6). $\bar{r}$ is the four quarter average of the federal funds rate, adjusted for inflation. UI is one minus the regional level average unemployment benefit replacement rate. y, Y, and Y^{pc} are average regional level output growth, log output and log output per capita, respectively, in the five years before sample start. Standard errors are clustered at the regional level.

Table 1.7. Growth rates

Sample:	US states			Euro area countries		
	[1]	[2]	[3]	[4]	[5]	[6]
y_{t-1}	0.0616**	0.00971	0.00840	0.250***	0.00309	-0.00471
	(0.0269)	(0.0335)	(0.0336)	(0.0636)	(0.0720)	(0.0769)
y_{t-2}	0.179***	0.143***	0.142***	0.224**	0.228**	0.216**
	(0.0215)	(0.0225)	(0.0226)	(0.0723)	(0.0852)	(0.0902)
$\bar{r}_{t-1}$	-0.0228			-0.00758		
	(0.0146)			(0.0112)		
$\bar{r}_{t-1} * UI$	0.0464*	0.0522*	0.0452	0.0630*	0.0700*	0.0677***
	(0.0242)	(0.0267)	(0.0289)	(0.0305)	(0.0380)	(0.0136)
UI	-0.187*			-0.257*		
	(0.0987)			(0.124)		
$\bar{r}_{t-1} * y$			-0.0995			2.859***
			(0.599)			(0.852)
$\bar{r}_{t-1} * Y$			0.00280			-0.0500
			(0.00179)			(0.0372)
$\bar{r}_{t-1} * Y^{pc}$			-0.000640			-0.0483
			(0.00210)			(0.0547)
Region FE	No	Yes	Yes	No	Yes	Yes
Period FE	No	Yes	Yes	No	Yes	Yes
N	6732	6732	6732	572	572	572
r2	0.0423	0.420	0.421	0.184	0.522	0.525

Notes: Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. All regressions estimated by OLS. The dependent variable is the growth rate of log real income of US states in columns (1)-(3), and of log real output of Euro area countries in columns (4)-(6). $\bar{r}$ is the four quarter average of the federal funds rate, adjusted for inflation. UI is one minus the regional level average unemployment benefit replacement rate. y, Y, and Y^{pc} are average regional level output growth, log output and log output per capita, respectively, in the five years before sample start. Standard errors are clustered at the regional level.

1.7 Conclusion

Precautionary savings have a small interest elasticity. This paper investigates how this influences the effectiveness of monetary policy, by considering unemployment risk as the main contributor to an individual's precautionary savings motive. In a parsimonious and hence very general New Keynesian model, I show that the effects of a change in the nominal interest rate are limited if individual income risk is high. It follows that, when precautionary savings motives are strong – that is, when households face large income risks due to unemployment – central banks fail to effectively stimulate demand. I provide empirical support for this hypothesis by examining the response to changes in the interest rates, considering both individual households as well as US states and Eurozone countries. I show that unemployment risk, whether proxied by unemployment rates or by unemployment benefits, substantially reduces the effectiveness of monetary policy.

Accounting for the low interest elasticity of precautionary saving suggests an additional advantage of both unemployment benefits and state employment during a crisis. Both fiscal policy measures are automatic stabilizers, since, by construction, they force fiscal policy to be expansionary during a recession. This paper suggests that these fiscal measures can also improve the stability of the economy by increasing the effectiveness of monetary policy. This is of particular relevance for countries that belong to a monetary union. In regions with high unemployment rates, monetary policy is less effective because it does not succeed in stimulating aggregate demand. It is precisely in such regions where strong unemployment protection or increased state employment can be beneficial in times of crisis.

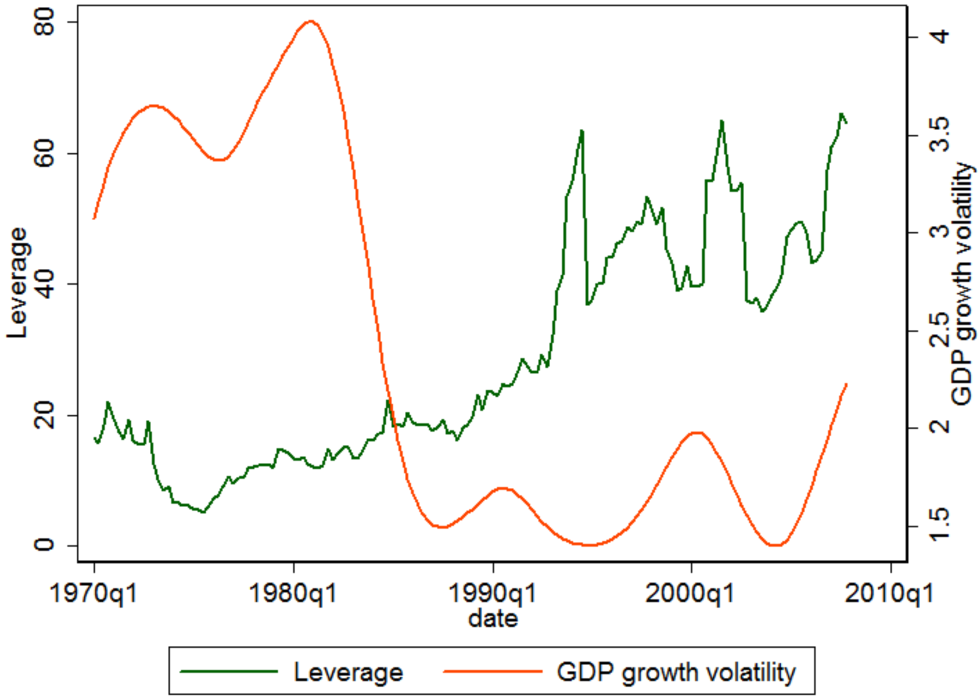
Chapter 2

FINANCIAL RISK AND THE STABILITY-RESILIENCE TRADE-OFF

2.1 Introduction

The recent financial crisis, which brought about large and persistent losses in output, followed a period characterized by a very stable macroeconomic environment. This period, known as the Great Moderation, started around 1984 and featured in particular very low volatility of both inflation and output. This reduction in aggregate volatilities has gone hand in hand with an increase in leverage rates. Figure 2.1 plots the evolution of instantaneous US GDP volatility and of leverage of security brokers and dealers until the end of 2007. GDP volatility fell sharply around 1984 and remained at low levels thereafter. Leverage rates were almost constant until the mid '80s, but increased steadily throughout the Great Moderation, peaking at the onset of the crisis. Excessive leverage is often named as a key contributor to recent financial instability. This observation begs the question whether low macroeconomic fluctuations may act as a driver of increased firm leverage and hence increased financial risk exposure.

Figure 2.1. Evolution of GDP growth volatility and Leverage



Notes: GDP growth volatility is the innovation of an estimated AR(1) for real GDP growth (HP trend). GDP data is from the Bureau of Economic Analysis, leverage data from the Flow of Funds.

This paper presents a trade-off between stability in the short run and resilience to rare and large adverse shocks. Can some degree of volatility in normal times be considered a good thing to make the economy resilient when rare shocks occur? To what degree can we think of the Great Moderation as containing the seed for the subsequent financial crisis? I address these questions by first investigating theoretically how periods of low fluctuations make an economy more vulnerable with respect to bad shocks. I show that low volatility periods can, through the endogenous adjustment in financial risk taking, cause larger downturns in crisis times. I then provide empirical support for the key theoretical predictions.

I construct a model with endogenous liability structure which builds on Gomes et al. (2014). This is a general equilibrium model in which firms may finance investment through retained earnings, short-term debt, or by issuing new equity. Intuitively, firms have a preference for debt financing, since it provides them with a tax advantage. On the other hand, leverage increases a firm's risk exposure. Access to new funds is limited in the short term, due to a collateral constraint on borrowing and to dilution costs on equity issuance. This exposes firms to a risk of liquidity shortage when revenue is depressed, with this risk being increasing in the amount of outstanding debt obligations. In a standard fire sales spiral, endogenous asset prices feed back into the collateral constraint of firms, amplifying adverse shocks in crisis times. I consider two types of shocks. Changes in productivity cause fluctuations in output during "normal" times. Large capital destruction shocks hit the economy on rare occasions. I investigate how a reduction in volatility during normal times, potentially due to monetary policy measures, affects the endogenous financial risk taking and how this, in turn, affects the fragility of the economy with respect to the rare shocks.

This analysis delivers two main results. First, crisis shocks have more severe effects if the economy experienced low volatility in the preceding periods, suggesting a stability-resilience trade-off. The intuition for this result is straightforward: some degree of fluctuations during normal times limits the incentives of firms for financial risk-taking. As this volatility becomes smaller, firms choose to operate at increasing leverage levels. As a result, the economy is more fragile to the capital destruction shock, and is more likely to enter a fire sales spiral in response. Second, if the amplification through feedback effects is sufficiently strong, crisis events can be so devastating as for an an initial reduction in normal times fluctuations to lead to a more volatile economy overall. This result is a particular case of the volatility paradox of Brunnermeier and Sannikov (2014), focusing on the case of a reduction in volatility during normal times.

The trade-off between short run stability and resilience is present in the data.

A key prediction of the model is that firms that experience low macroeconomic volatility in normal times will operate with higher financial risk and thus be more affected by large adverse shocks. Using a large panel of European firms, I show that firms who operated in relatively stable environment in the years before 2007, entered the financial crisis with larger financial risk exposure, as measured by both leverage and liquidity ratios. Using a wide range of measures for firm performance, I find strong evidence that these firms did worse during the crisis years, even when limiting the comparison within country and industry. The result also holds on the aggregate level. I show that periods of low volatility not only predict financial crisis events, but, conditional on a crisis taking place, are also correlated with a worse economic performance during the crisis years.

The idea that short run stability of a system can reduce its long run resilience against large adverse shocks, due to the system's endogenous adaptation mechanisms, is well known in ecology and ecosystem management (see Holling (1973) and Holling and Meffe (1996) for a detailed description).[1] Only recently, economists have started to view the stability of the financial system from a similar perspective. Gai et al. (2008) show in a three period model with asset fire sales that financial innovation and phases of low volatility in productivity can spur financial risk taking, making financial crisis events more severe. Brunnermeier and Sannikov (2014) construct an infinite horizon model, in which a reduction in the exogenous volatility of financial shocks that affect the value of assets can lead to more severe crises and result in an increased volatility of output. Adrian and Boyarchenko (2012) take an alternative approach, by showing how financial intermediares can both reduce volatility during normal times as well as increase systemic financial risk. This paper extends the existing literature by focusing on the case of a stabilization during normal times and by providing empirical support for the trade-off.

Amplifying feedback loops that arise due to financial frictions and work

[1]An often cited example concern forest fires (Jensen and McPherson, 2008).

though endogenous asset prices have played a major role in macroeconomic modeling since the seminal papers of Bernanke and Gertler (1989), Kiyotaki and Moore (1997), and Bernanke et al. (1999). Unlike these original contributions and a large part of the literature that followed, which solve for the linearized dynamics around a steady state, I will solve for the global system dynamics, to capture the non-linearities below the steady state. Other papers with a similar approach include Mendoza (2010), He and Krishnamurthy (2012, 2013) and Brunnermeier and Sannikov (2014). The concept of fire sales in financial markets was introduced by Shleifer and Vishny (1992), and Lorenzoni (2008) demonstrates how the resulting pecuniary externalities give rise to excessive credit. A recent strand of literature considers how this overborrowing provides a motive for macro-prudential policies, see *e.g.* Mendoza and Bianchi (2010), Dib (2010), Farhi and Tirole (2012) and Stein (2012). While dealing with the same problem of excessive credit, this paper focuses on how stability in normal times contributes to socially inefficient leverage levels.

A recent strand of literature has explored policy responses to the financial crisis. The potentially large effects of unconventional policies during a crisis is documented by Gertler and Karadi (2011). On the other hand, such policies can create a moral hazard if they are expected by market participants. Gertler et al. (2012) consider the case of fiscal policy, while Farhi and Tirole (2009) consider how the commitment of central banks to crisis intervention increases leverage beforehand. Other related work in this strand of literature includes Diamond and Rajan (2012), Chari and Kehoe (2013) and Geanakoplos and Fostel (2008). Unlike these papers, which focus on policy measures after an economy enters a crisis, I investigate the consequences of the economic environment in normal times. One advantage of this approach is that, while it may be politically unfeasible to limit bail-outs in the middle of a financial crisis, more room for adjustment may exist during more tranquil times.

The remainder of the paper is organized as follows. Section 2.2 describes the model and section 2.3 discusses the solution algorithm, parametrization and simulation results. Section 2.4 presents empirical support for the suggested stability-resilience trade-off. Finally, section 2.5 concludes.

2.2 Model

2.2.1 Firms

The economy consists of a continuum of identical firms of mass one. Firms are owned by households and produce a homogeneous consumption good using a production function of the form

$$y_t = A_t k_t^{\alpha} l_t^{1-\alpha} - F k_t^i$$

where A_t is an exogenous aggregate technology process, F is a fixed cost in production, and k_t and l_t are the factor inputs of capital and labor, respectively. Denoting by i_t a firm's investment expenditures per unit of capital and by q_t the price of capital in terms of the consumption good, we can write the law of motion for a firm's assets as

$$s_{t+1} = (1-\delta)k_t + \frac{i_t}{q_t} k_t \equiv g(i_t, q_t) k_t$$

where δ is the depreciation rate.
The economy is exposed to a rare aggregate capital destruction shock ζ_t, so that workable capital in period t is given by

$$k_t = \zeta_t s_t$$

with

$$\zeta_t = \begin{cases} 1 & \text{with probability } p \\ \zeta < 1 & \text{with probability } 1-p \end{cases}$$

Given a firm's production function, we can define the implicit return to capital R_t using the solution to the firm's labor choice problem

$$R_t k_t = \max_{l_t} (P_t y_t - W_t l_t)$$

Denote the resulting real return to capital by $r_t = R_t/P_t = \alpha y_t/k_t - (1-\alpha)F$.

Firms finance capital investments by issuing equity and non-defaultable, nominal debt. The face value of the stock of current outstanding debt is denoted by B_t and the current market price of a bond with face value one is denoted by p_t^B. The market value of outstanding debt at the end of period t is then $p_t^B B_{t+1}^i$. It is assumed that debt pays a fixed coupon s which is shielded from corporate taxes; taxes are subtracted from profits at rate τ.

Firms pay out dividends or issue new equity, but face a standard quadratic cost of deviating from a target rate. Denoting dividend payout relative to a firm's capital stock by $d_t = D_t/k_t$, dividend costs per unit of capital are given by

$$\varphi(d_t) = d_t + \kappa \left(d_t - \overline{d}\right)^2$$

where $\kappa \geq 0$ and $\overline{d}$ refers to the long run (steady state) dividend to asset target. Note that d_t^i can also be negative in case the firm issues new equity.

After combining dividend costs with the return to capital and debt issuance, a firm's flow of funds constraint becomes

$$\varphi(d_t) k_t = (1-\tau) r_t k_t - ((1-\tau)s + 1) b_t + p_t^B b_{t+1} - i_t k_t \tag{2.1}$$

Denoting debt relative to the capital stock by $\omega_t = b_t/s_t = (b_t/k_t)\zeta_t$, the flow of funds constraint (2.1) can be expressed in units of capital as

$$\varphi(d_t) = (1-\tau) r_t - ((1-\tau)s + 1)\frac{\omega_t}{\zeta_t} + p_t^B g(i_t, q_t)\omega_{t+1} - i_t \tag{2.2}$$

When issuing new debt, firms face a collateral constraint, that restricts the value of the maximum stock of outstanding debt to a fraction σ of a firm's assets, *i.e.* $b_{t+1} \leq \sigma q_t k_{t+1}$. In the numerical calibrations, this constraint will be binding only occasionally. The equity value of a firm is then (dropping the time subscripts) in recursive form

$$V(k, b; a, \mu) = \max_{i,b'} \left\{ D + E\{M'V(k', b'; a', \mu')\} \right\}$$

where the maximization problem is subject to the constraints

$$\begin{aligned} \varphi\left(\frac{D}{k}\right) k &= (1-\tau)rk - ((1-\tau)s+1)b + p^B b' - ik \\ k' &= \zeta' g(i, q)k \\ b' &\leq \sigma q k' \end{aligned}$$

and M' is the stochastic discount factor of the household. Normalizing by the level of capital, the equity value per unit of capital $v(.) = V(.)/k$ can be written as

$$v(\omega; a, \mu) = \max_{i,\omega'} \left\{ d + g(i, q)E\{\zeta' M' v(\omega'; a', \mu')\} \right\} \tag{2.3}$$

subject to

$$\begin{aligned} \varphi(d) &= (1-\tau)r - ((1-\tau)s+1)\frac{\omega}{\zeta} + p^B g(i, q)\omega' - i \\ g(i, q) &= \left(1 - \delta + \frac{i}{q}\right) \\ \omega' &\leq \sigma q \end{aligned}$$

The corresponding optimality conditions are

$$\begin{aligned} \xi p^B &= g(i, q)\left(\Delta p^B + E\{\zeta' M' v_\omega(\omega')\}\right) \\ 0 &= \Delta(p^B \omega' - q) + E\{\zeta' M' v(\omega')\} \\ v_\omega(\omega) &= -\Delta\left[(1-\tau)s + 1\right]/\zeta \\ 0 &= \xi(\sigma q - \omega') \\ \xi &\geq 0 \qquad (\sigma q - \omega') \geq 0 \end{aligned}$$

where ξ is the Lagrange multiplier on the collateral constraint and $\Delta = \frac{\mathrm{d}d}{\mathrm{d}\varphi(d)}$ is the value of an additional unit of income in terms of dividend payments or the shadow value of internal funds, given by

$$\Delta = \frac{1}{\sqrt{1 + 4\kappa\varphi}}$$

as long as $\varphi > -\frac{1}{4\kappa}$. Notice that Δ is larger if φ is small, implying that the value of internal funds increases in periods of low revenue, making firms more risk averse than households.

2.2.2 Capital producers

Competitive capital producers turn the consumption good into capital and sell it to firms. The aggregate law of motion of capital is given by

$$S_{t+1} = \Phi(I_t)K_t + (1 - \delta)K_t \tag{2.4}$$

where I_t is aggregate real investment per unit of capital and Φ is a concave production function. It follows that the equilibrium price for capital (in terms of the consumption good) is given by

$$q_t = [\Phi'(I_t)]^{-1} \tag{2.5}$$

In the numerical solution, $\Phi(I_t)$ will be specified as standard quadratic adjustment costs with respect to the steady state level of investment $I^{ss} = \delta$, resulting in a capital price of

$$q_t = 1 - \nu(\delta - I_t) \tag{2.6}$$

with $0 \leq \nu < 1$. Note that the aggregate investment level determines the price of capital, which in turn enters the borrowing constraint of firms, leading to standard fire sales externalities. The equilibrium is unique as long as $\frac{\partial q}{\partial I} < 1$ everywhere, which is guaranteed by setting $\nu < 1$.

2.2.3 Households

Households maximize lifetime utility given by

$$E \sum_{t=0}^{\infty} \beta^t U(c_t, l_t)$$

To simplify the numerical solution algorithm, I specify a utility function that is separable in consumption and hours, of the form

$$U(c_t, l_t) = \frac{(c_t)^{1-\theta}}{1-\theta} - \psi \frac{l_t^{1+\phi}}{1+\phi}$$

The budget constraint of the representative household is

$$c_t = (s+1)b_t^h - p_t^B b_{t+1}^h + d_t^h + T_t + \Pi_t + w_t l_t$$

where B^h is the household's holdings of debt, d_t are dividends from firm equity holdings, T_t are lump-sum government transfers of the proceedings of corporate taxes, and Π_t are capital producers' profits which arise off the steady state. Dropping time subscripts, this implies that

$$\begin{aligned} wc^{-\theta} &= \psi l^{\phi} \\ M' &= \beta \left(\frac{c}{c'}\right)^{\theta} \\ p^B &= E\{M'(s+1)\} \end{aligned}$$

2.2.4 Equilibrium

Imposing clearance in the markets for the consumption good, the capital good, debt and labor, the equilibrium in this economy is defined by

$$\xi p^B = g(i,q)\left(\Delta p^B - E\{M'\Delta'\left[(1-\tau)s+1\right]\}\right) \tag{2.7}$$

$$0 = \Delta(p^B\omega' - q) + E\{\zeta' M' v(\omega')\} \tag{2.8}$$

$$v(\omega) = d + g(i,q)E\{\zeta' M' v(\omega')\} \tag{2.9}$$

$$0 = \xi(\sigma q - \omega') \tag{2.10}$$

$$\xi \geq 0 \qquad (\sigma q - \omega') \geq 0 \tag{2.11}$$

$$g(i,q) = 1 - \delta + \frac{i}{q} \tag{2.12}$$

$$q = \left[\Phi'(I)\right]^{-1} \tag{2.13}$$

$$\varphi(d) = (1-\tau)r - ((1-\tau)s+1)\omega/\zeta + p^B g(i,q)\omega' - i \tag{2.14}$$

$$p^B = E\{M'(s+1)\} \tag{2.15}$$

$$M' = \beta\left(\frac{c}{c'}\right)^{\theta} \tag{2.16}$$

$$k' = \zeta' g(i,q)k \tag{2.17}$$

$$r = \alpha\frac{y}{k} - (1-\alpha)F \tag{2.18}$$

$$w = \psi c^{\theta} l^{\phi} \tag{2.19}$$

$$w = (1-\alpha)ak^{\alpha}l^{-\alpha} \tag{2.20}$$

$$y = ak^{\alpha}l^{1-\alpha} - Fk \tag{2.21}$$

$$y = c + ki \tag{2.22}$$

together with processes that describe the exogenous evolution of A_t. Equation (2.7) shows, that absent a binding collateral constraint (*i.e.* $\xi = 0$), the optimal issuance of new debt is determined by equalizing the returns from additional funds p_B, with the costs of increased debt burden next period, both valued with respect to their effect on the household's value of dividend payments. Optimal investment instead trades off the value of an additional unit of capital with the reduction of dividend payments today, as seen in equation (2.8). Adverse shocks to technology tighten the funds constraint through lower returns to capital (equation (2.14)). Absent a collateral constraint, firms would adjust their debt, in order to keep dividends constant and to satisfy equations (2.7) and (2.8). Instead, with a binding constraint, firms will lower dividends and, due to the dilution costs of new equity issuance, reduce capital investment. The latter reduces the price of capital (equation (2.13)) and thus leads to a further tightening of the collateral constraint, creating a downward spiral after sufficiently large shocks. Since firms do not internalize their effect on the price of capital, they take on too much risk and operate with debt levels that are higher than the socially optimal.

2.3 Model Solution and Results

2.3.1 Solution Algorithm

To capture the non-linear dynamics below the steady state, I use a policy function iteration approach to find the global solution. After specifying the exogenous process for technology, the algorithm starts with an initial guess for firm value and optimal choices of investment, debt and dividend payouts over the state spaces which spans, apart from technology, aggregate capital and outstanding debt. The solution to the optimality conditions is used to update the initial guesses, until all policy functions as well as firm value have converged.

2.3.2 Parameterization

Since a period in the model corresponds to a quarter, the discount factor β is set to 0.99 and the depreciation rate δ to 0.025. For the share of capital α, the conventional value of 0.34 is used. All parameter values are reported in Table 2.1.

In the household's utility function, θ and ϕ are set such that the degree of risk aversion and the elasticity of labor supply equal one and five, respectively. I choose the parameter governing the disutility of labor, ψ, so that households work during one third of their time endowment in the steady state.

The equity dilution costs depend mainly on the parameter κ which is set to 0.8. This yields an annualized expected premium on equity funding of about 15% ($E[\Delta] = 14.8\%$), which is close to the value of 13% in Sim et al. (2014). The tax advantage of debt financing is determined by the tax rate τ and the coupon rate c, which are jointly set such that the mean firm leverage hits the average US non-financial leverage during the Great Moderation of 0.461. Finally, given the chosen value of α, fixed costs in production F of 0.15 ensure that the mean dividend payout to income ratio matches the long run US average of 2.5% (Sim et al., 2014).

Table 2.1. Parameter values

α	Share of capital	0.34
β	Discount factor	0.99
δ	Depreciation rate	0.025
θ	Risk aversion	1
ϕ	Inverse Frisch elasticity	0.25
ψ	Utility weight of labor	4.2
F	Fixed costs	0.15
τ	Corporate taxes	0.05
c	Coupon rate	0.4
κ	Dilution costs	0.8
σ	Borrowing constraint	0.7
ρ_a	Persistence in technology	0.9
σ_a	Technology standard deviation	0.01

Technology is assumed to follow an AR(1). The autoregressive coefficient is set at the conventional value of 0.9. In the benchmark economy, the standard deviation of the innovation is assumed to be 0.01. In the exercise of this section, I will compare the benchmark case with economies that are characterized by a higher volatility parameter, *i.e.* with parametrization of σ_a of 0.03, 0.05, and 0.07, respectively. I compare aggregate data first moments with the ones resulting from simulating the benchmark economy. Data on non-financial firm leverage is from the Flow of Funds. As shown in

Table 2.2 the model can replicate the data means reasonably well.

Table 2.2. First Moments

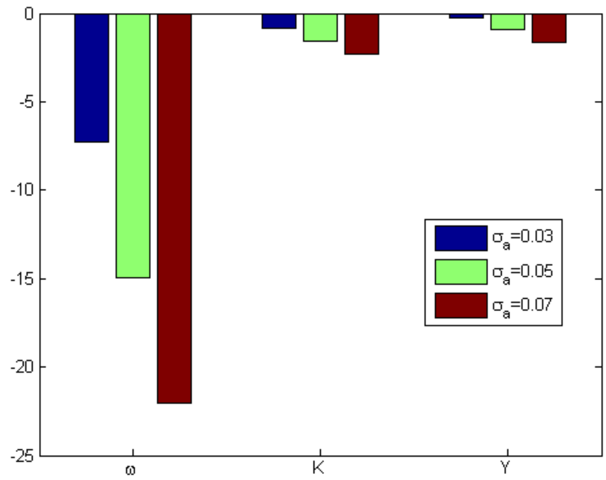
	Target	Model
Leverage	0.461	0.503
Δ	0.13	0.156
Dividend to Income	2.5%	2.56%

2.3.3 Results

I solve the model for four different economies, with are identical except for the parametrization of the volatility of the technology process. In the benchmark economy, $\sigma_a = 0.01$. This value is increased to 0.03, 0.05, and 0.07 in the comparison economies. For all specifications, the model is solved for the equilibrium dynamics, and the resulting policy functions are used to simulate the economies over 50,000 periods each, where the first 10,000 are discarded. From this simulated data, I compute first and second moments, as well as impulse responses, and compare them across economies, to see how changes in exogenous volatility affect financial risk taking, and how this in turn influences responses to a large shock.

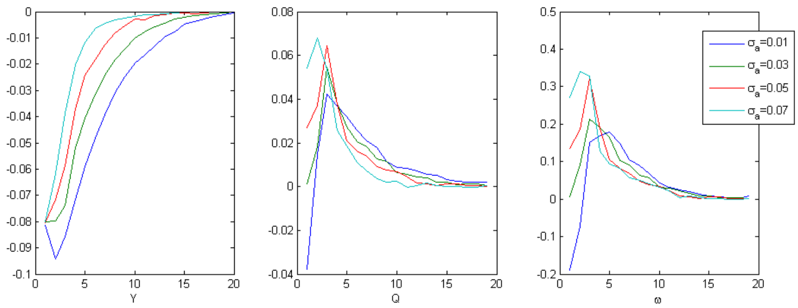
A comparison of long run means is presented in Figure 2.2. All values are expressed as percentage changes relative to the average value in the benchmark economy. As is clear by looking at the mean debt-to-capital ratio ω, a higher exogenous risk leads to more conservative financial risk taking by firms. Differences are substantial, with firms in the most volatile environment operating at a 22% lower debt ratio when compared to the benchmark economy. Average leverage is decreasing in the volatility parameter σ_a. In consequence, average output and capital are also smaller in the more volatile economies, yet differences remain small. The first result summarized in this comparison of means is that, in an environment of low exogenous volatility, firms will operate with higher leverage rates, and thus be exposed to larger financial risk.

Figure 2.2. Mean values, relative to benchmark economy ($\sigma_a = 0.01$), in percentage points



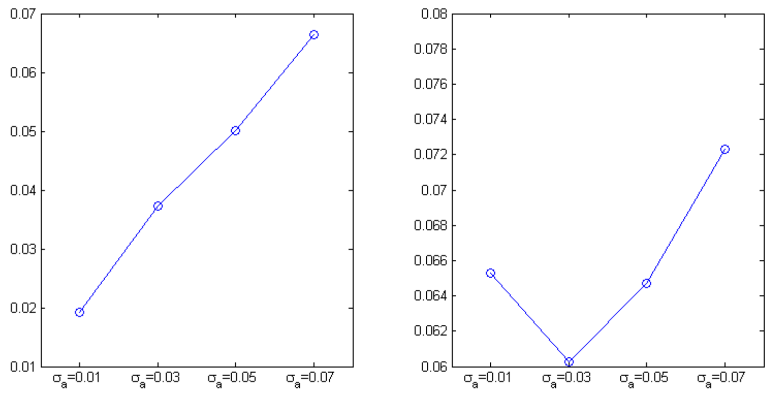
Different leverage ratios become relevant once we consider the rare financial shock. Figure 2.3 plots impulse responses to the financial shock in all four economies for log output, price of capital and debt ratio. On impact, the effect of a financial shock on output is by construction almost identical across economies, with small differences emerging due to the adjustment of hours worked. But large gaps arise in subsequent periods. In the low exogenous risk economy, output keeps dropping for one more period, before starting to recover only slowly. On the other side of the spectrum, the economy with highest exogenous risk and lowest mean leverage appears to recover quickly, and output starts to converge back to its initial level. The cause for these large differences across economies becomes clear when looking at the responses of capital prices and debt. The destruction of capital reduces available collateral, tightening the borrowing constraint. In the benchmark economy, where firms operate with relatively high debt ratios in normal times, the borrowing constraint becomes binding, and firms are forced to reduce their debt levels. In consequence, firms limit their investment expenditures, and this lowers the price of capital. The subsequent further decline in the value of collateral gives rise to the well studied feedback loop, causing the economy to contract also in the periods after the financial shock. On the other hand, in economies where firms operate with low debt ratios in normal times, the borrowing constraint does not become binding and firms are able to expand their borrowing in response to the loss in capital. In these economies, investment is increased and the capital stock and output recover quickly.

Figure 2.3. Impulse response to capital destruction shock



How do the different levels of financial risk and rare episodes of large output losses translate into aggregate volatility of output? I first look at periods without financial shocks. To do this, I simulate a separate set of data, using the policy functions as found above, but adding the restriction that the adverse financial shock does not occur, which allows me to observe how the economies behave in "normal times". In this case, the exogenous volatility in technology is the main driving force of output fluctuations, with differences in leverage rates playing only a minor role. As can be seen in the left panel of Figure 2.4, the benchmark economy with the lowest value of σ_a also experiences the smallest fluctuations during normal times, as measured by the standard deviation of log output, and volatility is strictly increasing in σ_a. The picture changes when taking into account the financial shock, as shown in the right panel. Volatility is increased in all economies, but particularly so in the benchmark case, for reasons described above. The resulting overall volatilities correspond to the volatility paradox of Brunnermeier and Sannikov (2014). The economy with $\sigma_a = 0.03$ has the lowest standard deviation of output, despite having a larger exogenous volatility than the benchmark economy.

Figure 2.4. Volatility of output if periods without capital destruction shocks (left panel) and overall (right panel)



In summary, these results indicate that there is a trade-off between stability in normal times and resilience to large adverse shocks. The economy with the smallest fluctuations suffers the most from a financial shock, and vice versa. With high average debt ratios, the benchmark economy experiences larger output drops and a much slower recovery in times of financial turmoil. In some cases, these effects are strong enough for an economy which enjoys low volatility due to exogenous processes to find itself with larger overall fluctuations, since agents will expose themselves to larger risk.

2.4 Empirical Analysis

The strategy in this empirical section is to first find support for the suggested mechanism through firms' financial risk exposure, before looking in the aggregate whether times of low volatilities predict financial crises. Thus I first investigate the firm level. The model predicts that when operating in a low volatility environment, firms will take on more financial risk and, in result, be more exposed to adverse credit shocks. To test this, is use a large panel of balance sheet and performance data of European firms and exploit the fact that the 2007-08 financial crisis constitutes a sizable and largely exogenous shock to firms across countries and industries. I observe how firms perform during and in the immediate aftermath of the financial crisis, and relate this performance to the volatilities that the they were exposed to in the years preceding the crisis shock. In accordance with model predictions, having experienced a more volatile environment before 2007 predicts a higher resilience to the financial shock, and thus a stronger performance during the crisis years. This results holds within country and industry. I further provide evidence that the relevant channel is firms' financial risk exposure at the onset of the crisis, which is shown to be decreasing in the preceding volatility.

How does this finding translate into an aggregate level? According to the model, countries with low volatility in the exogenous technology process will be less vulnerable to financial shocks. To test this, I turn to country level data in a second part. Using a long panel covering countries since 1970, I show that low volatility in estimated productivity positively predicts future financial crisis events. Additionally, and in line with theoretical predictions, low volatility in the years before a crisis is negatively correlated with various measures of a country's performance during a crisis.

2.4.1 Firm Level

I first investigate empirically the existence of a link between aggregate volatility in normal times and financial resilience at the firm level. I use the standard deviation of a firm's return on assets (RoA) in the years before the financial crisis[2] as a proxy for the volatility of a firm's operating environment. The RoA has the advantage of being effectively independent of financial leverage. I exploit the fact that the 2007-08 global financial crisis is a financial shock that is exogenous to an individual firm. The model presented in the previous chapter predicts that firms with a volatile RoA will choose to operate with a less risky financial structure. After a financial shock hits the economy, these firms will outperform comparable firms with lower pre-crisis volatility. Using a wide range of performance measures during the 2007-2009 financial crisis years, I show that this is indeed the case in the data. I further provide support for the suggested channel by demonstrating that firms with a volatile RoA operate with lower leverage and higher liquidity ratios. This holds both when using the 2007 levels as well as the 2004-2007 changes of leverage and liquidity ratios.

The source of firm level data is the Amadeus database. I use balance sheet information for over 500,000 firms from 44 European countries.[3] I examine the following five measures of firm performance during the financial crisis: the change in capital expenditures relative to total assets, the change in total assets, the change in value added, the change in employees, and the change in the return on assets. All changes refer to the period 2007–2009. Capital expenditures are computed as the change in the value of tangible fixed assets plus depreciation. To correct for a few extreme outliers, capital expenditure measures are winsorized at the 1% and 99% levels.

I use the pre-crisis standard deviation of a firm's return on assets as a proxy for volatility. This measure corresponds most closely to the volatility con-

[2]Data on RoA is only available from 2004 onwards, so the pre-crisis volatility covers the years 2004-2007.

[3]The countries covered include Albania, Austria, Bosnia and Herzegowina, Belgium, Bulgaria, Belarus, Switzerland, Cyprus, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, Great Britain, Greece, Croatia, Hungary, Ireland, Iceland, Italy, Kosovo, Liechtenstein, Lithuania, Luxembourg, Latvia, Monaco, Moldova, Montenegro, Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Sweden, Slovenia, Slovakia, Turkey, and the Ukraine. Incomplete data for some countries significantly reduces the number of firms included in the regression analysis.

sidered in the model, and has the advantage of being independent of a firms' financial leverage. The empirical specification takes the form

$$\begin{aligned}\Delta_{07-09}y_{i,j,c} =& c + \beta std(roa)_{i,j,c} + \gamma_1 \Delta_{05-07}y_{i,j,c} + \gamma_2 y^{2007}_{i,j,c} \\ &+ \delta x_{i,j,c} + r_j + s_c + \epsilon_{i,j,c} \qquad (2.23)\end{aligned}$$

where the coefficient of interest, β, shows how the standard deviation of a firm's return on assets in the pre-crisis years affects firm performance during the financial crisis. I always control for the change in the dependent variable before the crisis over the same number of years, as well as the level of the dependent variable in 2007. The vector x contains firm specific controls at the onset of the crisis, while r and s are industry and country fixed effects, respectively. All standard errors are clustered at the country level.

Tables 2.3 and 2.4 show regression results without and with industry fixed effects, respectively. Including industry fixed effects may be crucial, since different industries by there very nature should be differently affected by a financial shock. All regressions include country fixed effects. To control for firm pre-crisis profitability and size, all specifications control for the 2007 levels of the RoA and RoA growth from 2004–07, as well as 2007 levels of the logarithm of total assets, the logarithm of total employees, and external financial dependence as measured by the difference between fixed investment and cash flow, divided by fixed investment. The latter control ensures that we are not capturing differences in dependency on external credit, which could be correlated with the pre-crisis RoA, and of course plays a crucial role during a financial crisis with the associated shortage in credit. The second specification includes as additional controls the 2007 levels of leverage and liquidity ratios, measuring a firm's financial risk exposure.

As seen in the first column for each dependent variable of Table 2.3, and consistent with the model's prediction, a higher pre-crisis volatility is consistently and significantly correlated with a better performance during the crisis years. After the financial crisis hits the economy, firms with a larger standard deviation in the RoA experience larger growth (or smaller losses) in investment levels (as measured by the capital expenditures to assets ratio), in the value of total assets, in the total value added, the number of employees, as well as in the RoA. The second specification results show that this relationship continues to hold after controlling for the pre-crisis levels of leverage and the liquidity ratio. This indicates that RoA volatility affects financial resilience beyond what is captured by these relatively crude measures. As shown in Table 2.4, that these results hold when including industry fixed effects, with the exception of the effect on employment, which is now just outside the 90% confidence threshold.

The estimated effects are not only statistically significant, but also of economically relevant size. A one standard deviation increase in the pre-crisis volatility is estimated to lead to a 0.44 percentage point increase in investment, a 3.1% increase in total asset value, a 4.4% increase in employment, and a 0.59 percentage point increase in RoA during the financial crisis years. These results constitute strong evidence that firms which operated in a volatile environment were better prepared to deal with the challenges that came with the financial crisis shock, outperforming otherwise comparable firms across a wide range of measures.

Insight on the mechanism is provided by analyzing how RoA volatility affected 2007 levels of leverage and liquidity ratios. According to the predictions of the model, firms with a large standard deviation in the RoA should be less willing to take financial risk and should hence operate with lower levels of leverage and higher levels of liquidity. Table 2.5 reports results from regressions of both measures in 2007 on the 2004–2007 standard deviation of the RoA, both with and without controlling for the 2004 levels of the dependent variables. In the latter case, the effect of volatility on the change in the RoA is tested. All regressions include country and industry fixed effects and standard errors are clustered at the country level. The estimated sign corresponds to the predictions of the model in all regressions, though the results are only statistically significant for liquidity ratios.

Table 2.3. OLS regression output with country fixed effects

Dep. variable:	ΔInvestment		ΔTotal assets		ΔValue added		ΔEmployment		ΔRoA	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
StD of RoA (2004–2007)	0.0439*** (0.0158)	0.0406** (0.0169)	0.310*** (0.110)	0.324*** (0.115)	0.444* (0.223)	0.468** (0.224)	0.274* (0.137)	0.252* (0.133)	0.0592** (0.0264)	0.0558*** (0.0200)
Investment to assets	-0.677*** (0.0555)	-0.676*** (0.0568)								
External finance dependence	0.0000960 (0.0000809)	0.0000988 (0.0000799)	-0.00194*** (0.000553)	-0.00192*** (0.000554)	0.00333*** (0.000738)	0.00332*** (0.000731)	0.00102 (0.00111)	0.000987 (0.00106)	-0.000188 (0.000130)	-0.000182 (0.000134)
RoA	0.000306 (0.000292)	0.000317 (0.000300)	0.00289*** (0.000954)	0.00301*** (0.000977)	0.00246 (0.00176)	0.00184 (0.00108)	0.00315*** (0.00100)	0.00283** (0.00110)	-0.00498*** (0.000279)	-0.00492*** (0.000249)
Log Total assets	-0.188 (0.141)	-0.192 (0.143)	-2.022*** (0.522)	-2.027*** (0.527)	13.02*** (3.032)	12.40*** (2.712)	2.838* (1.393)	2.603* (1.388)	-0.278 (0.183)	-0.263 (0.173)
Log Employment	0.291* (0.148)	0.275* (0.150)	0.707* (0.403)	0.672 (0.396)	8.723*** (1.813)	8.368*** (1.659)	-8.652*** (1.941)	-8.419*** (1.976)	0.0894 (0.249)	0.0529 (0.244)
ΔRoA (2004–2007)	-0.00290 (0.0191)	-0.00571 (0.0200)	-0.152** (0.0670)	-0.176** (0.0687)	-0.384*** (0.120)	-0.407*** (0.125)	-0.166** (0.0697)	-0.163** (0.0712)	-0.0894*** (0.0107)	-0.0827*** (0.0133)
Leverage		0.000515 (0.000982)		0.00246 (0.00184)		-0.00526** (0.00215)		-0.00151* (0.000881)		-0.000365** (0.000138)
Liquidity ratio		0.0323 (0.0203)		-0.280** (0.133)		-0.0921 (0.489)		-0.00402 (0.464)		-0.108*** (0.0381)
Log Value added					-26.56*** (4.171)	-25.53*** (3.647)				
N	6202	6125	6243	6168	3983	3960	6427	6355	7175	7074
r2	0.466	0.470	0.0606	0.0640	0.122	0.118	0.0671	0.0643	0.341	0.336

Notes: Standard errors clustered at the country level are in parentheses. Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. The sample includes all firms from the Amadeus dataset for which sufficient data is available. All independent variables are measured in 2007, unless otherwise noted. All regressions include country fixed effects.

Table 2.4. OLS regression output with country and industry fixed effects

Dep. variable:	ΔInvestment		ΔTotal assets		ΔValue added		ΔEmployment		ΔRoA	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
StD of RoA	0.0337**	0.0296*	0.234**	0.245**	0.518**	0.536**	0.140	0.116	0.0683***	0.0620***
	(0.0143)	(0.0153)	(0.0984)	(0.102)	(0.233)	(0.235)	(0.161)	(0.142)	(0.0227)	(0.0184)
Investment to assets	-0.681***	-0.679***								
	(0.0509)	(0.0523)								
External finance dependence	0.000112	0.000111	-0.00181**	-0.00179**	0.00318***	0.00315***	0.000952	0.000931	-0.000255	-0.000245
	(0.000158)	(0.000155)	(0.000756)	(0.000753)	(0.000823)	(0.000817)	(0.00132)	(0.00128)	(0.000163)	(0.000169)
RoA	0.000301	0.000314	0.00253**	0.00266**	0.00220	0.00181**	0.00298***	0.00274**	-0.00516***	-0.00509***
	(0.000290)	(0.000299)	(0.00108)	(0.00112)	(0.00137)	(0.000859)	(0.000923)	(0.00102)	(0.000243)	(0.000237)
Log Total assets	-0.269**	-0.282**	-3.180***	-3.173***	12.82***	12.43***	5.778***	5.443**	-0.233	-0.203
	(0.125)	(0.125)	(0.531)	(0.523)	(2.848)	(2.610)	(2.018)	(2.072)	(0.193)	(0.173)
Log Employment	0.311*	0.304*	1.608***	1.549***	9.272***	8.959***	-12.07***	-11.71***	0.149	0.113
	(0.155)	(0.157)	(0.509)	(0.481)	(2.081)	(1.960)	(2.867)	(2.973)	(0.221)	(0.213)
ΔRoA (2004–2007)	-0.00418	-0.00643	-0.148**	-0.172**	-0.304**	-0.337***	-0.159**	-0.160**	-0.0818***	-0.0756***
	(0.0187)	(0.0198)	(0.0656)	(0.0678)	(0.114)	(0.112)	(0.0693)	(0.0694)	(0.0132)	(0.0147)
Leverage		0.000483		0.00228		-0.00621***		-0.000503		-0.000481***
		(0.000877)		(0.00205)		(0.00213)		(0.000477)		(0.000167)
Liquidity ratio		0.0402*		-0.275**		-0.150		-0.0359		-0.0981**
		(0.0202)		(0.130)		(0.503)		(0.456)		(0.0464)
Log Value added					-26.72***	-25.95***				
					(3.989)	(3.602)				
N	6182	6105	6220	6145	3970	3948	6402	6331	7147	7047
r2	0.514	0.519	0.128	0.132	0.241	0.233	0.131	0.128	0.394	0.389

Notes: Standard errors clustered at the country level are in parentheses. Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. The sample includes all firms from the Amadeus dataset for which sufficient data is available. All independent variables are measured in 2007, unless otherwise noted. All regressions include country and industry fixed effects.

Table 2.5. OLS regression output for leverage and liquidity ratios

Dep. variable:	Leverage 2007		Liquidity ratio 2007	
	[1]	[2]	[3]	[4]
StD of RoA	-0.363	-0.447	0.0370***	0.0314***
	(0.533)	(0.615)	(0.00699)	(0.00566)
Leverage 2004		0.189**		
		(0.0866)		
Liquidity ratio 2004				0.303***
				(0.0403)
N	13614	12856	192824	187189
r2	0.0170	0.0211	0.0420	0.140

Notes: Standard errors clustered at the country level are in parentheses. Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. The sample includes all firms from the Amadeus dataset for which sufficient data is available. All regressions include country and industry fixed effects.

2.4.2 Country Level

To investigate the suggested link between volatility in productivity and financial crisis outcomes on the country level, I make use of the Systemic Banking Crises Database compiled by Laeven and Valencia (2008, 2012). The database contains information on all financial crisis events during the period 1970–2011. I combine this data with series on multi-factor productivity from the OECD. The latter is the series believed to correspond most closely to the technology process in the model. I complement this data with series for output, gross fixed capital formation relative to output, total employment and unemployment rates from the OECD. The final dataset used for the analysis contains information for 20 OECD-member countries for the period 1985–2012.

As a measure for past volatility in the productivity process, I compute the standard deviation of multi-factor productivity over the past 5 years. I also control in all regressions for the mean and the change in productivity over the same time frame. I run regressions of the form

$$\begin{aligned} I_{c,t} =& \alpha_0 + \alpha_1 I_{c,t-1} + \beta_1 y_{c,t-1} + \beta_2 I_{c,t-1} * y_{c,t-1} + \gamma_1 s(a)_{c,t-1} \\ &+ \gamma_2 I_{c,t-1} * s(a)_{c,t-1} + \delta_1 m(a)_{c,t-1} + \delta_2 I_{c,t-1} * m(a)_{c,t-1} \\ &+ \delta_3 d(a)_{c,t-1} + \delta_4 I_{c,t-1} * d(a)_{c,t-1} + s_c + \tau_t + \epsilon_{c,t} \end{aligned} \tag{2.24}$$

where $I_{c,t}$ is an indicator variable equal to 1 if country c experiences a financial crisis event at time t. Log GDP per capita is denoted with y, while $s(a)$, $m(a)$ and $d(a)$ denote the standard deviation, mean and change, respectively of multi-factor productivity over the past five years. Finally, $s_c + \tau_t$ denote country and year fixed effects, respectively.

The coefficients of interest are γ_1, the effect of past volatility on the probability of entering a crisis state in normal times and γ_2, the same effect conditional on already being in a financial crisis, i.e. the probability of not exiting a crisis in a given year. Table 2.6 reports results for these two coefficients from estimating equation (2.24). Column 1 contains no fixed effects, while columns 2 and 3 add country and year fixed effects, respectively. All standard errors are clustered at the country level.

The first row shows estimates for the effect of past volatility on the probability of a crisis during normal time. In all specifications, the estimated coefficient is negative, as predicted by the theory. The estimates are also highly significant, though the coefficient becomes somewhat smaller once year fixed effects are included. This specification implies that a one standard deviation increase in past volatility reduces the probability of entering a financial crisis in the next period by about 2 percent. The estimated interaction coefficients are positive, but small and insignificant. This implies that past volatility also increases the likelihood of exiting from a crisis sooner, though this effect is somewhat smaller. These results indicate that low past volatility does indeed increase the probability of a financial crisis, as well as its duration.

Table 2.6. Crisis probability

Dep. variable:	Crisis Indicator		
	[1]	[2]	[3]
StD of productivity	-0.0461***	-0.0519***	-0.0311**
	(0.0113)	(0.0158)	(0.0143)
Lag Crisis*StD of productivity	0.0146	0.0156	0.0142
	(0.0245)	(0.0194)	(0.0243)
Controls	Yes	Yes	Yes
Country FE	No	Yes	Yes
Year FE	No	No	Yes
N	426	426	426
r2	0.737	0.747	0.839

Notes: Standard errors clustered at the country level in parentheses. Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. Dependent variable is a binary indicator for financial crisis event in year t. Independent variables are the standard deviation of TFP over the years $t-1$ to $t-5$ and its interaction with the lagged crisis indicator. Additional controls included are the mean and the growth of productivity over the years $t-1$ to $t-5$ and their interaction with the lagged crisis indicator, and the lagged indicator itself. The sample includes OECD-member countries for the period 1985–2012.

I next investigate the effect of past volatility on the performance of an economy during a financial crisis. The model predicts that countries that experienced relatively large volatility in productivity will be more resilient to a financial shock and perform better during a crisis. I measure the performance in crisis times with the two year growth rate in log GDP, investment, log total employment and the unemployment rate, and estimate equations of the form

$$\begin{aligned} x_{c,t+1} =& \alpha_0 + \alpha_1 x_{c,t-1} + \alpha_2 I_{c,t} + \beta_1 y_{c,t-1} + \beta_2 I_{c,t} * y_{c,t-1} + \gamma_1 s(a)_{c,t-1} \\ &+ \gamma_2 I_{c,t} * s(a)_{c,t-1} + \delta_1 m(a)_{c,t-1} + \delta_2 I_{c,t} * m(a)_{c,t-1} + \delta_3 d(a)_{c,t-1} \\ &+ \delta_4 I_{c,t} * d(a)_{c,t} + s_c + \tau_t + \epsilon_{c,t} \end{aligned} \tag{2.25}$$

where the coefficients of interest are again γ_1 and γ_2. The former represents the effect of past volatility of performance during normal times, which we expect to be zero. On the other hand, γ_2 corresponds to the effect on the economy's performance if a financial crisis occurs, so it is expected to be positive when the dependent variable is growth in GDP, investment or employment, and negative in the case of the unemployment rate. Again, all standard errors are clustered at the country level.

Table 2.7 reports estimation results for the two coefficients of interest for all dependent variables. As expected, and as shown in the first row, past volatility has almost zero effect on economic performance in the absence of a financial shock. Yet if the economy enters a financial crisis, economic outcomes depend positively and significantly on the volatility experienced during prior years. A one standard deviation increase in past volatility predicts a 2 percentage points larger GDP growth (or smaller losses) during a financial crisis. It also predicts a 5.5 percent higher investment to output ratio, 0.8 percent higher employment, and a 1 percentage point lower unemployment rate. All these results are statistically significant and economically relevant.

Table 2.7. Performance measures

Dep. variable:	Δ GDP	GFCF	Employment	Unemployment
	[1]	[2]	[3]	[4]
StD of productivity	0.000328	0.595	0.000228	0.000406
	(0.00277)	(0.987)	(0.00148)	(0.00262)
Crisis*StD of productivity	0.0312***	8.857**	0.0131**	-0.0169*
	(0.0102)	(3.332)	(0.00531)	(0.00868)
Controls	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	386	386	386	386
r2	0.767	0.652	0.978	0.915

Notes: Standard errors clustered at the country level in parentheses. Significance levels: *** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$. Dependent variables are all in year t. Independent variables are the standard deviation of TFP over the years $t-1$ to $t-5$ and its interaction with a binary indicator for a financial crisis in year t. Additional controls included are the mean and the growth of productivity over the years $t-1$ to $t-5$ and their interaction with the crisis indicator, the indicator itself, and the lagged dependent variable. The sample includes OECD-member countries for the period 1985–2012.

2.5 Conclusion

This paper constructs a general equilibrium model with endogenous liability structure to investigate the trade-off between short run stability and resilience to large adverse shocks. A reduction in the volatility of “small” shocks during normal times gives firms incentives to choose a higher risk exposure, in particular to operate with a larger leverage ratio. This increases the exposure of firms to large financial shocks that tighten a borrowing constraint, since they have already exhausted more of their debt capacity. Forced to adjust investment downwards, the economy enters a fire sales spiral with low investment depressing the value of collateral, which in turn reduces credit and investment. I provide empirical support for the stability-resilience trade-off. I show that firms that operate in a more stable environment prior to the 2007–08 financial crisis choose larger financial risk, and consequently suffer more during the crisis years. On the country level, periods of low volatility predict financial crisis events, as well as a poorer performance conditional on a crisis occurring.

This paper argues that a higher level of fluctuations can in fact be a good thing. This gives rise to the question of how we should think of a reduction in volatility in normal times. Here, I modeled volatility simply as a lower variance in the exogenous driving force of technology. While this is a convenient way of keeping the global solution tractable, it does not provide much insight about potential policy measures. A more policy-relevant source of increased stability in normal times are central banks. In fact, reduced fluctuations during the Great Moderation are often attributed to improvements in the conduct of monetary policy. We can thus think of the more stable environment in normal times as being the result of central bank policy, which stabilizes economic fluctuations in response to relatively small shocks. At the same time, monetary policy may face limitations in countering large adverse shock, as became obvious during the recent financial crisis. Such limitations can be modeled with the use of a zero lower bound on nominal interest rates, at which point central banks have to rely on unconventional monetary policy measure to influence demand. As the case analyzed in this paper, a reduction in the volatility of small shocks is thus not accompanied by a similar volatility reduction in rare large shocks. This puts into question whether short run stabilization in normal times is a desirable policy. While left out of this paper, the effects of stabilization policy in normal times on the occurrence and magnitude of crises is the topic of an ongoing parallel research project.

Chapter 3

TOO MUCH STABILITY? MACROECONOMIC VOLATILITY, MONETARY POLICY AND THE GREAT RECESSION

3.1 Introduction

Which countries suffered most and which fared relatively better during the Great Recession of 2008-09? The answer to this question is not only of historical interest, but is also crucial for drawing lessons for future crisis prevention. This paper takes a systematic look at the particularly high macroeconomic stability in the years before the crisis outbreak as an explanatory variable for the magnitude of the crisis. Starting from 1984, the Western world has experienced substantial declines in volatility of both inflation and output growth rates, a period now referred to as the Great Moderation. This reduction in fluctuations was accompanied by a rapid increase in private debt, resulting in large leverage rates, which are generally considered to have been socially excessive and, at least partially, responsible for the severe impact of the subsequent financial crisis. Improvements in the conduct of monetary policy are believed to have been a key factor in the reduction of volatility.[1] This paper connects the stabilizing effect of monetary policy during normal times to the financial crisis, thus raising concerns about the 'success' of such a policy.

In this paper, I provide ample evidence that countries who enjoyed greater macroeconomic stability during the years before the crisis, suffered from significantly larger downturns during the Great Recession of 2008-09, and experienced a slower recovery in the following years. This result is remarkably robust across different measures of pre-crisis volatility and of performance during the crisis. The literature so far has struggled to determine robust predictors of economic performance during the Great Recession. Several recent papers start from a large set of potential explanatory variables and attempt to identify measures with predictive power, but results are inconclusive and depend on the exact measure of economic performance and whether the sample contains only advanced economies or also includes development countries (Rose and Spiegel, 2010). Berkmen et al. (2012) find that countries with flexible exchange rates suffer less, while Acosta-González et al. (2012) conclude that the percentage of bank claims in the privae sector over deposits in the year 2006 is the only variable that has predictive power on the severity of the downturn. The role of initial level of development and openness to trade is highlighted in Lane and Milesi-Ferretti (2011) as well as in Blanchard et al. (2010) who focus on developing countries, yet in neither analysis does a clear picture emerge. Possible channels of contagion remain unclear. Neither Rose and Spiegel (2010) nor Kamin and Demarco (2010) find a significant influence of financial linkage with the US, leading Bacchetta and van Wincoop (2013) to suspect that a self-fulfilling global panic was triggered by the initial problems in the US financial sector. Due to the lack of any clear predictors, Rose and Spiegel (2011) conclude that *"While countries with higher income and looser credit market regulation seemed to suffer worse crises, we find few clear reliable indicators in the pre-crisis data of the incidence of the Great*

[1] Examples include Clarida et al. (2000), Coibion and Gorodnichenko (2011) and Summers (2005).

Recession".

My main measure for volatility is the absolute difference between predicted and actual GDP growth, aggregated over then ten years before the crisis, capturing the unpredictable component of output volatility. Given the difficulties documented in the literature, it is remarkable that such a broad measure proves to be robustly correlated with the country specific crisis experienced. Economic performance during the crisis is measured in several ways, such as changes in stock market indices, real growth and difference to pre-crisis predictions. I control for a large set of other potential explanatory variables, including the candidate variables identified by previous studies, yet none of them changes my findings in a significant way. Interestingly, in a regression that includes all variables mentioned above, pre-crisis volatility, level of development and the bank credit to GDP ratio are the only ones to significantly predict crisis outcomes.

Has monetary policy 'overstabilized' the economy and thus contributed to the large fallout of the financial crisis? Empirically, this question is difficult for answer, since the strength of a stabilizing policy is inherently difficult to measure. In this paper, I use the degree of central bank independence as a proxy for the stabilizing potential of monetary policy. There is wide consensus in the literature that the independence of the central bank is indeed a crucial component for its ability to use monetary policy as a stabilizing tool,[2] a view that is also confirmed by my data. I then show that central bank independence is negatively correlated with an economy's crisis performance. This result holds over a range of specification and data samples.

To rationalize the proposed relationship between volatility and resilience to financial shocks, I construct a three period model of endogenous financial risk taking. The model illustrates how low volatility in normal times can give agents incentives to take on more financial risk, which in the model manifests through increased leverage rates. As a consequence, the economy

[2]See Berger et al. (2001) for a survey.

is more fragile in response to rare financial shocks, which occur in the form of a reduction of the collateral value of assets. Firms struggle to roll over debt and are forced to liquidate assets, which can trigger a fire sales spiral that results in a severe recession with large losses in aggregate output. If this amplification mechanism is sufficiently strong, a reduction in the exogenous volatility during normal times can result in an increase of total volatility of output. Thus the model can generate the *'volatility paradox'* as described in Brunnermeier and Sannikov (2014), but in a much more stylized and tractable setting.

The amplification mechanism in this model relies on a feedback loop working through asset prices, which has become standard in macroeconomic modeling since the seminal papers of Bernanke and Gertler (1989), Kiyotaki and Moore (1997), and Bernanke et al. (1999). Shleifer and Vishny (1992) show how forced liquidation of assets can trigger fire sales in financial markets. This gives rise to a pecuniary externality which results in excessive credit, as first described in Lorenzoni (2008). This effect is exacerbated in my model by high stability in normal times. Gai et al. (2008) show in a related paper that financial innovation and phases of low volatility in productivity can spur financial risk taking, with financial crisis events becoming more severe. The literature has mainly focused on dealing with overborrowing through the means of macro-prudential regulation. Recent examples include Mendoza and Bianchi (2010), Dib (2010), Farhi and Tirole (2012) and Stein (2012). This paper takes the implicit view that macro-prudential policy is either not effective in controlling all relevant channels of risk-taking, or is difficult to implement.[3] The appeal of considering volatility in normal times as a mechanism to increase the resilience of an economy, is that it does not target specific channels of risk-taking, and hence its success does not rely on identifying all such channels, as well as all relevant agents. Instead, it works through limiting the attractiveness of risk taking per se. Another suggestion for adjustment in monetary policy during normal times, which has

[3] A recent empirical study that questions the efficacy of macro-prudential policies is Aiyar et al. (2012), who document substantial 'leakage' of regulation in capital requirements.

become more frequently mentioned after the financial crisis, is a policy of 'leaning against the wind', characterized by an increase in interest rates in response to a growth in credit or asset prices that is perceived as being excessive.[4] Indeed, a recent empirical literature finds that extended perods of low levels of real interest rates spur financial risk taking (see e.g. Dell'Ariccia and Marquez (2013), Maddaloni and Peydró (2011), and Dell'Ariccia et al. (2014)). Others have questioned the practicality of this approach, given the difficulties of identifying such excessive growth (Bernanke, 2002), and the theoretical foundations of 'leaning against the wind' policies (Galí, 2014).

I explicitly model monetary policy as a source of increased stability. A central bank can lower interest rates, facilitating rolling over of debt for distressed firms. A zero lower bound limits the extent to which the interest can counteract the effects of a severe shock. This allows me to focus on the role of monetary policy during normal times. An expansionary response during mild recessions reduces the tampering effect of such downturns on the appetite for financial risk. In response, entrepreneurs increase leverage, and the economy becomes more vulnerable to financial shocks. This emphasis on conventional monetary policy during normal times is in contrast with the existing literature, which has mainly focused on the adverse effects of unconventional policy measures in response to a crisis. Farhi and Tirole (2009) find that agents increase leverage when they expect a monetary policy intervention in the case of a crisis, while Diamond and Rajan (2012) reach a similar conclusion by focusing on monetary policy measures to prevent bank runs. The moral hazard created by fiscal policy intervention during a crisis is investigated by Gertler et al. (2012) as well as Chari and Kehoe (2013), who focus on bailout policies. A attractive feature of looking at policy during normal times is that the time inconsistency problem is less severe, since the costs of non-intervention are aggravated once an economy is in a crisis state.

This paper proceeds as follows: I start by presenting the model in section (3.2). The effects of a reduction in exogenous volatility are discussed in sec-

[4]See e.g. Lowe and Borio (2002) for an early advocacy of such an adjustment.

tion (3.3). In section (3.4) I present the empirical evidence and in section (3.5) I offer concluding remarks.

3.2 Model

In this section, I present a stylized three-period model that illustrates how stabilization in normal times can, through endogenous risk taking, contribute to worse crisis outcomes. It also shows how total volatility can increase in response, making it a simple example of the volatility paradox, as described in Brunnermeier and Sannikov (2014). The model builds on Farhi and Tirole (2009) and combines an endogenous capital structure with rare shocks to the collateral value of assets. Entrepreneurs leverage an initial endowment to invest in risky projects. In an intermediate period, short term debt is repaid using a first stream of revenue. In the bad state of the world, the intermediate revenue is reduced, and entrepreneurs may need to roll over part of the debt. This may not be possible in a credit crunch state, during which entrepreneurs have a lower borrowing capacity. When this is the case, capital can be liquidated and sold to a traditional sector, but an endogenous response of asset prices can trigger fire sales of capital, leading to substantial losses of output.

3.2.1 Entrepreneurs and optimal leverage

The economy exists for three periods $t = 0, 1, 2$. There is a unit mass of identical entrepreneurs who have access to a project, and a large set of identical consumers. All individuals, regardless of their type, have a utility function given by

$$U(.) = c_2$$

so that period 2 consumption is maximized. There is a storage technology with gross return 1. Entrepreneurs are endowed with E units of investment capital. At period $t = 0$, they leverage their endowment with short term, non-defaultable debt and invest $I = E/(1 - d)$ in the scalable project, so that dI is total debt owed.

In the beginning of period 1, the aggregate state of the world is revealed. The economy is either facing normal times, or finds itself in a rare credit crunch state. The economy avoids the crunch with probability α. During normal times, the aggregate state is good with probability β and bad with $1-\beta$. I will use superscripts G, B, and C for the good, bad, and crunch state, respectively. The return on the project in the intermediate period in state s is $F^s I$, with $F^G \geq F^B \geq F^C$. I will assume parameters such that $F^G > d$, so that in the good state there are always sufficient funds from the intermediate period return to repay all debt. The second period return is of size G per unit of invested capital, independently of the state of the economy. Of this return, only a share $\rho^B \leq G$ is pledgeable by the investor during normal times. In a crunch state, this fraction drops to $\rho^C < \rho^B$. This limits the capacity of entrepreneurs to issue new debt in the intermediate state, which makes clear why I refer to this state as the credit crunch.

In $t = 1$, the project can be downsized and invested capital can be sold to a traditional sector, which uses a concave production function $T(x)$. The price of capital is endogenously determined by $p = P(x) = T'(x)$, where x is the total capital used in the traditional sector. After downsizing and capital liquidation, the project continues at a fraction j of the initially invested capital. I will assume conditions that ensure that capital is only sold as a last resort to generate the funds needed to repay short term debt, which requires in particular that $G \geq p$ in all states. Finally I assume the existence of a storage technology, so that participation requires a gross return of at least one.

Denoting with F the expected intermediate return, given by $\alpha\beta F^G + \alpha(1-\beta)F^B + (1-\alpha)F^C$, the maximization problem of the entrepreneur can be written as

$$\max_{d,j^B,j^C}[F - d + \alpha\beta(G) + \alpha(1-\beta)(p^B(1-j^B) + j^B G) + (1-\alpha)(p^C(1-j^C) + j^C G)]I \tag{3.1}$$

subject to

$$0 \leq j^B \leq 1$$
$$0 \leq j^C \leq 1$$
$$\rho^B \geq d - F^B - p^B(1-j^B)$$
$$\rho^C \geq d - F^C - p^C(1-j^C)$$

I restrict parameters such that $G > p(x) > \rho^B > \rho^C$ for all relevant values of x, ensuring that additional funds can actually be generated by liquidating capital. In $t = 1$, the entrepreneur then only issues new debt if current returns are smaller than outstanding debt obligations, and only liquidates capital if the capacity to issue new debt is not sufficiently large either. Since the entrepreneur takes prices as given, we thus determine the optimal choice of capital liquidation and issuance of new debt in state $s \in B, C$, depending on initial debt and intermediate returns:

	j^s	d_2^s
$d - F^s \leq 0$	1	0
$0 < d - F^s \leq \rho^s$	1	$d - F^s$
$\rho^s < d - F^s$	$1 - \frac{d-F^s-\rho^s}{p^s}$	ρ^s

In period 0, the entrepreneur chooses debt issuance conditional on her optimal intermediate period actions. Notice that as long as $d \leq F^C + \rho^C$, no capital liquidation is ever necessary, and entrepreneurs thus load up on debt if $F + G \geq 1$. The capacity to roll over debt is exhausted in the crunch state once $d > F^C + \rho^C$, and the need to liquidate part of the project reduces incentives to increase leverage. As $d > F^B + \rho^B$, the same holds for the bad state, which further reduces the returns to each additional unit of debt. Since this problem is linear in debt, it is convenient to define the thresholds that determine the optimal level of debt:

$$S^0 = F + G$$
$$S^1 = F + G - (1-\alpha)\left(\frac{G}{p^C} - 1\right)\left(1 - F^C - \rho^C\right)$$
$$S^2 = F + G - \alpha(1-\beta)\left(\frac{G}{p^B} - 1\right)\left(1 - F^B - \rho^B\right) - (1-\alpha)\left(\frac{G}{p^C} - 1\right)\left(1 - F^C - \rho^C\right)$$

where $S^0 \geq S^1 \geq S^2$. From the maximization problem (3.1), it is then straightforward to derive the resulting optimal $t = 0$ schedule of debt issuance

$$d^* = \begin{cases} 0 & \text{if } S^0 < 1 \\ \in [0, F^C + \rho^C] & \text{if } S^0 = 1 \\ F^C + \rho^C & \text{if } S^0 > 1 \text{ and } S^1 < 1 \\ \in [F^C + \rho^C, F^B + \rho^B] & \text{if } S^1 = 1 \\ F^B + \rho^B & \text{if } S^1 > 1 \text{ and } S^2 < 1 \\ \in [F^B + \rho^B, F^C + p^C] & \text{if } S^2 = 1 \\ F^C + p^C & \text{if } S^2 > 1 \end{cases}$$

where $p^C + F^C$ is the maximum debt capacity of the entrepreneur, and I assume that $p^C + F^C > F^B + \rho^B$.

3.2.2 Equilibrium

While individual entrepreneurs take the price of capital as given, in equilibrium the price in the intermediate period depends on the total supply of capital through liquidation, which in turn depends on the average level of initial debt. In any state s with non-zero liquidation, the price of capital solves

$$p^s = P(I(1 - j^s))$$

with

$$j^B = min\left\{1, 1 - \frac{d - F^B - \rho^B}{p^B}\right\}$$

$$j^C = min\left\{1, 1 - \frac{d - F^C - \rho^C}{p^C}\right\}$$

With endogenous prices, threshold levels $S^1(d)$ and $S^2(d)$ now depend on d, and both thresholds are decreasing in the debt level. In what follows, I will always assume that the participation condition is satisfied, *i.e.* $S^0 > 1$. Combining the optimal debt schedule of the individual entrepreneur with the definition of the price, we can then characterize equilibrium debt by

$$d^* = \begin{cases} \rho^C + F^C & \text{if } S^1\big(\rho^C + F^C\big) < 1 \\ d_1 & \text{if } S^1\big(\rho^C + F^C\big) > 1 \text{ and } S^1\big(\rho^B + F^B\big) < 1 \\ \rho^B + F^B & \text{if } S^1\big(\rho^B + F^B\big) > 1 \text{ and } S^2\big(\rho^B + F^B\big) < 1 \\ d_2 & \text{if } S^2\big(\rho^B + F^B\big) > 1 \text{ and } S^2\big(\bar{d}\big) < 1 \\ p^C + F^C & \text{if } S^2\big(p^C + F^C\big) > 1 \end{cases}$$

where $d_1 \in [\rho^C + F^C, \rho^B + F^B]$, is determined by $S^1(d_1) = 1$, and equivalently, $d_2 \in [\rho^B + F^B, p^C + F^C]$, determined by $S^2(d_2) = 1$.

Given the assumption of $S^0 > 1$, entrepreneurs always take on debt at least to the point that the capacity to roll over debt in the crunch state is exactly exhausted, *i.e.* $d \geq \rho^C + F^C$. If, at this level of debt, S^1 is less than one, we know that we have reached an equilibrium. If this is not the case, entrepreneurs increase debt, driving down the value of S^1, until the latter reaches one, and we either have an equilibrium, or d reaches $\rho^B + F^B$. In the second case, any further increase in leverage will trigger capital liquidation in the bad state as well, and so S^2 becomes the relevant threshold.

Entrepreneurs increase debt as long as $S^2 < 1$, or until they reach their maximum debt capacity.

3.3 Reduction of exogenous volatility

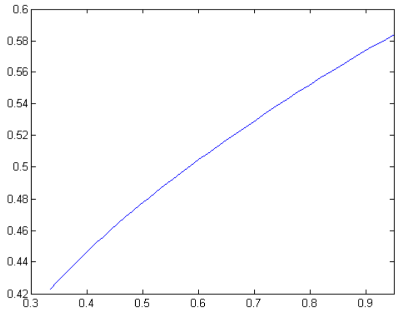
In this section, I investigate how a reduction in exogenous volatility affects the severity of crisis events and the overall volatility of the economy, through its effect on financial risk taking. In particular, starting from a situation with $F^A > F^B > F^C$, I will consider a reduction in the difference between F^A and F^B, leaving both F^C and F unchanged. This corresponds to a mean-preserving reduction of exogenous volatility during normal times, that does not affect any exogenous shocks that may create a credit crunch.

How does this reduction affect the optimal choice of leverage? If leverage at the initial point (with large volatility) is very low, changes in F^A and F^B will not affect optimal debt choice, since the latter is determined by the constraints in the crunch state. In particular, as long as $S^1\left(\rho^B + F^B\right) < 1$, this exercise will not result in any changes to optimal leverage. Similarly, economies with very high incentives to load on leverage will remain unaffected. If $S^2\left(p^C + F^C\right) > 1$, an increase in F^B will not change optimal debt, since firms are already using up all of their debt capacity. In the remainder of this paper, I will focus on the more interesting intermediate case. In particular, I will consider cases in the range where if $S^2\left(\rho^B + F^B\right) > 1$ and $S^2\left(\bar{d}\right) < 1$, such that the equilibrium debt levels are determined by the solution to $S^2(d_2) = 1$.

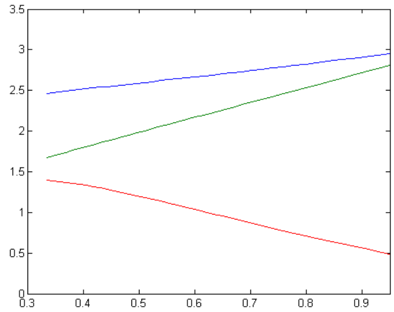
For the rest of this paper, I will assume that $\beta = 0.5$, so that within normal times, the good and the bad state are equally likely. I will also define a parameter $f \geq 0$ so that we can write $F^A = F^N + f$ and $F^B = F^N - f$. The expected intermediate period revenue during normal times is then given by F^N, and the difference between good and bad times by $2f$. The exercise of reducing exogenous volatility during normal times then corresponds to a reduction in the value of f. In the region of interest and given the definition of S^2, the fact that $S^2(d^*) = 1$ implies that

$$\frac{\partial d^*}{\partial f} = \frac{\alpha(1-\beta)\left(\frac{G}{p^B}-1\right)}{\alpha(1-\beta)\frac{G}{{p^B}^2}\frac{\partial p^B}{\partial d}(1-(F^N-f)-\rho^B)+(1-\alpha)\frac{G}{{p^C}^2}\frac{\partial p^C}{\partial d}(1-F^C-\rho^C)} < 0$$

where the last inequality comes from $\partial p^B/\partial d < 0$ and $\partial p^C/\partial d < 0$. Thus, in response to the increased stability of the exogenous process, and hence the limited disciplining strength of bad times, entrepreneurs increase their financial risk by taking on a higher leverage. As can be seen in the left panel of Figure 3.1, debt levels steadily increase as the ratio of F^A/F^B moves towards one or, equivalently, as f moves towards zero.[5]



(a) Debt



(b) Output

Figure 3.1. Response of debt (left panel) and output (right panel) to a reduction in exogenous volatility. In the right panel, the lines represent state A (blue), state B (green), and state C (red), respectively. The x-axis indicates the ratio of F^A to F^B.

The reduced external volatility affects output along several channels. Its obvious direct effect is to increase output in the bad state and reduce it in the good state, working as a stabilizer during normal times. On top of this, it increases output in all states through larger investment, something that is possible due to increased stability allowing for higher leverage. But

[5]In all that follows, I assume that states A and B are equally likely, and that state C occurs with a probability of 2.5%, which in a quarterly interpretation of a period corresponds to one crunch shock every ten years. The second period return is equal to the expected first period return in normal times, *i.e.* $G = F^N$. I assume limited pledgeability and set $\rho^B = 0.5$ and $\rho^C = 0.1$

there is a third effect that has an adverse impact on output during a crunch state: with insufficient capacities to roll over all debt, increased leverage requires entrepreneurs to liquidate a larger share of their project in the crunch state, thus depressing asset prices and aggregate output. The resulting state-specific aggregate output is shown in the right panel of Figure 3.1. As F^A and F^B become more equal, output in the bad state increases rapidly, catching up with the good state and reducing the output volatility in normal times significantly. But since entrepreneurs take on more and more financial risk in response, the effects of a crunch shock become increasingly devastating to the economy. As normal times become increasingly stable, the rare crunch state becomes progressively worse.

Interestingly, the reduction in exogenous volatility also has an ambiguous effect on the total output volatility of the economy. The green line in Figure 3.2 depicts the coefficient of variation of aggregate output across the good and the bad state, as a function of F^A/F^B. Naturally, the reduction in exogenous volatility leads to a reduction in the volatility during normal times, and the coefficient of variation drops rapidly as f approaches zero.

The blue line however shows a different picture for volatility across all states. Initially reducing the coefficient of variation, a reduction of exogenous volatility has the effect of increasing the overall output volatility of the economy as one moves further to the left. This is due to the endogenous response of entrepreneurs, who increase their financial risk exposure, and the amplifying effects of asset prices during a crunch state. This result is very similar to the volatility paradox described in Brunnermeier and Sannikov (2014). Note that at already relatively low levels of stability, with technology in the bad state being just somewhat above 60% of the good state, any further increase in exogenous stability leads to an amplification of total volatility of output.

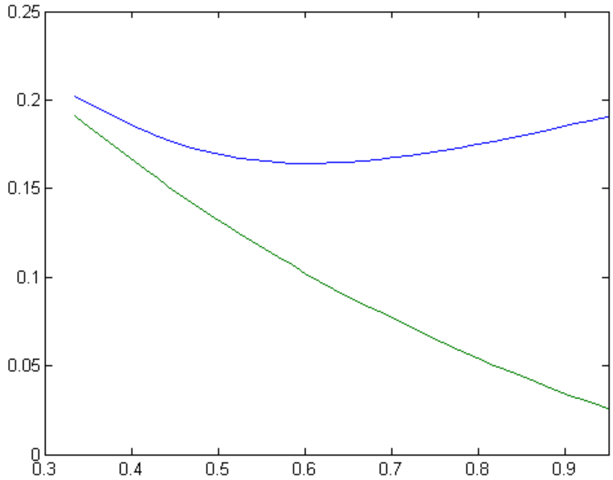


Figure 3.2. Coefficient of variation of total output across states in normal times (green line) or all states (blue line). The x-axis indicates the ratio of F^A to F^B.

3.3.1 Stabilization policy by a central bank

The previous section discussed the possibly detrimental effects of a reduction of exogenous volatility, yet it remains unclear what the source of such a change should be. This seems unsatisfying, in particular since the reduced aggregate volatility during the Great Moderation is typically seen not as a result of chance, but of specific policies, in particular of improvements in the conduct of monetary policy. In this section, I will discuss how a stabilization policy by a central bank that reduces volatility during normal times can lead to worse crisis outcomes and increased overall uncertainty.

To introduce monetary policy in this model, I assume that the government issues a bond in the intermediate period, which yields a gross interest rate R^s in period 2. To keep things simple, I specify that the government redistributes the revenue from bond issuance lump sum to households, and that later repayment of bonds is in turn financed through a lump sum tax. I consider interest rates that satisfy $G > R^s$, so that continuing the project is strictly preferred to buying the bond. I also assume that households have access to a storage technology, providing a zero lower bound for the interest rate at $R^s = 1$. The interest rate determines the borrowing capacity of entrepreneurs in the intermediate period, which for a state s is now given by ρ^s/R^s. An expansionary monetary policy, in the form of lower rates, expands the borrowing capacity of entrepreneurs and can thus limit the amount of liquidation needed to refinance debt. Therefore, the interest rate can be used to stabilize output after an adverse shock.

In the same spirit as the previous exercise, I assume that the central bank always lowers interest rates in the crunch state as much as possible, *i.e.* until the rate hits the zero lower bound. So $R^c = 1$ and for simplicity I will refer to the interest rate in the bad state as R, dropping the superscript.[6] Given this interest rate policy, the threshold level S^2 then becomes

$$S^2 = F + G - \alpha(1-\beta)\left(\frac{G}{p^B} - 1\right)\left(1 - F^B - \frac{\rho^B}{R}\right) - (1-\alpha)\left(\frac{G}{p^C} - 1\right)\left(1 - F^C - \rho^C\right)$$

In the bad state, the central bank can limit downward pressure by lowering the interest rate, thus reducing the difference between the good and the bad state. However, if the central bank adopts such a stabilizing policy, the expectation of an accommodating response to a bad shock limits the moderating effect such a shock has on financial risk taking. In response, entrepreneurs increase optimal leverage, as in

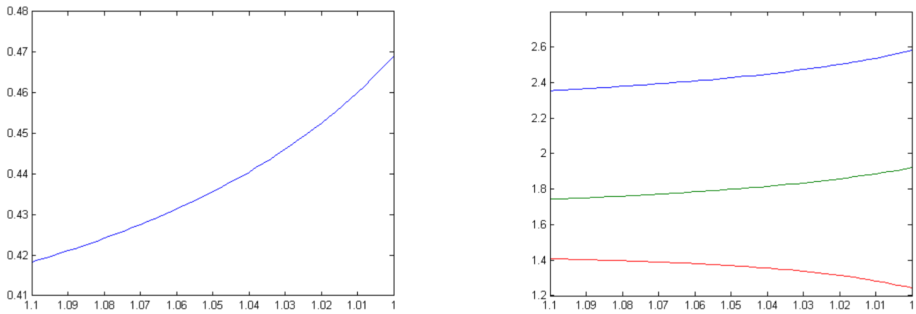
$$\frac{\partial d^*}{\partial R} = \frac{\alpha(1-\beta)\left(\frac{G}{p^B}-1\right)\frac{rho^B}{R^2}}{\alpha(1-\beta)\frac{G}{{p^B}^2}\frac{\partial p^B}{\partial d}(1-(F^N-f)-\rho^B)+(1-\alpha)\frac{G}{{p^C}^2}\frac{\partial p^C}{\partial d}(1-F^C-\rho^C)} < 0$$

where the inequality again follows from $\partial p^B/\partial d < 0$ and $\partial p^C/\partial d < 0$. The response of d to a reduction of the interest rate from 10% to 0% is shown in the left panel of Figure 3.3, where I always assume that the respective interest rate is correctly anticipated by the agents. It follows that the stabilization policy has a positive effect on output through increased investment across

[6]Since no debt needs to be rolled over in the good state, the corresponding interest rate does not have any impact on the outcome.

all possible states. In state A, this directly translates into higher output, as can be seen by the upward sloping blue line in the right panel of Figure 3.3. In state B, the policy has the additional effect of limiting the need of asset liquidation, yet this is almost completely offset by the endogenous increase in leverage. Overall, output in the bad state increases only slightly more than when compared to the good state, as shown by the green line in Figure 3.3. It is, however, important to keep in mind that for given debt levels, a higher interest rate would substantially increase the difference between the two states.

The increased risk exposure leads to an economy that is more vulnerable to the crunch shock. The red line in Figure 3.3 shows how output in state C declines with the level of the interest rate. A more aggressive stabilization policy results in more asset liquidation and thus a steeper drop of output during a crisis. And, as can be seen in Figure 3.4, this translates into a higher volatility across states. While the stabilization policy succeeds in reducing the coefficient of volatility during normal times, the amplification of financial risk in the crunch state is sufficiently strong to overturn this result when all possible states are considered. In sum, this central bank policy leads to worse crisis events and to an increase in output volatility overall.



(a) Debt (b) Output

Figure 3.3. Response of debt (left panel) and output (right panel) to a reduction in the interest rate. In the right panel, the lines represent state A (blue), state B (green), and state C (red), respectively. The x-axis indicates the gross rate R in state B.

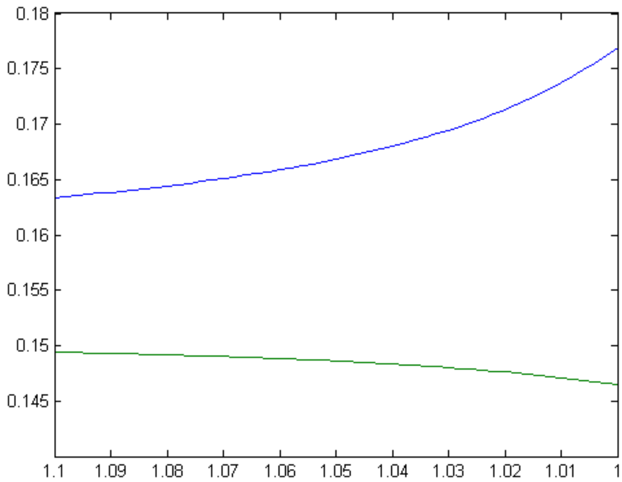


Figure 3.4. Coefficient of variation of total output across states in normal times (green line) or all states (blue line). The x-axis indicates the gross interest rate R in state B.

3.4 Empirical evidence

In this section, I systematically investigate if periods of low volatility tend to leave countries more vulnerable to financial shocks, and if central bank policy plays a role in this. In particular, I use the financial crisis of 2008-09 as a global financial shock, and test which pre-crisis characteristics predict country level economic performance during and after the crisis years. The main focus is on how volatility in real GDP growth up to 2007 correlates with the severity of the subsequent crisis.

To capture the unpredictable component in fluctuations of GDP, my main measure of volatility is the absolute difference between actual real growth and the forecast of the IMF World Economic Outlook from the fall of the previous year, aggregated over the years 1998-2007.[7] Formally, it is given by

$$E_{2007} = \sum_{t=1998}^{2007} |y_t - y^e_{t-1,t}|$$

I will refer to this measure of volatility simply as “error”. Real GDP growth and forecasts are from the IMF World Economic Outlook Database. My preferred measure for economic performance during the crisis is the change in the main stock market index from end of 2007 to end of 2009. Data on stock market performance is taken from Rose and Spiegel (2011). In all of the analysis that follows, I always control for real GDP per capita and real GDP growth, both from 2007, to capture pre-crisis differences in development and growth rates. To keep countries comparable, I restrict the sample initially to advanced economies as defined by the IMF, but I later extend the analysis to the whole sample.

Figure 3.5 plots the relationship between the stock market performance during crisis years and the error measure. The graph shows a clear positive relationship between the two. The slope of the regression line is estimated to be 0.914, statistically significant at the 99% level of confidence. The coefficient indicates that one standard deviation increase in pre-crisis volatility corresponds to an improvement in stock market performance by 9.5 percentage points.[8] Iceland seems to be an outlier, as it experiences the largest drop in the stock market despite relatively modest pre-crisis volatility.

Regression outputs are shown in Table 3.1, with the specification in Column 1 corresponding to the scatter plot. To strengthen the case for a causal relationship, I subsequently add controls that have been identified by the literature as possible explanatory variables for crisis performance.[9] To control for market size effects, I first include the log GDP of 2006, which is itself highly significant but only strengthens the coefficient of interest. The ex-

[7] All results are robust to using the forecast from the spring of the previous year as well as the spring of the current year.

[8] On average, stock markets dropped by 35% during this time frame.

[9] Control variables are from Rose and Spiegel (2011).

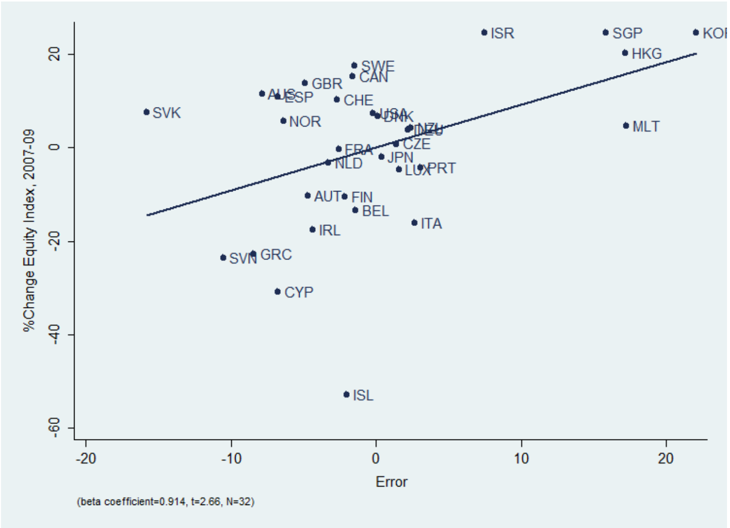


Figure 3.5. Scatter plot of stock market performance (2007-2009) on error (2007) after controlling for GDP per capita and annual growth (both 2007)

planatory power of trade relations with the US is discussed in Lane and Milesi-Ferretti (2011) and Blanchard et al. (2010), while Berkmen et al. (2012) find that flexible exchange rate regimes have predictive power for the severity of the crisis. Both trade related variables are included in Column 3. They are imprecisely estimated and do not affect the main finding. Acosta-González et al. (2012) suggest bank claims over deposits as a predictor, which is added in Column 4 together with bank credit over GDP. While the latter is negatively associated with crisis performance, the coefficient on volatility becomes somewhat smaller, yet remains highly significant. More liberal credit market regulations have been found to predict a worse crisis outcome by Giannone et al. (2010) and Rose and Spiegel (2011). I include the 2006 EFW credit market regulation index[10], where a higher value indicates more liberal regulation. The index has an insignificant and, surprisingly, positive effect on crisis performance. Column 5 also accounts for the percentage increase in housing prices from 2000-06, since this is often considered to have been at the center of the crisis, yet its estimated effect is essentially zero. Despite a small loss in precision, pre-crisis volatility remains a positive predictor of

[10]See Gwartney et al. (2006).

crisis performance, significant at the 95% confidence level.

Table 3.1. Baseline results

Dep. variable:	%Change Equity Index, 2007-2009				
	[1]	[2]	[3]	[4]	[5]
Error	0.914***	0.995***	0.944***	0.795***	0.780**
	(0.295)	(0.231)	(0.252)	(0.236)	(0.299)
Real ΔGDP 2007	-4.615**	-2.188	-2.862	-4.447**	-3.884*
	(2.140)	(1.658)	(1.747)	(1.882)	(1.917)
Log GDP p.c.	-4.689	-9.057	-7.052	-2.021	-6.442
	(8.051)	(7.752)	(8.479)	(6.513)	(12.64)
Log GDP		5.823***	5.263*	3.552*	5.160**
		(2.018)	(3.042)	(1.725)	(2.234)
Trade w USA/Total Trade			0.0478	0.173	0.153
			(0.124)	(0.105)	(0.194)
Fixed Exchange Rate			-9.655	-10.84*	-10.34
			(6.656)	(5.747)	(6.898)
2006 Bank Claims / Deposits				-3.500	-3.850
				(5.842)	(8.024)
2006 Dom Bank Credit / GDP				-0.0991*	-0.0927*
				(0.0488)	(0.0517)
2006 Credit Mkt Regns					2.859
					(5.923)
Rl Housing Price App'n '00-'06					0.0513
					(0.134)
Constant	18.49	-101.4	-98.79	-78.93	-106.3
	(83.35)	(70.09)	(78.35)	(58.10)	(115.4)
N	32	32	31	29	27
r2	0.230	0.443	0.517	0.628	0.664

Notes: Robust standard errors in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Since it is difficult to measure the degree of exogenous volatility in an economy, it is important to check that these results are robust to using different measurements. So far I have used the error of the WEO forecast. This is an appealing measure because it captures the surprise component in GDP growth, which should be the relevant volatility in a risk taking decision. On the other hand, a larger error could also simply mean that the WEO forecasting model is less elaborate for a specific country. I use two different volatility measures as a robustness check. The first is the innovation of a country-specific AR(1), with its absolute value summed up over the years 1998-2007. This measure ensures that the forecasting models for each country have an identical degree of sophistication. The second is simply the standard deviation of GDP growth over the same time frame.

Table 3.2 presents the estimated coefficient for all three measures. All regressions used the full set of controls, equal to the specification of Column 6 in Table 3.1, for different measures of pre-crisis volatility. For simplicity, only the coefficient of interest is reported in the table. The results are remarkably robust to the volatility measure used. The coefficient remains significant and stable in terms of magnitude. A one standard deviation in pre-crisis volatility improves performance during the crisis by 8.4 percentage points if measured with the WEO error, by 8.0 in case of the AR(1) innovation, and by 6.8 percentage points when using the standard deviation of growth.

Table 3.2. Robustness: Alternative measures of volatility

Dep. variable:	%Change Equity Index, 2007-2009		
	[1]	[2]	[3]
Error	0.780**		
	(0.299)		
AR(1) Residual		1.031***	
		(0.303)	
SD of Real ΔGDP			6.912**
			(2.410)
N	27	27	27
r2	0.664	0.683	0.662

Notes: Robust standard errors in parentheses. Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. All regressions control for pre-crisis GDP growth, GDP per capital, log GDP, trade with USA over total trade, fixed exchange rate dummy, bank claims in private sector over total deposits, domestic bank credit over GDP, credit market regulation, and housing price appreciation from 2000-06.

The stock market performance is an appealing measure for the impact of the crisis, since it does not only take into account immediate losses, but also changes the long term economic outlook. To see this in more detail, I also consider a set of alternative performance measures as dependent variables. In particular, I estimate the impact of volatility on actual GDP growth from the end of 2007 to the end of 2009, 2010 and 2011, respectively. As an additional outcome, I use the difference of GDP growth rates over the same time frame to its predicted values, taken from the World Economic Outlook of fall 2007. The estimated coefficients on volatility, using again WEO error as measure and the specification with full controls, are reported in Table 3.3.

Interestingly, the increased resilience of volatile economies seems to manifest mainly in the long run, as a faster recovery from the immediate crisis impact. Over the 2007-2009 time frame, the coefficients on growth and difference to forecast are positive, but small and insignificant. As this time frame is extended, both coefficients become large and highly significant. The coefficients for 2007-2011 suggest that a country with a one standard deviation higher pre-crisis volatility has 3.1% higher accumulated growth, and outperforms by 2.5% relative to WEO forecast.

Table 3.3. Robustness: Alternative outcomes

Dep. Var:	%Change Eq. Index 2007-09	ΔGDP 2007-09	ΔGDP 2007-10	ΔGDP 2007-11	Diff. IMF 2007-09	Diff. IMF 2007-10	Diff. IMF 2007-11
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Error	0.780**	0.0864	0.263***	0.349***	0.0361	0.162**	0.189*
	(0.299)	(0.0845)	(0.0841)	(0.103)	(0.0726)	(0.0650)	(0.0924)
N	27	27	27	27	27	27	27
r2	0.664	0.438	0.688	0.690	0.359	0.643	0.607

Notes: Robust standard errors in parentheses. Significance levels: *** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$. All regressions control for pre-crisis GDP growth, GDP per capital, log GDP, trade with USA over total trade, fixed exchange rate dummy, bank claims in private sector over total deposits, domestic bank credit over GDP, credit market regulation, and housing price appreciation from 2000-06.

The sample was so far restricted to countries labeled by the IMF as advanced economies. Table 3.4 reports results when extending the sample to all countries for which data is available. Column 1 shows that in a regression which includes only 2007 GDP growth and GDP per capita as controls, pre-crisis volatility continues to positively predict crisis performance in this more diverse set of countries. When estimating the full specification, data limitations restrict the sample substantially, as can be seen in Column 2. Nevertheless, the estimated coefficient remains large and loses only little in terms of significance. The estimated effect on GDP growth, both actual and relative to the WEO forecast, is positive and of similar size compared to the original sample, but only significant at the 90% level of confidence. Both alternative measures of volatility strongly predict performance, with comparable magnitudes and significance as in the sample of advanced economies.

Table 3.4. Robustness: Alternative sample

Dep. Var.	%Change Eq. Index, 2007-09		ΔGDP 2007-11	Diff. IMF 2007-11	%Change Eq. Index 2007-09	
	[1]	[2]	[3]	[4]	[5]	[6]
Error	0.597**	0.599*	0.290**	0.235*		
	(0.290)	(0.344)	(0.120)	(0.132)		
AR(1) Residual					0.734*	
					(0.397)	
SD of Real ΔGDP						6.682**
						(2.914)
N	83	41	41	41	41	41
r2	0.241	0.453	0.555	0.505	0.456	0.487

Notes: Robust standard errors in parentheses. Significance levels: *** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$. The regression in the first column controls for pre-crisis GDP growth and GDP per capital. All other regressions additionally control for pre-crisis log GDP, trade with USA over total trade, fixed exchange rate dummy, bank claims in private sector over total deposits, domestic bank credit over GDP, credit market regulation, and housing price appreciation from 2000-06.

3.4.1 The role of monetary policy

Pre-crisis volatility is a robust predictor of economic performance during the crisis. What remains unclear is whether central banks have played a role in decreasing volatility through their conduct of monetary policy. In this section I provide some insight into this question. The strength of any 'stabilization policy' is difficult to measure, since any such policy should respond endogenously to actual and expected fluctuations of exogenous shocks. My strategy is to use the degree of independence of a central bank as a proxy for the capacity of a policy maker to act as a stabilizing force. Central bank independence is generally believed to be a crucial component for the effectiveness of a stabilizing monetary policy.[11] My data confirms this view, exhibiting a strong negative correlation between central bank independence and pre-crisis volatility.

To measure central bank independence, I use an index created by Crowe and Meade (2007), which aggregates ratings for the year 2003 along the components of appointments of governors, policy formulation, policy objectives, and limits to central bank lending to government. I use regression equations identical to the ones in the previous section, but with central bank independence replacing volatility as the independent variable of interest. Table 3.5 reports the estimated coefficients from a simple specification, which uses only the 2007 value of GDP growth and GDP per capita as controls, as well as from the full specification used in the previous section. Columns 1 and 2 restrict the sample to advanced economies, while Columns 3 and 4 make use of the whole sample.

In the simple specification, central bank independence appears to have a strong and highly significant detrimental effect on crisis performance, independent of the sample considered. Including the additional controls reduces the size of the effect, but the coefficients remain significant at the 90% level. The point estimates are relatively large, indicating that a one standard deviation increase in central bank independence worsens stock market performance during the crisis by 6.9 percentage points in the restricted sample and by 6.0 percentage points otherwise.

[11] See *e.g.* Arnone et al. (2009), Bernanke (2010), Berger et al. (2001) and Cukierman (2008).

Table 3.5. Central Bank independence

Dep. variable:	%Change Equity Index, 2007-2009			
	[1]	[2]	[3]	[4]
CBI	-40.83***	-29.26*	-28.99***	-25.48*
	(9.480)	(13.77)	(9.841)	(13.61)
N	30	25	70	38
r2	0.384	0.715	0.208	0.451
Sample	Advanced	Advanced	All	All
Spec.	Simple	Full	Simple	Full

Notes: Robust standard errors in parentheses. Significance levels: *** p< 0.01, ** p< 0.05, * p< 0.1. The simple specification controls for pre-crisis GDP growth and GDP per capital. The full specification additionally controls for pre-crisis log GDP, trade with USA over total trade, fixed exchange rate dummy, bank claims in private sector over total deposits, domestic bank credit over GDP, credit market regulation, and housing price appreciation from 2000-06.

3.5 Conclusion

This paper has provided ample evidence that volatility has significant predictive power for the performance of an economy during the financial crisis. In the theoretical framework, I provided a causal interpretation for this observed correlation: high levels of stability during normal times lead to a build-up of financial risk, which makes the economy less resilient in response to large adverse shocks. This logic implies that by allowing for stronger aggregate fluctuations during the pre-crisis years, a central bank could have limited the downturn experienced during the Great Recession.

Yet to what degree do the empirical findings lend credit to the idea that stability caused the magnitude of the crisis? In my view, the biggest thread to a causal identification are factors that determine both the volatility of an economy during 'normal times', as well as the vulnerability to financial shocks. I try to alleviate this concern by controlling for several such potential factors. The robustness of the estimated coefficient with respect to the inclusion of control variables indicate that neither trade, the size of the financial sector, housing prices, the structural composition of the economy or the exchange rate regime challenge a causal interpretation of the effect of stability on crisis performance.[12]

The claim of this paper is not that a stabilizing policy is necessarily counterproductive, nor that a phase with low volatility is always unwelcome. Yet the results indicate that it is mainly in the more tranquil times when financial risk accumulated, and when thus heightened attention is warranted. Systemic risk can grow but remain out of our sight absent periodic adverse shocks, which would serve to uncover such risk exposure. If we do not feel sufficiently certain about the ability of financial regulation to detect or prevent such a build-up of risk, then some degree of volatility in normal times may indeed be helpful to avoid a future crisis event.

[12]In addition to the results presented in this paper, I further found that the inclusion of none of the following variables significantly affects the coefficient of stability: trade to GDP, relative size of the financial sector, shares of manufacturing and services, membership of a monetary union.

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