

Credit Risk Transfer and the Macroeconomy*

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Abstract

The recent financial crisis highlighted the limits of the "originate to distribute" model of banking, but its nexus with the macroeconomy remains unexplored. I build a business cycle model with banks engaging in credit risk transfer (CRT) under informational externalities. Markets for CRT provide liquidity insurance to banks, but the emergence of a pooling equilibrium can also impair the banks' monitoring incentives. In normal times and in face of standard macro shocks the insurance benefits of CRT prevail and the business cycle is stabilized. In face of financial/liquidity shocks the extent of informational asymmetries is larger and the business cycle is amplified. The macro model with CRT can also reproduce well a number of macro and banking statistics over the period of rapid growth of this banks' business model.

Keywords: credit risk transfer, informational externalities, capital re-cycling.

JEL classification: E3, E5, G3 .

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1 Introduction

The 2007-2009 crisis has shown that banking and financial structures can at times interact with macroeconomic conditions and policies in ways that generate significant – even disruptive – systemic instability. In recent discussions two sources of risk have been identified: a prolonged expansionary monetary policy¹ and a banking sector that relies heavily on credit risk transfer². Prior to the crisis securitization and credit risk-transfer techniques expanded at an unprecedented scale (see data in section 2.1 and appendix). In normal times this business model, by providing insurance and liquidity, guaranteed a smooth functioning of the intermediation activity and contributed to stabilize the business cycle. In presence of large fractions of non-performing loans however the possibility of transferring credit risk in opaque markets can impair banks' commitment to monitor clients³: this channel amplifies the business cycle impact of financial and liquidity shocks, like those occurred in 2007. Against this background the consequences of the securitization process on macroeconomic and financial stability are largely unknown and unexplored. While after the 2007 many papers addressed the interaction between banking and financial frictions and the macroeconomy⁴, none considered the role of credit risk transfer.

My paper fills this gap by embedding a micro-founded "Originate to Distribute" (OTD) business model of banking into a standard business cycle framework. Credit risk transfer is modelled so as to account for both its ability to provide insurance and liquidity as well as its detrimental effects on banks' monitoring incentives. Banks in my model are delegated monitors and are granted the possibility of trading in secondary markets for credit risk transfer (sometimes the abbreviation CRT will be used in the text). Banks need to monitor projects since firms might shirk on returns, but monitoring is costly and this triggers banks' hazardous behavior toward uninformed investors. Furthermore, banks trade in credit derivatives when confronted with liquidity shocks or when they intend to re-cycle toxic loans. As delegated monitors banks learn about projects' quality and through this they acquire proprietary rights that induce asymmetric information between them and uninformed (atomistic) investors⁵. Investors in secondary markets hold subjective beliefs

¹See, eg, Taylor [37].

²Rajan [35] discusses problems related to weakened banks' monitoring.

³See empirical evidence from Dell'Ariccia, Igan and Laeven [15], Loutskina and Strahan[28].

⁴This literature is growing fast. In section 2 I review some papers which are closer to my own.

⁵Parlour and Plantin [31] also analyze this aspect of credit risk transfer in a finance model. They introduce

about the probability of banks' liquidity shortage, but cannot discern the presence of toxic loans. As a consequence a *pooling* price emerge in the market for credit risk securities. Overall, trading in CRT has two opposing effects. On the one side, it improves asset-liability management as banks can redeploy capital in face of liquidity shocks without the need for costly project liquidation. On the other side, since banks use the secondary markets to re-cycle non-performing loans, asymmetric information in markets for derivative reduce the informative content of prices. Interestingly informational asymmetries also undermines banks' monitoring incentives and facilitates hazardous behavior. Mis-incentives affect the macroeconomy in several ways. First, through the dynamics of investment which is affected by banks' rents⁶ and by the liquidity in secondary markets. Secondly, the evolution of firms' and of banks' wealth, which depends upon rents and investment, also play a role in the transmission of shocks.

Whether the beneficial or the detrimental effects of credit risk transfer prevail depends primarily on the type of shock that affect the business cycle. In presence of traditional macro shocks (productivity or government spending) CRT helps to stabilize the economy relatively to the case in which this possibility is missing. Under those shocks improved liquidity management and insurance help to stabilize the economy. This effect is also consistent with the observation that prior to the 2007 financial shock the business cycle was very stable (the so-called Great Moderation). On the other side in response to asset price and/or liquidity shocks (the latter modelled as disturbances to investors' subjective probability of illiquidity) the model with CRT produces sharp amplification effects. With those shocks the share of toxic assets increases and so do the banks' incentive to re-cycle credit risk. Both asymmetric information and moral hazard problems become more pervasive. This increases the volatility of banks' rents, which in turn increases the volatility of investment. Importantly and realistically, the calibration of those shocks is done using estimated values⁷ which take into account shocks' correlation and stochastic volatility⁸. The latter captures well the uncertainty and the swings in market sentiments that are pervasive in those markets. The quantitative

secondary markets for credit risk transfer in a banking model à la Holmström and Tirole [26].

⁶Banks in my model extract rents as they are delegated monitors.

⁷See also Jermann and Quadrini[27] for a model estimating financial shocks.

⁸To capture this link between asset price and liquidity shocks, I estimate a VAR in the (quarterly) S&P 500 index and the 3 month LIBOR_OIS spread; the latter is subsequently estimated as GARCH(1), whose shocks feature an heteroskedastic component linked to the residual of the S&P 500 index. Notice that to capture the non-linearities induced by those shocks into the model quantitative simulations are done also using third order approximations.

assessment of the model is completed by comparing business cycle statistics for a number of macro and banking variables in the model with their empirical counterparts for the period of rapid growth in securitization (1992Q4-2009Q4)⁹. The model does well in this respect.

Section 2 contains a literature review. The same section shows some stylized facts. Section 3 describes the model. Section 4 shows the model's quantitative implications. Section 5 concludes. Tables, figures and a technical appendix follow.

2 Literature Review and Empirical Facts

The core mechanism of my model stems from the possibility that credit risk transfer can exacerbate banks' moral hazard. Asymmetric information in CRT markets, by inducing pooling equilibria, reduces the degree of transparency and the informative content of prices. This in turn impairs banks' monitoring incentives (see for instance Dell'Ariccia, Igan and Laeven [15], Loutskina and Strahan[28] for empirical evidence on this).

My paper is related to the literature that analyzes jointly asymmetric information in secondary markets and banks' monitoring incentives: see for instance Dell'Ariccia and Marquez [14]. It also contributes to the growing literature on macro-finance¹⁰. My paper explores the consequences of estimated financial and liquidity shocks: a contributions in this direction has been given by Jermann and Quadrini[27]. The paper is also related to the contributions that explore the role for the macroeconomy of banks as delegated monitors. Gersbach and Rochet [23] analyze aggregate investment externalities in presence of dual moral hazard à la Holmström and Tirole [26]. Chen [11] and Meh and Moran [29] introduce dual moral hazard into a full-fledged DSGE model and study business cycle dynamics¹¹. Compared to these papers my model analyzes the role of liquidity shocks in a model with information externalities, introduces credit risk transfer and studies jointly asymmetric information (in CRT markets) and banks' moral hazard.

The finance literature has discussed merits as well as weaknesses of credit risk transfer. Some

⁹The model can capture well the dynamic of macro and banking variables. For this reason it is also well suited for policy analysis. Appendix B shows an extension of the model with nominal rigidities and conducts quantitative analysis of different monetary policy rules.

¹⁰Here I discuss some papers which are more closely related to mine.

¹¹I follow for instance some of the general equilibrium assumptions introduced in those models, like the division of the population in consumers, entrepreneurs and bankers.

papers focused on optimal security design and highlighted the beneficial risk sharing and signaling properties of credit risk transfer. In particular some papers stated that the possibility of retaining the junior tranche of asset backed securities should have guaranteed the emergence of signalling price equilibria and mitigate the informational asymmetries¹². Other papers instead have stressed the monitoring mis-incentives associated with loan sales¹³: those issues have been analyzed by relying primarily on the *dual moral hazard problem* (à la Holmström and Tirole [26]).

The OTD business model of banking spread quickly in the decade prior to the 2007 crisis, bringing several advantages, including better risk sharing possibilities for lenders, lower cost of capital and increased availability of funds for borrowers. Appendix A shows the evolution of asset backed securities for the period 1985 to 2013.¹⁴ However, over time several dys-functionalities emerged. Among them are incentive problems associated with trading in asset-backed securities, asymmetric information in secondary markets and the related valuation difficulties. For this reasons CRT markets collapsed after the financial crisis, although they recovered recently. Certainly both the rapid as well as their collapse in face of large financial shocks signal the importance of those markets for the macroeconomy.

Prior to the 2007 crisis several economists¹⁵ have argued that securitization might have dampened the effects of productivity and demand shocks thereby contributing to the observed macroeconomic stabilization (the so-called Great Moderation). Other authors¹⁶ argue that banking coupled with trading in asset backed securities or other short-term liabilities can cushion the economy from traditional macro and monetary shocks. To corroborate this aspect I assess empirically the link between cyclical fluctuations in output and growth in secondary markets trading. For this I use the dataset for ABS trading volumes outstanding described in Appendix A and time series for real GDP¹⁷ for the US and the euro area (EA hereafter) over the period 1990-2007. Using Hodrick

¹²Subsequent papers have generalized this idea to alternative types of securities (such as debt, ABS) or tranches thereof. See Duffie and De Marzo [16], Oldfield [30] among others.

¹³Pennacchi [33] and Gorton and Pennacchi [25] emphasized that transfer of loan risk to a third party might impair the incentives to monitor.

¹⁴See also evidence in ECB [17] and BIS [4] and Gorton and Metrick[24].

¹⁵See for instance Blanchard and Simon [7], Peek and Wilcox [32] among others.

¹⁶See Angeloni and Faia[1], Angeloni, Faia and Lo Duca [2], Brunnermerier and Sannikov[8].

¹⁷The series for the US and the Euro Area GDP have been extracted from the OECD website. The measure of these series is millions of US dollars, volume estimates, fixed PPPs, OECD reference year, annual levels, seasonally adjusted. The data on GDP is available in quarterly frequencies. The GDP data for the Euro Area consists of the 15 Euro Area countries.

Table 1: **Regression results of GDP volatilities (over 10 years rolling window from 1992 to 2007) over an index for ABS growth in outstanding volumes for both the US and EA.**

	<i>ABS_index_US</i>	<i>ABS_index_EU</i>
coefficient	-0.59	-0.43
t-statistic	-2.72	-2.25
P-value	0.03	-0.05

Prescott de-trended GDP series, I compute standard deviations over rolling windows of 10 years¹⁸. Second, using the ABS trading volumes for different categories of assets¹⁹ I compute an index of ABS transaction growth²⁰. I then regress the rolling GDP volatilities over the ABS growth index. Table 1 shows that for both the US and Europe there is a negative relation between the two (the coefficient in the regressions are significant at the 95% or the 97% level).

The regression remained robust and significant also when considering different definitions of the ABS index (with different weights on the different types of underlying assets). The negative relation confirms the link between macroeconomic stabilization and ABS growth observed prior to the 2007 crisis and discussed in previous literature. Following instead the financial shock of 2007 securitization had contributed to amplify instability.

The differential impact that securitization had over the business cycle, namely a stabilizing effect in face of standard macro shocks and a destabilizing effect in face of asset price or liquidity shocks, is captured well by my model. In the model standard macro shocks (productivity or demand shocks) affect banks' return on equity and balance sheet only indirectly and mildly: they therefore have little impact on banks' incentives to recycle toxic loans. On the other side, asset price or liquidity shocks impair sharply banks' returns and wealth, thereby increasing their incentives toward recycling of toxic assets. This steepens informational externalities, impairs the signaling

¹⁸The data on GDP for the period 1992:Q4 – 2011:Q4 has been detrended with HP filter (1600 smoothing parameter). The volatility of the GDP series has been calculated on a rolling window starting with the first decade 1992:Q4 – 2000:Q4 and going forward until 2007. Time series of the GDP volatility have been obtained then by moving the window forward by one year at the time.

¹⁹Since the data on ABS for both, US and Europe, is in nominal US dollars, it has been deflated using the GDP deflator for the USA extracted from the FRED database (<http://research.stlouisfed.org/fred2/>). The GDP data is already in real terms.

²⁰The data on ABS has been detrended by first-log-differencing the annual series. As for GDP data I have time series for the same years. The ABS index for the US includes outstanding volumes for the following categories: Automobile, Credit Card, Home Equity, Manufactured Housing (equal weights) - ABS Outstanding. The ABS index for the EU includes volumes for the following categories: Auto, Consumer, Credit Card, Other (equal weights).

role of ABS prices in secondary markets and exacerbates financial instability.

3 The Model

The economy is populated by three types of agents: households/workers, entrepreneurs and a bank. Following standard practice in the macro literature with credit frictions I assume that the latter two are finitely lived and risk neutral: the assumption prevents buffer asset accumulation that would overcome the need for external finance and allows me to obtain a tractable aggregation of the respective consumption functions²¹. Production of final goods takes place in a competitive sector which employs capital and labour. A second sector produces physical capital goods. Firms in this sector obtain funds from the bank to finance investment projects. The bank obtain funds either through deposits (this is the sole source of funding in absence of secondary markets for credit risk transfer) and through asset backed securities (in presence of secondary markets) and also invest their bank capital.

The moral hazard problems arising between firms and banks on the one side and the bank and uninformed investors on the other is solved via a three party contract (see Holmström and Tirole [26]). The nature of the moral hazard problems can be summarized as follows. On the one side, firms can influence the probability of success of a project which can be high (p_h) or low (p_l) and obtain private benefits (which can be high, low or very low in absence of bank monitoring). To overcome such moral hazard problem two things are needed: the bank's monitoring activity and entrepreneurial stakes (in the form of net worth) into the project. On the other side, monitoring activity is costly. Such costs are at the origin of a second moral hazard problem which arises between the bank on the one side and depositors, or uninformed investors in the secondary market, on the other. The incentives to discipline this second moral hazard problem are given by the amount of bank capital involved in the project. Everything else equal, investors and depositors give more funds to a well capitalized bank: this provides a market based justification for the existence of

²¹ An alternative possibility would be to include all three agents within a single household optimization problem. The size of household would be kept constant by assuming a constant probability for each member of shifting across different jobs (worker, entrepreneur, banker). Household insurance would then allow all members to enjoy the same level of consumption. This alternative structure would not change results significantly as it would amount at including, within aggregate consumption, bankers and entrepreneurs consumption: the latter are nevertheless a small fraction of the total.

bank capital buffers.

The treatment of the secondary market for credit risk transfer is done along the lines indicated in Parlour and Plantin [31]. It is assumed that the bank is subject to liquidity shocks. In absence of a secondary market such shocks induce the bank to discount the proceeds from the investment activity. In presence of secondary markets, the bank can sell loans, and they will do so in two circumstances (or both): if they receive a liquidity shock, and if they hold non-performing loans, namely projects with low probability of success, p_l ²². Uninformed investors are unable to distinguish among those two cases, hence in equilibrium a *pooling* price clears the market. In equilibrium this reduces the bank's incentives to monitor and reinforces the moral hazard problem with the uninformed investors.

Notice that in the description below an index b is used to indicate any variable related to the banker, an index e is used for any variable related to the entrepreneurs and an index h will be used for any variable related to the uninformed investors.

Notice that in the model it is assumed that ABS are issued to transfer risks for loans on productive capital: this assumption renders the model more general²³ and is consistent with the observation (obtained from the securitization data shown above) that ABS on corporate loans, equipment and productive capital represent a significant, if not the largest, fraction, both in the US and Europe. Needless to say the model below can accommodate the possibility that the asset underlying the ABS is a durable good, used either for production or for utility services: the mechanisms characterizing the impact of securitization on the macroeconomy remain unaffected in this case as they are linked to monitoring incentives and to the price formation process in the secondary market.

3.1 Households

A continuum of households consume, work in the production sector, invest in bank deposits and physical capital. They take consumption decisions to maximize the following lifetime expected

²²In the model a more general case than the one derived in Parlour and Plantin [31] is considered. Parlour and Plantin [31] assume that the investment project succeeds with probability p if the bank monitors and with probability 0 if it does not; in my model I consider instead that projects succeed with probability p_h if the bank monitors and with probability p_l if the bank does not monitor.

²³See Parlour and Plantin [31] for a similar assumption.

utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \{U(C_t) - V(H_t)\} \quad (1)$$

where C_t denotes households consumption and H_t labour hours. Their budget constraint, in real terms, reads as follows:

$$C_t + q_t I_t^h + D_{t+1} = (1 + r_t^d) D_t + Z_t K_t^h + w_t H_t - \tau_t \quad (2)$$

where q_t denotes the price of capital, I_t^h denotes capital investment done by households, $(1 + r_t^d)$ is the gross interest rate received on deposits, D_t are real deposits, Z_t is the real rental rate of capital, K_t^h is the amount of physical capital invested by households, $w_t H_t$ is real labour income and τ_t are lump sum taxes. The capital investment evolves according to $K_{t+1}^h = (1 - \delta) K_t^h + I_t^h$. The first order conditions of the above problem read as follows:

$$u'(C_t) = \beta E_t \left\{ u'(C_{t+1}) (1 + r_t^d) \right\} \quad (3)$$

$$q_t u'(C_t) = \beta E_t \left\{ u'(C_{t+1}) (q_{t+1} (1 - \delta) + Z_{t+1}) \right\} \quad (4)$$

$$w_t u'(C_t) = -v'(H_t) \quad (5)$$

Equation 3 is the standard Euler condition with respect to deposits. This equation determines the interest rate paid to depositors through the stochastic discount factor:

$$\frac{1}{(1 + r_t^d)} = \beta E_t \left\{ \frac{u'(C_{t+1})}{u'(C_t)} \right\} \quad (6)$$

Equation 4 is the first order condition with respect to capital holding. Finally, equation 5 is the first order condition with respect to labour hours. The set of first order conditions must hold alongside with a no-Ponzi condition on wealth.

3.2 Final good firms

The final goods in this economy are produced by a continuum of competitive firms operating under a Cobb-Douglas production function, $Y_t = A_t (H_t)^{1-\alpha} (K_t)^\alpha$, where A_t is an aggregate productivity shock which follows an AR(1) process, α is the share of capital in production, K_t denotes rental

physical capital and H_t is the labour input. Each firm chooses production input optimally by minimizing costs. Optimality conditions read as follows:

$$w_t = mc_t A_t (1 - \alpha) (H_t)^{-\alpha} (K_t)^\alpha, Z_t = mc_t A_t (H_t)^{1-\alpha} \alpha (K_t)^{\alpha-1} \quad (7)$$

where mc_t is the lagrange multiplier on the production function and represents firms' marginal costs.

3.3 Investment and External Finance

Following Holmström and Tirole [26] I assume that a continuum of entrepreneurs has access to the same technology for producing capital goods, although their returns are subject to idiosyncratic risk, R_t^j . To invest in capital goods entrepreneurs require funds from banks. We assume that there exist a continuum of banks which are ex ante identical and across which the performance of the portfolio is i.i.d. Notice that as in Holmström and Tirole [26] projects returns are perfectly correlated within the portfolio of a single intermediary, but not across banks. This assumption²⁴ implies that idiosyncratic project returns do not turn into aggregate risk, hence do not enter the aggregate (entrepreneurs' and bankers') wealth accumulation equations as well as the returns on investors' securities.

Projects have a variable scale I_t^j and are financed partly with entrepreneurial net worth, NW_t^j , and partly with bank loans, L_t^j . Although all projects produce the same publicly visible returns, they have different probability of success. The latter is determined by the entrepreneurs. In absence of proper incentives or outside monitoring, entrepreneurs might shirk, i.e. reduce the probability of success of the project in order to enjoy a private benefit. The moral hazard problem is formalized by assuming that entrepreneurs can choose among three different project outcomes. The first project, labeled as good project, has a high probability of success p_h and zero private benefits. The second project, labeled as bad project, is associated with an entrepreneur who shirks: it has a lower probability of success, $p_l < p_h$, and provides private benefits b . Finally, the third project still delivers a probability of success p_l but allows for private benefits $B > b$. Private benefits are assumed to be proportional to the value of investment, $q_t I_t^j$. It is assumed that there are two levels

²⁴Similar assumptions are made in Chen [11] and Meh and Moran [29].

of shirking with the same probability of success in order to allow for a rich characterization of monitoring, alongside with the entrepreneurs preferring the high benefit project.

The linear technology characterizing investment goods, as well as the linearity underlying the private benefits accruing to the entrepreneur, permit easy aggregation. Hence from now on the index j is dropped from the maximization problems.

3.4 Banks

Banks have access to a monitoring technology which takes different forms: inspection of firms' balance sheet position and potential cash flow, management quality, verification that the firm conforms with financial covenants, etc.. It is assumed that monitoring can prevent the shirking project with benefits B , but not the one with benefits b . This reduces the incentive to shirk, but not fully, so as to retain some role for entrepreneurial net worth as a discipline device.

Bank monitoring is privately costly and such cost, c , is proportional to the project scale, I_t . This creates a second moral hazard problem between the bank, on the one side, and informed investors (depositors or traders in secondary markets), on the other. The mis-incentives to reduce the amount of monitoring (a form of bank shirking) become particularly severe when the bank can transfer risks in secondary markets. Such moral hazard problem is disciplined by the amount of bank capital invested in the project, BK_t . Once the cost of monitoring have been paid, the bank is able to lend an amount $L_t = BK_t + D_t - cI_t$.

The contract takes place over three periods. Hence I assume that each date t is divided in *three sub-period*, 0, 1 and 2. At time 0 the lending and deposit contracts are written and the behavior of the firm and the bank (shirk versus no shirk) are decided. At time 1 the monitoring bank privately learns about the quality of the project. At this stage the bank also learns whether they have been hit by a liquidity shock (details described in next paragraph). They may therefore engage in a risk-transfer transaction for either of the above reasons, namely getting rid off of non-performing loans or facing liquidity shortages. At period 2 the outcome of the project becomes common knowledge and all payoffs are realized.

To model the bank appetite for liquidity I follow Parlour and Plantin [31] and assume that the bank has a stochastic discount factor. The discount factor becomes indeed higher in presence of liquidity shocks. Liquidity shocks can be rationalized in several ways. One possibility is to consider

them as a manifestation of an exogenous increase in bank capital regulations. Another relates to the possibility of liquidity in interbank markets. Consider a bank which obtains liquidity from the interbank market and suppose that at time 1 there is an unexpected increase in counter-party risk, hence the precautionary demand for liquidity by the bank increases²⁵. Unless the central bank fully and immediately accommodates the increased liquidity demand, the discount factor for each bank will increase. I assume that liquidity shortage occurs with a probability ζ , which can be interpreted as a subjective market belief.

The stochastic discount factor is modeled as follows: $\theta \in (0, 1)$ with probability ζ_t and to 1 with probability $(1 - \zeta_t)$. The probability that a liquidity shortage will occur is modeled as time-varying as later on (in the calibration section) I will introduce a shock component into it. Such formulation for the discount factor captures unanticipated changes in the opportunity cost of carrying out outstanding loans. In absence of secondary markets for credit risk transfer, the bank is unable to liquidate its investment, hence the return for the bank of investing in the portfolio of project I_t will be discounted by the average factor $\bar{\theta}_t = \zeta_t \theta + (1 - \zeta_t)$. On the other side, in presence of secondary markets banks can sell loans if a liquidity shock materializes and enjoy a unitary discount factor. As explained earlier, ζ_t will be modeled later on as a GARCH (1) stochastic process: the stochastic volatility embedded in the GARCH(1) process allows me to model the uncertainty and the swings in market sentiment pervasive in markets for CRT. The behavioral interpretation of the stochastic volatility of this shock is one possible interpretation, but of course others are possible. It is important to stress that the comparison of the transmission mechanisms of the models with and without CRT is independent from the interpretation assigned to the stochastic volatility of this shock.

Consistently with the set up of Holmström and Tirole [26] and Parlour and Plantin [31], projects' returns are assumed to be perfectly correlated within the portfolio of a single bank. Such an assumption is useful from a technical point of view, as it makes irrelevant the exact distribution of assets among all parties. The assumption is also realistic as if project's shocks were un-correlated eventually full risk insurance would overcome informational asymmetries. Recall however that projects returns are i.i.d. across the continuum of banks with total mass of one. This implies that

²⁵ Abrupt and large increases in liquidity hoarding by banks has been observed in the most acute phases of the financial crisis after September 2008 both, in the US and in Europe.

idiosyncratic project returns do not turn into aggregate risk and therefore do not affect investors' returns in secondary markets and aggregate wealth accumulations.

3.5 The Financial Contract in Absence of Secondary Markets

In absence of secondary markets for credit risk transfer, the bank provides finance to entrepreneurs by employing funds from depositors and its own net worth. A three party contract²⁶ among depositors, the bank and the entrepreneurs delivers a return of zero if the project fails and a gross return, R , if the project succeeds. Total project return is linearly divided among depositors, R_t^h , banks, R_t^b , and entrepreneurs, R_t^e : $R = R_t^h + R_t^b + R_t^e$. Limited liability ensures that no agent earns a negative return. Since the bank monitors firms, it is assumed ex-ante that projects succeed with probability p_h . This rules out the project with benefit B . The firm is then left to choose between the project with benefit b and the one with zero benefit. Entrepreneurs in this context have the bargaining power so the financial contract is designed to maximize their expected return given the participation constraint for uninformed investors and the bank and the incentive compatibility constraints for the bank and the entrepreneurs. The optimization plan determines the investment scale, I_t , banks' capital, BK_t , funds from uninformed investors, D_t , alongside with returns, R_t^h, R_t^b, R_t^e and takes the following form:

$$Max_{\{I_t, BK_t, D_t, R_t^h, R_t^b, R_t^e\}} q_t p_h R_t^e I_t \quad (8)$$

subject to:

$$p_h R_t^e q_t I_t \geq p_l R_t^e q_t I_t + q_t I_t b \quad (9)$$

$$\bar{\theta}_t p_h R_t^b q_t I_t - c I_t \geq \bar{\theta}_t p_l R_t^b q_t I_t \quad (10)$$

$$\bar{\theta}_t p_h R_t^b q_t I_t \geq (1 + r_t^m) BK_t \quad (11)$$

$$p_h R_t^h q_t I_t \geq (1 + r_t^d) D_t \quad (12)$$

$$I_t \leq NW_t + BK_t + D_t - c I_t; R = R_t^h + R_t^b + R_t^e \quad (13)$$

²⁶The convention in macro models is based on assuming repetition of the contract over all periods. This allows to preserve recursivity. The underlying assumption behind this convention is that anonymity in competitive markets would not allow to distinguish borrowers and financiers across periods. A dynamic extension of this type of contract is considered in Darraq-Paries, Faia and Palenzuela [13]: while the dynamic aspects might bring insights in other contexts, the complication seems unnecessary in the context of the present model which focuses on the interaction between moral hazard and credit risk transfer.

Constraint 9 is the incentive compatibility constraint for the entrepreneur; it states that the returns from pursuing the zero benefit project should be higher than the expected returns from pursuing the project returning at a private benefit b . Equation 10 is the incentive compatibility constraint of the bank; it states that the expected returns from monitoring should be higher than the expected returns from non-monitoring. The time t value of the expected payout depends on the average realization of the stochastic discount factor, $\bar{\theta}_t$. Equation 11 and 12 are the participation constraints for the bank and the uninformed investors²⁷ as they state that expected returns from this contract should at least cover market driven returns. The average stochastic discount factor also affects the bank's returns, hence it enters the bank's participation constraint. Finally, equations 13 state that loanable funds must cover the financing needs and that projects' returns are linearly allocated among the parties. The return structure is determined by knowing that in equilibrium the incentive compatibility constraints, 9 and 10, hold with equality²⁸ and by using the linear allocation rule.

This delivers:

$$R_t^e = \frac{b}{p_h - p_l}; R_t^b = \frac{c}{\bar{\theta}_t q_t (p_h - p_l)}; R_t^h = R - \frac{b}{p_h - p_l} - \frac{c}{\bar{\theta}_t q_t (p_h - p_l)} \quad (14)$$

Notice that the severity of the moral hazard problem, as represented by the private benefits b and the cost of monitoring c , optimally determines the share of returns allocated to the entrepreneurs and to the bank. The higher are the benefits from shirking, the tighter is the moral hazard problem and the higher are the returns that the bank and the entrepreneurs can extract. To assess the role of the liquidity shock, it suffices to notice that the lower the expected value of the stochastic discount factor (the further away $\bar{\theta}_t$ is from unity), the lower the returns accruing to the banker, R_t^b . After merging the return to uninformed investors, R_t^h , together with depositors' participation constraint, 12, and with equation 13, it is possible to obtain the optimal amount of investment:

$$I_t = \frac{NW_t + BK_t}{1 + c - \frac{q_t p_h}{1 + r_t^d} \left(R - \frac{b}{p_h - p_l} - \frac{c}{\bar{\theta}_t q_t (p_h - p_l)} \right)} \quad (15)$$

²⁷Since households are risk averse, they discount all their expected returns by the stochastic discount factor $\Lambda_{t,t+1} = E_t \left\{ \frac{u_{c,t+1}}{u_{c,t}} \right\}$. Since such a stochastic discount factor applies to both sides of the participation constraint (equation 12) and since project returns are i.i.d., it can be canceled out.

²⁸See Holmström and Tirole [26].

The scale of the project is larger, the larger the stakes of the entrepreneur and of the bank into the project. On the other side, an increase in the cost of monitoring and in the private benefits for the entrepreneurs, reduce the scale of investment, as the moral hazard problem becomes more severe. An increase in the price (value) of capital, q_t , increases investment. This is so also since asset price booms increase the value of available funds for investment. Finally, an increase in the nominal interest rate, r_t^d , reduces the scale of investment. The participation constraint to the bank determines the market driven rate to bankers:

$$(1 + r_t^m) = \frac{\bar{\theta}_t q_t p_h R_t^b I_t}{BK_t} \quad (16)$$

The latter serves the purpose of defining the reservation value for the bank, hence it includes returns from various possible alternative uses of bank capital, which could be exogenously given, provided that they satisfy the participation constraint 16. After substituting the equation for the optimal return accruing to the banker, R_t^b , into equation 16, it is possible to obtain the optimal amount of bank capital:

$$BK_t = \frac{p_h c I_t}{(p_h - p_l)(1 + r_t^m)} \quad (17)$$

Higher monitoring costs induce more severe moral hazard problems, hence they require a higher stake of bank capital into the project as discipline device. Also the higher is the market return, the lower is the amount of capital that the banker is willing to invest in the project, since it loses other profitable opportunities. It is also possible to define the bank capital ratio as: $bk_t = \frac{BK_t}{BK_t + D_t}$. Finally, the optimal amount of deposits is determined using the participation constraint to depositors, 12, combined with the optimal return on deposits, R_t^h , $D_t = \frac{q_t p_h I_t (R_t - \frac{b}{p_h - p_l} - \frac{c}{\bar{\theta}_t q_t (p_h - p_l)})}{(1 + r_t^d)}$: higher returns accruing to the depositors increase the optimal amount of deposits. On the other side, the higher is the risk free nominal interest rate, r_t^d , the lower is the optimal amount of deposits, as the opportunity cost is higher.

3.6 The Financial Contract with Secondary Market for Credit Risk Transfer

In presence of a market for credit risk transfer, the bank has the possibility to sell a claim on loans' cash flows. In this respect there are possible gains from trade between the bank and outside investors. The bank might want to sell such claims either because it has received a liquidity shock

or because it recognized the project as a bad one. A secondary market is illiquid if the bank sells only in the second case, while it can be liquid when a *pooling equilibrium* arises. If the market is liquid, investors know that the bank will sell either because it has a non-performing loan, with probability $(1 - p_h)$, or because, despite its loans are performing, it has received a liquidity shock, with probability $\zeta_t p_h$. The pooling price in the secondary market is determined according to the following conditional expectation:

$$r_t = \frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h} \quad (18)$$

This price reflects both the unconditional default probability of the project as well as the banks' incentives to signal the quality of the projects. If the probability of a liquidity shock, ζ_t , is zero the price for the claim is also zero; investors know for sure that the bank will sell only bad loans. On the other side, when $\zeta_t = 1$ the price of the claim approaches the unconditional probability of success p_h . This is also the sense in which ζ_t can be interpreted as the (exogenous) subjective probability or beliefs that investors assign to the occurrence of a liquidity shock.

The three party contract in presence of secondary markets takes an equivalent form to the one described above with two exceptions related to the bank's participation and incentive compatibility constraints. The latter now read as follows:

$$p_h(1 - \zeta_t)R_t^{b,s}q_tI_t^s + (1 - p_h + p_h\zeta_t)r_tR_t^{b,s}q_tI_t^s \geq cI_t^s + p_l(1 - \zeta_t)R_t^{b,s}q_tI_t^s + (1 - p_l + p_l\zeta_t)r_tR_t^{b,s}q_tI_t^s \quad (19)$$

$$q_t p_h R_t^{b,s} I_t^s \geq (1 + r_t^{m,s}) B K_t^s \quad (20)$$

where the index s is used to denote the equilibrium values in presence of secondary markets. Notice that, since the bank can sell loans in presence of a liquidity shock, the average discount factor $\bar{\theta}_t$ is not relevant any longer. The rationale behind the bank's incentive compatibility constraint is as follows. When the bank monitors (left hand side of equation 19), it retains the loan when there is a high probability of success and when there is no liquidity shortage (something which happens with probability $p_h(1 - \zeta_t)$), while it decides to sell the loan on secondary markets either when the loan is not performing or when there is a liquidity shortage (something which happens with probability $(1 - p_h + p_h\zeta_t)$). A similar argument holds when the bank does not monitor (right hand side of equation 19): banks can either retain the loan, something which in this case happens with probability $p_l(1 - \zeta_t)$, or it can sell the loan on secondary markets, something which

happens with probability $(1 - p_l + p_l \zeta_t)^{29}$. Given the new structure of the optimal contract and given $r_t = \frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h}$, the optimal values for returns, investment, bank capital and deposits in this case read as follows:

$$R_t^{e,s} = \frac{b}{p_h - p_l}; R_t^{b,s} = \frac{c}{q_t \{p_h - p_l(1 - \zeta_t) - (1 - p_l + p_l \zeta_t)r_t\}}; R_t^{h,s} = R - R_t^{e,s} - R_t^{b,s} \quad (21)$$

$$I_t^s = \frac{NW_t^s + BK_t^s}{1 + c - \frac{q_t p_h}{1 + r_t^d}(R - R_t^{e,s} - R_t^{b,s})} \quad (22)$$

$$BK_t^s = \frac{q_t p_h R_t^{b,s} I_t^s}{(1 + r_t^m)}; D_t^s = \frac{q_t p_h I_t^s R_t^{h,s}}{(1 + r_t^d)} \quad (23)$$

One consideration is in order before we close the description of the contractual relationship in this context. Following Parlour and Plantin [31] we assume that investors which engage in CRT trading do not take into account fluctuations in future cash flows within each contractual period. If this were the case investors could use future defaults and/or future cash flows as a signal on whether the bank has monitored or not. This channel might create partial reputational mechanisms as the observation of future cash flows can represent a discipline device on banks' current monitoring behavior³⁰. The main effect of reputational mechanisms would be to change the banks' incentive compatibility constraint. It would indeed be easier to satisfy this constraint to the extent that banks are disciplined by the performance of future cash flows. Albeit those mechanisms are very interesting I neglect them in this model for several reasons. First, they are more relevant for CDS than for CRT markets. Second, the current macro model features already a complexity of externalities and channels: adding further dimensions would come at the cost of transparency. At last, introducing reputational mechanisms will render the macro model non-recursive and would require the analysis of multiple equilibria, something which goes well beyond the scope of this paper.

²⁹Notice that the monitoring activity is directed to increase the probability of project success, namely to reduce the moral hazard. However, even a bank that does not monitor knows the probability of a non-performing loan, which is p_l in this case.

³⁰See Parlour and Winton[32] for a model of credit risk transfer and credit insurance that embeds such dynamic incentives.

3.7 Closing the Model

The definition of the competitive equilibrium requires a few additional specifications, particularly for the case featuring secondary markets.

3.7.1 Households Portfolios with Secondary Markets

In presence of secondary markets uninformed investors can invest in deposits, in projects for physical capital or in credit derivatives, namely claims on loans' cash flows. Let's define such claims as one period discounted (real) bonds. By investing in deposits households receive a gross interest rate $(1 + r_t^d)$ which is determined by equation 6. According to equation 12 the share of project returns accruing to uninformed investors shall be equal to the gross return on deposits, $(1 + r_t^d)$. This is equally true in both the model with and without credit risk transfer. When households trade in credit derivatives the gross return is given by the cash flow from the project whose risk has been sold in the market. For the household to buy credit derivatives those assets shall offer a gross return which is at least equal to the one offered on deposits. We can define as, $(1 + r_t^c)$, as the gross return from credit derivatives. This is given by $(1 + r_t^c) = \frac{p_h q_t R_t^{b,s} I_t^s}{D_t}$. Arbitrage between deposits and credit derivatives implies that:

$$(1 + r_t^c) = \frac{p_h q_t R_t^{b,s} I_t^s}{D_t} = (1 + r_t^d) \quad (24)$$

The latter arbitrage condition is also consistent with the contractual condition given by equation 12.

3.7.2 Consumption and Asset Accumulation for Bankers and Entrepreneurs

Following the convention in most macro models with credit frictions, I assume that both bankers and entrepreneurs are finitely lived agents. This prevents accumulation of savings that would otherwise overcome the external finance constraints. In terms of consumption decisions both agents consume all available resources at the end of their life. I define γ^e and γ^b as comprising the survival probabilities as well as the fraction of earnings reinvested in asset accumulation respectively for entrepreneurs and bankers. Therefore $(1 - \gamma^e)$ and $(1 - \gamma^b)$ represent the fractions of expected returns from investment which are devoted to consumption. This implies the following schedules

of aggregate consumption, respectively for entrepreneurs, C_t^e , and bankers, C_t^b :

$$C_t^e = (1 - \gamma^e)q_t p_h R_t^e I_t; C_t^b = (1 - \gamma^b)q_t p_h R_t^b I_t \quad (25)$$

Equivalent expressions hold for the model with secondary markets but with the relevant financial contract variables (namely those which bear an index s). Following Meh and Moran [29] I assume that, after the contract returns are realized, surviving entrepreneurs and bankers receive the proceeds from the contract in the form of capital goods, so that $K_t^e = p_h R_t^e I_t$ and $K_t^b = p_h R_t^b I_t$. Such capital goods are then rent to producing firms or sold in the market. Hence the wealth, that surviving entrepreneurs and bankers carry over to the next period, is given by the returns from renting and selling capital goods, multiplied by the end of period capital. After substituting for the optimal investment schedule from equation 15, the aggregate net worth and bank capital accumulations read as follows:

$$NW_{t+1} = \gamma^e [Z_{t+1} + q_{t+1}(1 - \delta)] p_h R_t^e \left(\frac{NW_t + BK_t}{\Gamma_t} \right) \quad (26)$$

$$BK_{t+1} = \gamma^b [Z_{t+1} + q_{t+1}(1 - \delta)] p_h R_t^b \left(\frac{NW_t + BK_t}{\Gamma_t} \right) \quad (27)$$

where $\Gamma_t = \left[1 + c - \frac{q_t p_h}{1+r_t^d} \left(R_t - \frac{b}{p_h - p_l} - \frac{c}{\bar{\theta}_t q_t (p_h - p_l)} \right) \right]$ in absence of secondary markets and is equal to $\Gamma_t^s = \left[1 + c - \frac{q_t p_h}{1+r_t^d} \left(R_t^s - \frac{b}{p_h - p_l} - \frac{c}{q_t (p_h - r_t)} \right) \right]$ in presence of secondary markets.

3.8 Resource Constraints and Competitive Equilibrium

Aggregate capital, $K_t = K_t^h + K_t^e + K_t^b$, evolves according to the following law of motion:

$$K_{t+1} = (1 - \delta)K_t + p_h R I_t. \quad (28)$$

The resource constraint in this economy is given by:

$$Y_t - cI_t = C_t + C_t^e + C_t^b + I_t + G_t \quad (29)$$

where G_t is an exogenous government expenditure shocks. Since government expenditure is financed through lump sum taxation, it is not necessary to include the government budget constraint as fiscal policy plays a passive role. Notice that the term $-cI_t$ captures the resource costs induced

by the moral hazard pervasive in the monitoring activity. Given all the above relations it is possible to define the competitive equilibrium with and without secondary markets for credit risk transfer.

Definition 1. *Competitive equilibrium without secondary markets.* A competitive equilibrium is an allocation

$$\{C_t, C_t^e, C_t^b, I_t, Y_t, mc_t, H_t, K_{t+1}, R_t^b, R_t^h, D_t, NW_{t+1}, BK_{t+1}, (1 + r_t^d), (1 + r_t^m), (1 + r_t^k), q_t, w_t\}_{t=0}^{\infty}$$

that satisfies equations 3, 4, 5, 7, 14, 15, 16, 25, 26, 27, 28, 29.

Definition 2. *Competitive equilibrium with secondary markets.* A competitive equilibrium is an allocation

$$\{C_t, C_t^e, C_t^b, I_t^s, Y_t, mc_t, H_t, K_{t+1}, R_t^{b,s}, R_t^{h,s}, D_t^s, NW_{t+1}^s, BK_{t+1}^s, (1 + r_t^d), (1 + r_t^m), (1 + r_t^k), q_t, w_t\}_{t=0}^{\infty}$$

that satisfies equations 3, 4, 5, 7, 16, 21, 22, 23, 25, 26, 27, 28, 29.

3.9 The Role of Secondary Markets: Liquidity and Investment

Before turning to the dynamic implications of the model at business cycle frequencies we ask what is the effect of introducing secondary markets for credit risk transfer on liquidity and on aggregate investment/production in the long run. Notice that, as we are now dealing with long run variables, I skip the time index. The following proposition establishes under which parameters the introduction of secondary markets induces higher liquidity and higher investment.

Proposition 1. *Under secondary markets for credit risk transfer banks with liquidity needs are willing to sell their loans in the secondary markets when the following condition is met:*

$$\theta \leq \frac{\zeta p_h}{1 - p_h + \zeta p_h} \quad (30)$$

Aggregate investment is larger under secondary markets for credit risk transfer when the following condition is met:

$$\theta \leq \frac{p_h}{(p_h - p_l)} - \frac{(1 - \zeta)p_l}{(p_h - p_l)} - \frac{(1 - p_l + p_l\zeta)\zeta p_h}{(1 - p_h + \zeta p_h)(p_h - p_l)} \quad (31)$$

Proof. Condition, 30, requires that for the market to be liquid the pooling price, $r = \frac{\zeta p_h}{1 - p_h + \zeta p_h}$, is high enough that the illiquid bank is willing to sell at that price. Notice that for a given discount factor, θ , it is easier to meet the condition for investment projects with higher rating, e.g. probability of success. For given probability of default the market becomes more liquid when the cost for the bank of bringing the loan to maturity is higher.

The second condition, 31, stems from comparing the investment equations in the case with and without secondary markets. Secondary markets guarantee a higher aggregate investment when 22 is higher than 15. This also implies that the rents accruing to the bank under secondary markets are lower than in absence of them, namely when:

$$\frac{c}{\left\{p_h - p_l(1 - \zeta) - (1 - p_l + p_l\zeta)\frac{\zeta p_h}{1 - p_h + \zeta p_h}\right\}} \leq \frac{c}{\bar{\theta}(p_h - p_l)} \quad (32)$$

Rearranging 32 one obtains 31. In absence of secondary markets the bank requires a liquidity premium to hold the loan until maturity. The premium is larger the lower is the θ . The higher is the premium the lower is aggregate investment in absence of secondary markets. Notice that the discount factor in condition 32 represents the threshold below which aggregate investment is always larger in presence of secondary markets.

Notice that in the macroeconomic model the calibration of parameters (in both the models with and without CRT) is consistent with the existence and liquidity of CRT markets.

3.9.1 Bank Capital Ratios

It is interesting to consider the role and the properties of the bank capital ratios in the models with and without credit risk transfer, particularly with reference to the trade off between liquidity and monitoring incentives. Recall that bank capital is determined optimally to mitigate the severity of the bank's moral hazard. However higher capital ratios reduce available liquidity.

Let's first examine the behavior of the bank capital ratio in the model without credit risk transfer. The bank capital ratio here reads as follows:

$$bk_t = \frac{BK_t}{BK_t + D_t} = \frac{c(1 + r_t^d)}{c(1 + r_t^d) + R_t^h q_t(p_h - p_l)(1 - r_t^m)} \quad (33)$$

As we shall see later on in the dynamic simulations, the above capital adequacy ratio behaves pro-cyclically (with respect to bank risk and counter-cyclically with respect to the business cycle). Expansionary shocks, by increasing asset prices, relax the bank's incentive compatibility constraint, thereby the capital ratio needed to discipline the bank is lower. The more so, the lower is the monitoring cost.

Capital ratios in presence of secondary markets are given by:

$$bk_t^s = \frac{BK_t^s}{BK_t^s + D_t^s} = \frac{c(1 + r_t^d)}{c(1 + r_t^d) + R_t^{h,s} q_t (p_h - \frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h})(1 - r_t^{m,s})} \quad (34)$$

For given ζ_t , as long as $R_t^{h,s}(p_h - \frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h})(1 - r_t^{m,s}) > R_t^h(p_h - p_l)(1 - r_t^m)$, an expansionary shock reduces capital ratios by more in presence of secondary markets. In this case secondary markets help to free up liquidity. This case occur when three conditions are contemporaneously satisfied: $R_t^{h,s} > R_t^h$, $\frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h} \leq p_l$ and $r_t^{m,s} \leq r_t^m$. First, if the return accruing to the uninformed investors is higher in presence of secondary markets, this implies that the rents extracted by bankers, $R_t^{b,s}$, are instead lower. Bankers extract lower rents when the extent of the moral hazard is lower. In this case it is easier to meet the bankers' incentive constraint and bank capital can fall by more in face of expansionary shocks to assets prices. Second, if the pooling price in the secondary market, $\frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h}$, is lower than p_l , secondary markets are highly liquid. Since banks can easily refinance themselves in secondary markets there is less need to raise bank capital. At last, if the return on alternative investments is lower under secondary markets, investors have higher incentives to trade in secondary markets: this makes those markets highly liquid, again reducing the need to raise bank capital.

3.10 Calibration, Shocks and Steady State Results

This section is devoted to discuss the parameters and shock calibration used in quantitative simulations of the next section.

Household preferences and production. The time unit is the quarter. The utility function of households is $U(C_t, H_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} + \nu \log(1 - H_t)$, with $\sigma = 2$, as it is in most real business cycle literature aimed at capturing risk aversion. The parameter ν is set equal to 6 and has been chosen in such a way to generate a steady-state level of employment $H \approx 0.3$. The discount factor is set to $\beta = 0.99$, so that the annual real interest rate is equal to 4%. The production function is a Cobb-Douglas, $F(\bullet) = K_t^\alpha (H_t)^{1-\alpha}$, with $\alpha = 0.3$. The quarterly aggregate capital depreciation rate δ is 0.025.

Banking and financial parameters. The parameters characterizing the banking contract are p_h, p_l, c, R, b , the ones characterizing the wealth accumulation are γ^e, γ^b . The criteria followed to

determine the calibration of those primitive parameters are as follows. First the calibration shall be chosen so that the condition for existence of the markets for CRT, namely equation 30, holds. Second, the calibration of the primitive parameters is set equally across the two models, with and without secondary markets. Third, the calibration is set so that the model with CRT markets can reproduce a number of realistic long run financial values and ratios. The p_h , namely the probability of project success, is set equal to 0.97 to reproduce firms' quarterly failure rate in industrialized countries, as reported in most of the "financial accelerator" literature. The remaining parameters, namely the probability of project failure, p_l , the cost of monitoring, c , the total return from the project, R , and the private benefit, b are set so as to induce the following steady state values. 1. A capital ratio, $\frac{BK}{BK+D}$, at around below 15% in line with BIS data [5]. The calibration is done on a de facto capital ratio, although in many countries which adopted the Basel regulation this coincides with the de jure capital ratio. 2. A ratio of investment over output, $\frac{I}{Y}$, approximately of 0.20, a value compatible with most RBC studies. 3. A ratio of capital over output, $\frac{K}{Y}$, in a range between 9 and 10, a value set in accordance with ranges considered in the RBC literature. 4. A ratio of investment over entrepreneurial net worth of, $\frac{I}{NW}$, of around 2.5. This value is compatible with the macro literature featuring credit frictions and with financial accelerator models. 5. A quarterly return on bank equity (ROE), $\gamma^b [Z_{t+1} + q_{t+1}(1 - \delta)] p_h R_t^b$, at around 10% compatibly with values observed prior to the 2007 crisis (see EU banking sector stability report of 2007[19] and The Profits and Balance Sheet Developments at U.S. Commercial Banks in 2007, Federal Reserve Bulletin 2008[20]). 6. Banks' operating costs (BOC in the table 2), given by $\frac{\mu I}{NW}$, in the order of 4% to 5% of investment. Given the above criteria parameters' values are set as follows: $c = 0.016$, $R = 1.21$, $b = 0.16$, $\gamma^e = 0.85$, $\gamma^b = 0.55$, $\theta = 0.7$, $\zeta = 0.125$, $p_l = 0.6$. Notice that ζ refers to the probability of liquidity shortage in absence of the stochastic component. In the model with credit risk transfer those parameters generate steady state ratios as reported in the first row of Table 2. Robustness checks were performed within ranges of the parameters that satisfy condition 30.

It is of interest also to analyze the comparison of the steady state results across the two models considered. Steady state results for the model without credit risk transfer are reported in the second row of Table 2. Compared to the data equivalent described above the model without CRT clearly

Table 2: **Steady state results in the models with and without credit risk transfer.**

	$\frac{I}{NW}$	$\frac{K}{Y}$	$\frac{BK}{BK+D}$	BOC	ROE	$\frac{I}{Y}$
Model CRT	2.7	9.6	16%	5.4%	10%	0.20
Model No CRT	2.9	10.27	3.5%	5.7%	2%	0.22

performs less well than the model with CRT. The ratios for capital to output, investment to output and investment to net worth are larger in the model without CRT than in the data. CRT markets have both beneficial and detrimental effects and the relative size of the two depends upon certain parameters as explained in proposition 1. Steady state results show that, given the data based calibration, the detrimental effect of CRT markets on investment tends to prevail in the long run. Most strikingly the values for the capital ratios and return on equity are very far from the ones observed in the data. The return on equity is clearly lower in the model with no CRT. This is so since in this case it is not possible to diversify the risk from the liquidity shock. Recall that our ROE depends in the model with CRT upon the R_t^b and that the latter is reduced when the risk of a liquidity shortage increases. In the years prior to the 2007 crisis the possibility of transferring credit risk had allowed banks to increase significantly banks' returns on equities and their returns on assets³¹. This observation and the comparison with the data is compatible with the result of a ROE higher (and closer to the data) for the model with CRT. On the other side, as the risk of moral hazard is smaller in absence of CRT the required capital ratio is also lower. Banks cannot recycle toxic assets in absence of CRT markets, therefore the need for a discipline device is smaller. Recall that in the years prior to the 2007 crisis Basel II prescriptions required a capital ratio no lower than 8%, a value much larger than the one generated by the model with no CRT. Data for industrialized countries also show that prior to the 2007 de facto capital ratios ranged from a low level of 7% to a 12%³². Once again this empirical observation shows that the model with CRT can capture better the average banking statistics for the decades prior to the 2007 crisis. The operating

³¹The EU banking sector stability report of 2007[19] reports that the largest share of EU banks had, in the years prior to 2007, returns on equities in the range between 10% and 15%. The Profits and Balance Sheet Developments at U.S. Commercial Banks in 2007, Federal Reserve Bulletin 2008[20] reports for the years prior to 2007 returns on equities for all banks ranging from 10% to 14%.

³²The EU banking sector stability report of 2007[19] reports that the largest share of EU banks had, in the years prior to 2007, tier 1 ratios at around 7% to 8% and total capital ratios between 10% and 12%. The Profits and Balance Sheet Developments at U.S. Commercial Banks in 2007, Federal Reserve Bulletin 2008[20] reports for the years prior to 2007 Tier 1 ratios for US banks in the range between 9% and 10% and total capital ratios in the range of 10% to 12%.

costs are somewhat higher in the model without credit risk transfer. This is well in line with the model intuition. Since it is not possible to transfer risk onto the market portfolio management costs are somewhat higher in this model. Regarding the data, while there is no univocal measure of banks' operating costs there is clear evidence that credit risk transfer had allowed banks to reduce operating costs, an observation in line with the results in the two models.

Shocks. The shocks considered include the standard macro shocks (productivity and government spending) as well as asset price and liquidity shocks. Productivity shocks are modeled as AR(1) processes, $A_t = A_{t-1}^{\rho_\alpha} \exp(\varepsilon_t^\alpha)$, where the steady-state value A is normalized to unity. As in most RBC literature the persistence of this shock is set to $\rho_\alpha = 0.9$ and its variance to $\sigma_{\varepsilon^\alpha} = 0.005$. The log-government spending evolves according to the following exogenous process, $\ln\left(\frac{g_t}{g}\right) = \rho_g \ln\left(\frac{g_{t-1}}{g}\right) + \varepsilon_t^g$, where the steady-state share of government consumption, g , is set so that $\frac{g}{y} = 0.22$ and ε_t^g is an i.i.d. shock with standard deviation σ_g . Empirical evidence for the US in Perotti [34] suggests a persistence for this shocks of $\rho_g = 0.9$. The standard deviation is set to $\sigma_g = 0.004$ so as to generate a volatility of GDP compatible with the one observed in the data for the period 1992 to 2009.

Financial and liquidity shocks are estimated through a combination of VAR and GARCH(1) models³³. Several authors have stressed of the positive correlation between asset price and financial shocks (see Cifuentes, Ferrucci and Shin [12] among many others). The hypothesis behind the connection between those two shocks is generally as follows. In the 2007 crisis, the write-downs in values of asset backed securities resulted from a self-reinforcing combination of a fall in the returns of banks' loans (the asset price shock) and an increase in the probability of foreclosure (early loans liquidation). The second shock produced a liquidity shortage and triggered an overall increase in the equilibrium cost of funding. In turn the increase in the cost of funding produced an overall increase in the cost of credit thereby reducing asset prices (the price of investment in my model). The structural assumptions behind our estimation must take into account this spiraling connection and consider liquidity and asset price shocks in combination. Furthermore liquidity shocks (shocks to the probability of early liquidation) had larger and more long lasting effect and carried larger uncertainty. It seems therefore important to include stochastic volatility in those

³³The estimation strategy follows Frank, Gonzalez-Hermosillo and Hesse [22], which is itself adapted from Engle [18] and Capiello, Engle and Sheppard [10].

shock processes. This can indeed capture the uncertainty and the psychological motives that are pervasive in financial markets and particularly in markets for asset backed securities.

In the model the asset price shock, ψ_t , takes the form of an AR (1) process, $\psi_t = \psi_{t-1}^{\rho_\psi} \exp(\varepsilon_t^\psi)$, which enters the households' first order condition for capital investment as follows:

$$q_t = \frac{1}{\psi_t} \beta E_t \left\{ \frac{u'(C_{t+1})}{u'(C_t)} (q_{t+1}(1 - \delta) + Z_{t+1}) \right\}$$

The liquidity shock is introduced by modeling the subjective probability ζ_t through the following mean reverting process:

$$\zeta_t = (1 - \rho_\zeta) \bar{\zeta} + \rho_\zeta \zeta_{t-1} + \sigma_t^\zeta \quad (35)$$

whose idiosyncratic component has the following ARCH(1) process:

$$\sigma_t^\zeta = (\sqrt{c + \alpha(\varepsilon_{t-1}^\psi)^2 + \beta(\varepsilon_{t-1}^\zeta)^2}) \varepsilon_t^\zeta \quad (36)$$

To determine the parameters of the above processes I take the following two-step strategy. First I estimate a VAR, of order one, in two variables: the quarterly³⁴ series for the S&P 500 index and the 3 month LIBOR_OIS spread (difference between the OIS and the interbank offered rate). Data refer to the US and cover the period Q4-2003 to Q1-2012. The S&P 500 index is used to proxy the shock to asset prices in the model, while the 3 month LIBOR_OIS spread is used to proxy the liquidity shock in the model.

In a second step, using the residuals from the estimated VAR, an ARCH(1) for the LIBOR_OIS spread was estimated. The mean equation contains a constant as well as the lagged S&P 500 index and LIBOR_OIS spread. The variance equation is specified so as to include the lagged squared residuals of the S&P 500 (i.e. the asset price shock) as an additional regressor. The formal specification for the variance equation is as follows:

$$GARCH = c + \alpha * (spread_residual(-1))^2 + \beta * (returns_residual(-1))^2$$

The estimated parameters were used in the calibration of the model's shocks as follows. The correlation between the financial, ε_t^ψ , and the liquidity shock, σ_t^ζ , was computed using the correlation

³⁴The estimation was repeated also with monthly, weekly and daily series. For higher frequency data persistence of shocks, namely the coefficient in the lagged series in the VAR, becomes larger. For regressions at all frequencies significance stays in a range from 92% to 98%. The reason for choosing the parameters estimated under quarterly data stems from the need to match the data frequency in the model.

of the VAR residuals which takes a value of 0.40. This value confirms the initial conjecture that the asset price and the liquidity shocks are indeed positively correlated. The persistence of the asset price shock is taken from the VAR coefficient linking the S&P 500 index to its lagged series and takes a value of 0.8. The persistence of the liquidity shock is taken from the VAR coefficient linking the LIBOR_OIS spread to its lagged series and takes a value of 0.85. The estimated parameters characterizing the GARCH process take the following values: $c = 0.031$, $\alpha = 0.000000253$ and $\beta = 0.17$.

An important aspect in the quantitative assessment of shock processes with stochastic volatility is the role that non-linearities play in the theoretical model. When simulating shocks with stochastic volatility in the theoretical model we cannot rely on simple first order approximations. The assumption of certainty equivalence would indeed miss the volatility driven fluctuations. In second order approximations shocks to the stochastic volatility would not enter the policy function with an independent argument. With third order approximations they would do so (see Fernandez-Villaverde, Guerron-Quintana, Rubio-Ramirez and Uribe [21]). Therefore in what follows the model will be solved using third order approximations whenever asset price or liquidity shocks are considered.

4 Quantitative Properties: The Role of Secondary Markets

In this section I examine the quantitative properties of the model in response to the standard macro shocks, to asset price shocks and to combined asset price and liquidity shocks. The impulse response analysis is used to compare the relative performance of the model with and without credit risk transfer. The validation of the model with credit risk transfer is then done by comparing selected data statistics (standard deviations and auto-correlations of order 1) for selected macro, financial and banking variables.

Figure 1 shows impulse responses of selected variables to a 1% positive productivity shock. The increase in productivity brings about an increase in output, investment demand and in the return on capital. Let's now examine the banking and the financial sector. First, due to the increase in both, the investment demand and the return from investment, both entrepreneurial net worth and bank capital increase (not shown in the figure). As the scale of required investment

increases, both entrepreneurs and banks increase their stake into the projects. The increase in asset prices reduces the severity of the moral hazard problem, as it is easier to meet the incentive compatibility constraints for both banks and entrepreneurs. This implies that the share of returns from the project accruing to banks falls, while the share accruing to the outside investors increases. The bank capital ratio decreases, hence it behaves counter-cyclically with respect to GDP and pro-cyclically with respect to aggregate risk. The behavior of the bank capital ratio is compatible with empirical evidence during the period in which Basel II-type capital requirements were in place. Interestingly in this model the cyclical behavior of the bank capital ratio arises as an endogenous result of market discipline: as the moral hazard problem becomes less severe, capital ratios are relaxed to free up liquidity. The above description applies qualitatively to both models, with (solid line) and without (dashed line) credit risk transfers. However some differences in the quantitative properties arise. In the model with credit risk transfer banks' capital ratio falls by more. In presence of CRT markets banks can accommodate liquidity shocks by selling loans, which reduces the capital required to sustain its lending activity and thus allows banks to lend more. The return to banks falls by a larger amount in presence of credit risk transfer: it becomes easier to satisfy the incentive compatibility constraint. The additional liquidity brought in through the engagement in the secondary market activity allows to increase the overall funding devoted to investment demand, which indeed increases to a larger extent. A similar pattern is observed for output.

Simulations to a government expenditure shock (not reported for brevity but available upon request) show similar dynamics across the two models. Output increases, while consumption and investment fall due to the crowding out effect. Once again the model with credit risk transfer dampens fluctuations in macro variables while amplifying fluctuations in banking and financial variables.

With both macro shocks credit risk transfer provides more liquidity and reduces the extent of project liquidation (the beneficial effect) and at the same time reduces banks' incentives to monitor (the detrimental effect). In presence of stable beliefs about the price in secondary markets, the beneficial liquidity/insurance motive tends to prevail and this tends to stabilize also the dynamic of macro variables (compare to the model without credit risk transfer).

Things are different in presence of asset price and liquidity shocks.

Figure 2 shows impulse responses of selected variables to a 1% (negative) asset price shock (the shock is considered here in isolation from liquidity shocks). As expected output, investment and the return to capital decline. Capital ratios increase (therefore behaving countercyclically), as banks' incentive compatibility constraint is now tighter. Due to both a fall in banks' balance sheet values and a worsening of the moral hazard problems, depositors returns fall while bankers' rents increase. Banks indeed need to be given higher incentives for monitoring and needs to be compensated for the loss in balance sheet values. The quantitative properties of the models' dynamic are different with (solid line) and without (dashed line) credit risk transfer. As before banking variables are more amplified in the model with credit risk transfer: banks' moral hazard is stronger in this case, therefore larger movements in bank capital ratios are needed to discipline incentives to monitor. For the macro variables the impact change is larger for the model without credit risk transfer (investment and output fall by more in this case). For given ζ (notice that here we do not have liquidity shocks, hence the value of this parameter is exogenous) and under the condition that $\frac{c}{\left\{p_h - p_l(1-\zeta) - (1-p_l-p_l\zeta)\frac{\zeta p_h}{1-p_h+\zeta p_h}\right\}} \leq \frac{c}{\theta(p_h-p_l)}$ changes in investment are more sensitive to fluctuations in asset prices in the model without credit risk transfer. Intuitively, in presence of credit risk transfer banks' access to liquidity is easier, therefore the fall in investment, ensuing the fall in asset prices, is dampened.

Figure 3 shows impulse responses of selected variables to a 1% (negative) liquidity shock (the shock here is considered in combination with the asset price shock and correlated to it). As the amount of liquidity available to banks declines, credit to firms declines as well bringing about a fall in output, investment and of the return on capital. In this case and contrary to the previous ones, the amplification in presence of credit risk transfer (solid line) is much larger than in absence of it. The reason for this is as follows. An increase in the probability of a liquidity shock ζ_t tightens liquidity and increases the pooling price in the secondary markets. As the cost of liquidity has increased the fall in investment and output is larger under secondary markets. An increase in the pooling price also implies that it is now easier for banks to recycle toxic loans. As the moral hazard problem has now worsened banks can extract higher rents, but it is also required to hold more capital relatively to the case without credit risk transfer³⁵.

³⁵It is interesting to notice that the business cycle instability is driven solely by the dynamic of the model and the channels behind the CRT market and is independent from the parametrization and the stochastic process governing

Overall we see that under standard macro shocks markets for credit risk transfer tend to smooth aggregate volatilities in the real economy, while amplifying volatilities for banking variables. This is consistent with the evidence presented in section 2.1 which shows that the proliferation of asset backed securities had reduced the volatility of GDP and contributed to the Great Moderation observed prior to the 2007 crisis. The model simulations also show that credit risk transfer can instead have disruptive consequences in presence of combined liquidity and financial shocks. In this case indeed the detrimental effect of credit risk transfer, namely the reduction in monitoring incentives, prevails over the beneficial effects, namely the increase in liquidity and insurance. The result is that under asset price and liquidity shocks the possibility of credit risk transfer can produce severe contractions also in the real economy.

4.1 Comparison of Model Statistics with the Empirical Counterpart

To complete the assessment of the quantitative properties of the model with credit risk transfer and of its empirical validation, table 3 compares a number of statistics (standard deviation and persistence measured by auto-correlation of order 1) in the model with its empirical counterpart. To compute the empirical statistics I use quarterly data for real GDP, consumption, employment, investment, bank capital and the bank capital ratio for both the US and Europe for the period 1992Q4-2009Q4³⁶. The choice of the sample size allows me to strike an optimal balance between the need to guarantee the longest possible sample and the need to exclude more recent years for which the importance and the size of the market for credit risk transfer has fallen sharply³⁷. All data, except the bank capital ratio, have been de-trended with Hodrick Prescott, computed over the entire time sample. For bank capital ratios the statistics have been computed over the quarterly change.

The table shows that the matching is very good. The standard deviations of consumption and employment in the model are somewhat lower than the ones observed in the data, for both in the

the shock. To corroborate this fact I have simulated the same impulse responses under alternative shock assumptions and the qualitative results remain unaltered.

³⁶Data for real GDP, consumption and investment in the US are taken from NIPA-BEA, while data for real GDP, consumption, investment and employment in the euro area as well as employment in the US are taken from the OECD statistics. Data for bank capital as well as for bank capital ratios in the US are taken from the Federal Deposit Insurance Corporation (FDIC), while data for the euro area have been computed by the ECB through back casting procedures.

³⁷Changing the sample size of a few years backward does not change empirical results significantly.

Table 3: **Statistics (standard deviations and autocorrelations of order 1) in the data and the model with credit risk transfer. St.Dev. stands for standard deviation, while Per. stands for the first order autocorrelation.**

Variables	St. Dev. US	St. Dev. EA	Per US	Per EA	St.Dev. Model	Per. Model
Output	1.22	1.18	0.88	0.89	1.45	0.96
Consumption	0.87	0.71	0.86	0.87	0.60	0.92
Employment	0.79	0.64	0.91	0.91	0.51	0.91
Investment	5.3	2.9	0.87	0.91	3.17	0.97
Bank capital	1.76	1.80	0.88	0.85	3.10	0.97
Bank cap. ratio	0.68	1.68	0.84	0.70	0.64	0.54

US and Europe: this is due to the fact that the model neglects nominal or real frictions that would otherwise increase volatility in those two variables. The standard deviation of investment (higher in the US than in the euro area) in the model is closer to the value observed for the euro area. Importantly the model matches well on average both, the standard deviation and the persistence of bank capital and of the bank capital ratio. Both the persistence and the standard deviation of the capital ratio is very close to the ones observed for US data. The standard deviation of the bank capital is somewhat larger than in the data: this is due to the fact that the model does not account for adjustment costs in the market for equity capital.

At last notice that the model performs well in reproducing a negative correlation between GDP and the capital ratio, a fact which many recent macro models with banking fail to reproduce. In the model the correlation between GDP and the bank capital ratio is -0.37. As discussed also in the previous section the countercyclical behavior of the bank capital ratio with respect to GDP is compatible with empirical evidence during the period in which Basel II regulations were in place.

5 Conclusions

This paper constructs a macro model with banks that operate according to the originate to distribute business model. Credit risk transfer produces a trade-off between an improvement in risk insurance and liquidity management (the beneficial effect) and a reduction in banks' incentives toward monitoring (the detrimental effect). The model performs well in capturing the business cycle dynamics of macro and banking variables. For this reason it is well suited also for policy analysis. The model can indeed be fruitfully used to answer questions related to prudential regulation. All

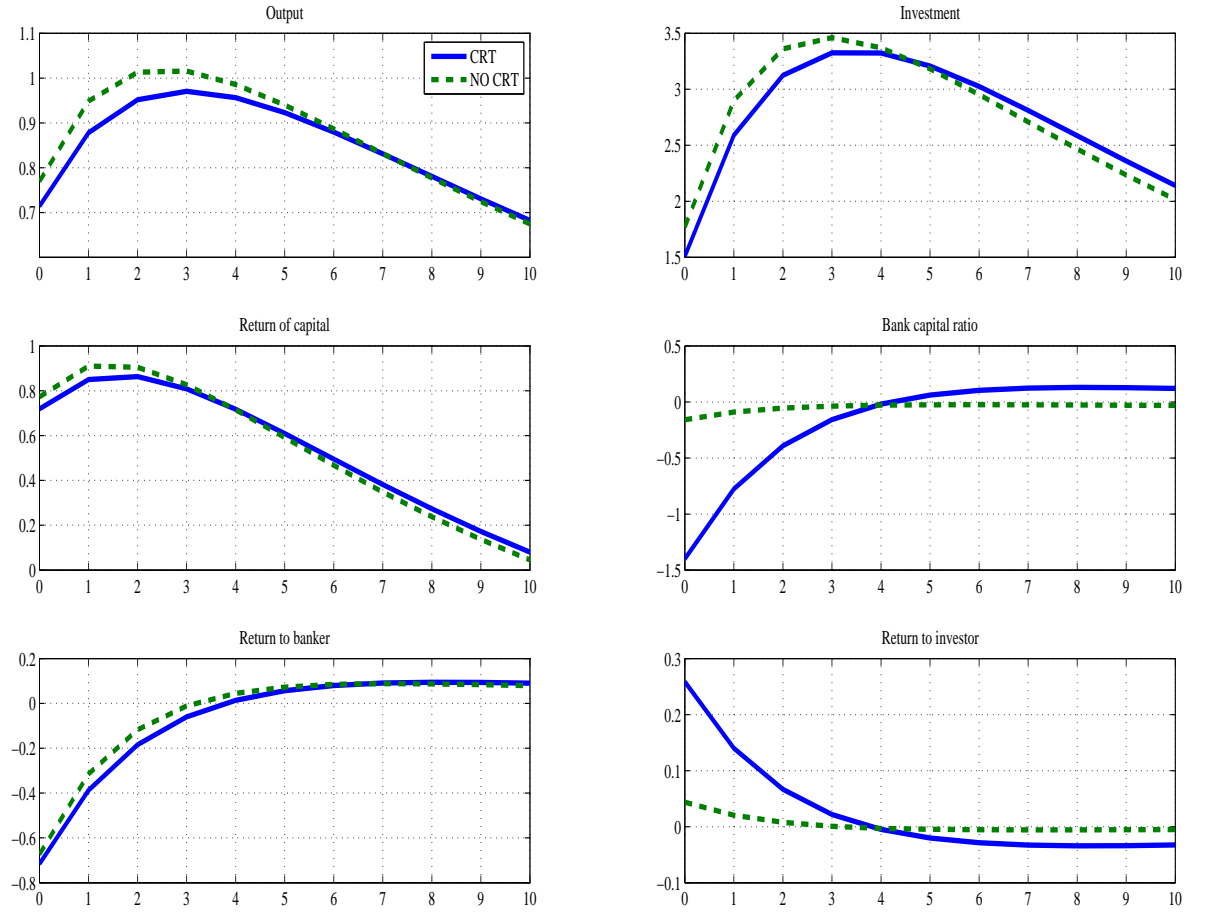


Figure 1: Impulse responses of selected variables to 1% (positive) productivity shock in the model with and without credit risk transfer.

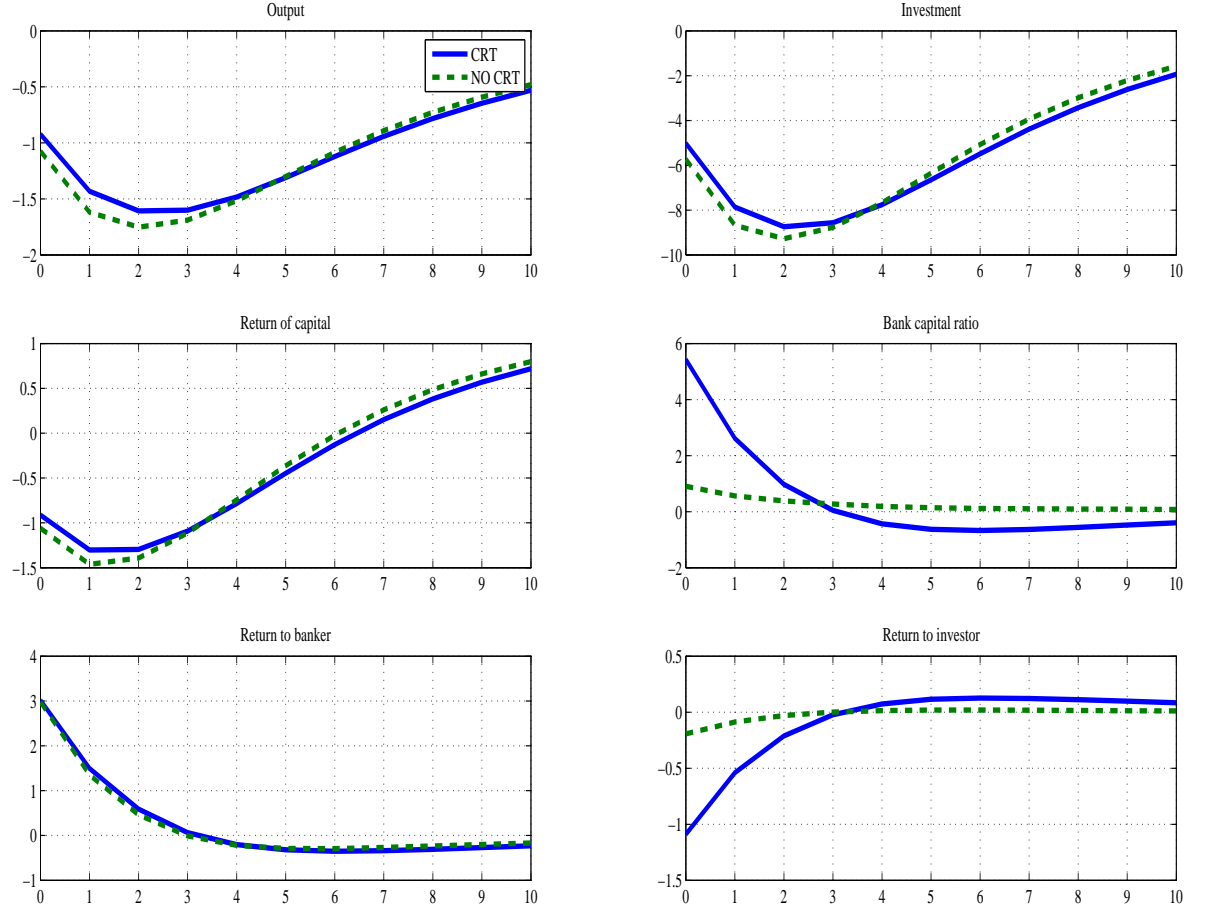


Figure 2: Impulse responses of selected variables to 1% (negative) asset price shock in the model with and without credit risk transfer.

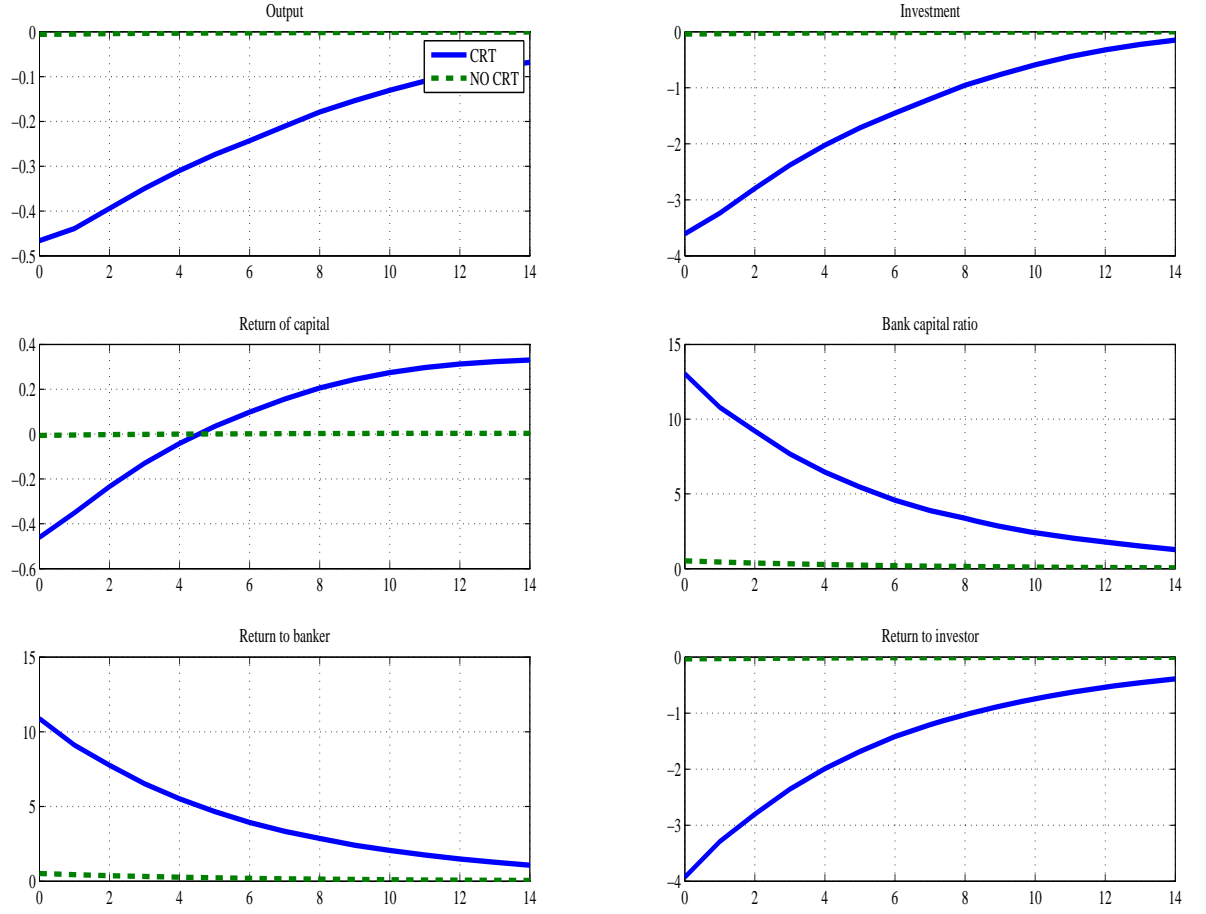


Figure 3: Impulse responses of selected variables to 1% (negative) liquidity shock (considered in combination with the asset price shock and correlated to it) in the model with and without credit risk transfer.

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6 Appendix A. The Evolution of Asset Backed Securities in the Data.

This appendix presents data on the evolution ABS data both in the US and in Europe. Figure 4 to 5 show trends for asset backed securities for the U.S. (figures 4) and Europe (figures 5) for the period 1985-2012. Data refer to both, the outstanding amounts and the new issuances³⁸. Several facts emerge. First, in all cases and as argued before the phenomenon of securitization has a surge in the late 90s with an exponential growth over the last decade. Second, after the crisis there has been a decline in new issuances, but outstanding securities are still largely traded in the market.

7 Appendix B. The Role of Monetary Policy in the Model with Credit Risk Transfer

We have shown above that the model with credit risk transfer can explain some patterns observed in financial markets over the last two decades and can help to interpret the interactions between financial markets and the macroeconomy. This makes the model suitable for policy analysis. The originate to distribute model of banking also features significant frictions: there are indeed resource costs from the monitoring activity, cI_t , as well as informational externalities arising from the pooling equilibrium of the secondary markets. It is therefore interesting to examine the role of policy in overcoming those externalities. To this purpose in this appendix I analyze the role of monetary policy in the model with credit risk transfer. Needless to say the model can also be used to analyze other policies such as financial and prudential policies.

³⁸For the U.S. data for asset backed securities are available for the following sub-categories: automobile, credit cards, home equity, manufactured housing, student loans, equipment and other categories (the last two are ABS on corporate loans which account for the largest fraction). For Europe the distinction between asset backed securities, mortgage backed securities (mixed, commercial and residential) and collateralized debt obligations (which includes ABS on corporate loans) is available. Data are available from SIFMA website and are obtained from combining various sources, which include SIFMA, AFME, Bloomberg, Dealogic, Fitch Ratings, Moody's, prospectus filings, Standard and Poor's, Thomson Reuters.

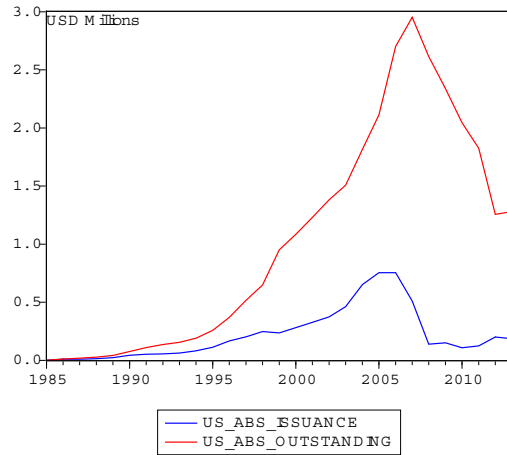


Figure 4: U.S. Asset-backed securities issuance and outstanding for the period 1985-2012. USD. Source: SIFMA.

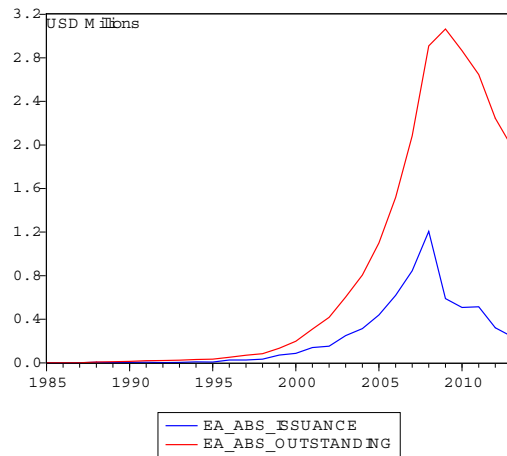


Figure 5: Euro area. Securitization outstanding and issuance for the period 1985-2011, USD. Source: AFME and SIFMA Members, Bloomberg, Thomson Reuters, prospectus filings, Fitch Ratings, Moody's, S&P.

For many years academics and policy makers had advocated for monetary policy a single mandate, namely price stability. The recent financial turmoil reignited the debate on whether monetary policy should have a mandate for financial stability and on whether monetary policy rules responding to financial variables might improve stabilization. Some central banks have indeed changed the scope of their mandate³⁹.

The assignment of a financial stability mandate to the monetary authority might turn particularly useful in presence of information externalities or liquidity disturbances as the ones characterizing my model. I therefore use the model to compare the effects of standard Taylor-type interest rate rules versus rules that respond additionally to asset prices. To this purpose I augment the model with nominal rigidities, by adding quadratic costs of adjustment on prices.

7.0.1 Adding Sticky Prices and Comparing Monetary Policy Rules

Production of goods is now run by two different sectors. A competitive final good sector assembles different varieties through a standard Dixit-Stiglitz aggregator, $Y_t \equiv \int_0^1 [(Y_t^i)^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$. The optimal allocation of expenditure on each variety is given by $Y_t^i = \left(\frac{P_t^i}{P_t}\right)^{-\epsilon} Y_t$, where $P_t \equiv \int_0^1 [(P_t^i)^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$ is the aggregate price index. A monopolistically competitive sector instead produces the different varieties using physical capital and labour. It is assumed that the households are the owners of the monopolistic sector, which indeed rebates to them real profits, Θ_t . Each firm in this sector produces the single variety i and has monopolistic power in the production of its own variety and therefore has leverage in setting the price. In changing prices it faces a quadratic cost equal to $\frac{\vartheta}{2} \left(\frac{P_t^i}{P_{t-1}^i} - 1\right)^2$, where the parameter ϑ measures the degree of nominal price rigidity. The higher ϑ the more sluggish is the adjustment of nominal prices. Each firm rents finished capital and assembles it with labour (supplied by the workers) to operate a constant return to scale production function for the variety i of the intermediate good: $Y_t^i = A_t (H_t^i)^{1-\alpha} (K_t^i)^\alpha$. Each monopolistic firm chooses a sequence $\{K_t^i, H_t^i, P_t^i\}$, taking nominal wages W_t and the rental rate of capital Z_t , as given, in order to maximize expected discounted nominal profits:

³⁹One leading example is that of the Bank of England. After the financial crises in 2008 a new legislation transferred the responsibility for financial regulation and supervision of the banking and insurance industries to the Bank of England. In 2011 a Financial Policy Committee (FPC) has been created to spearhead the Bank's new mandate on financial stability (see Bank of England Quarterly Bulletin first quarter 2013). Although the mandate for financial stability and macro-prudential regulation includes more broadly also the task of surveillance over the banking systems, part of it simply relates to the possibility of setting the interest rate in response to financial market conditions.

$$E_0\left\{\sum_{t=0}^{\infty}\Lambda_{0,t}[P_t^i Y_t^i - (W_t H_t^i + P_t r_t^k K_t^i) - \frac{\vartheta}{2}\left[\frac{P_t^i}{P_{t-1}^i} - 1\right]^2 P_t]\right\} \quad (37)$$

subject to the constraint $A_t(H_t^i)^{1-\alpha}(K_t^i)^\alpha \leq Y_t^i = \left(\frac{P_t^i}{P_t}\right)^{-\varepsilon} Y_t$, where $\Lambda_{0,t}$ is the households' stochastic discount factor. Let's denote by $\{mc_t\}_{t=0}^{\infty}$ the sequence of Lagrange multipliers on the above demand constraint, and by $\tilde{p}_t \equiv \frac{P_t^i}{P_t}$ the relative price of variety i . As all firms are symmetric, I can drop the index i . The first order conditions of the above problem read as follows:

$$\frac{W_t}{P_t} = mc_t A_t (1-\alpha)(H_t)^{-\alpha} (K_t)^\alpha; Z_t = mc_t A_t (H_t)^{1-\alpha} \alpha (K_t)^{\alpha-1} \quad (38)$$

$$\begin{aligned} 0 = & U_{c,t} Y_t \tilde{p}_t^{-\varepsilon} ((1-\varepsilon) + \varepsilon mc_t - U_{c,t} \vartheta \left[\pi_t \frac{\tilde{p}_t}{\tilde{p}_{t-1}} - 1 \right] \frac{\pi_t}{\tilde{p}_{t-1}} + \\ & + \vartheta E_t \left[U_{c,t+1} \pi_{t+1} \frac{p_{t+1}}{p_t} - 1 \right] \pi_{t+1} \frac{\tilde{p}_{t+1}}{\tilde{p}_t^2} \end{aligned} \quad (39)$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross aggregate inflation rate. Notice that all firms employ an identical capital/labour ratio in equilibrium, so individual prices are all equal in equilibrium. The Lagrange multiplier mc_t plays the role of the real marginal cost of production. In a symmetric equilibrium $\tilde{p}_t = 1$. This allows to rewrite equation 39 in the following form:

$$\begin{aligned} U_{c,t}(\pi_t - 1)\pi_t = & \beta E_t \{ U_{c,t+1}(\pi_{t+1} - 1)\pi_{t+1} \} + \\ & + U_{c,t} A_t (H_t)^{1-\alpha} (K_t)^\alpha \frac{\varepsilon}{\vartheta} \left(mc_t - \frac{\varepsilon - 1}{\varepsilon} \right) \end{aligned} \quad (40)$$

The above equation is a non-linear forward looking New-Keynesian Phillips curve, in which deviations of the real marginal cost from its desired steady state value are the driving force of inflation. Calibration of the Phillips curve parameters is done by comparing the log-linear formulation of equation 40, in which the elasticity of inflation to real marginal cost (normalized by the steady-state level of output) takes the form $\frac{\varepsilon-1}{\vartheta}$, with the log-linear formulation of the Phillips curve under the Calvo-Yun approach, for which the slope coefficient can be expressed as $\frac{(1-\hat{\vartheta})(1-\beta\hat{\vartheta})}{\hat{\vartheta}}$, where $\hat{\vartheta}$ is the probability of not resetting the price in any given period. Given a value of the demand elasticity of $\varepsilon = 6$ (this value is compatible with a monopolistic mark-up of 1.2, which is the value

in line with the data), and given a value of $\hat{\vartheta} = 0.75$ (this value is consistent with most empirical evidence on the average length of price adjustment), equating the slope coefficients between the two Phillips curves delivers a value $\vartheta = \frac{Y\hat{\vartheta}(\varepsilon-1)}{(1-\hat{\vartheta})(1-\beta\hat{\vartheta})} \approx 30$, where Y is steady-state output. This model is closed by adding the following resource constraint, $Y_t - cI_t - \frac{\vartheta}{2}(\pi_t - 1)^2 = C_t + C_t^e + C_t^b + I_t + G_t$, and the following monetary policy rule, $\ln\left(\frac{1+r_t^n}{1+r^n}\right) = \left[\phi_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \phi_y \ln\left(\frac{Y_t}{Y}\right) + \phi_f \ln\left(\frac{q_t}{q}\right)\right] + em_t$. In the policy rule all variables are deviations from the target or steady state (symbols without time subscript). As it is standard with Taylor type rules the steady state (net) inflation is set to zero, ϕ_π is set to 1.5 and ϕ_y is set to 0.5/4. The term $\phi_q \ln\left(\frac{q_t}{q}\right)$ indicates the response to asset price. Finally em_t is an AR(1) monetary policy shock whose persistence is set to 0.3 and whose volatility is set to 0.006. Such calibration is consistent with estimates in Rudebusch [36]⁴⁰. Given the presence of inflation we now define the interest rate on deposits as $1 + r_t^n = (1 + r_t^d) \frac{P_{t+1}}{P_t}$.

Figure 6 shows in the model with credit risk transfer the impulse response of selected variables to asset price shocks under two alternative monetary policy regimes. The first regime (solid line) is associated with a standard Taylor rule ($\phi_\pi = 1.5, \phi_y = 0.5/4, \phi_q = 0$), while in the second (dashed line) the interest rate is moved also in response to changes in asset prices $\phi_p = 0.5$ ⁴¹. The response to asset prices appears to have a stabilizing role for many quarters. By stabilizing asset prices the policy maker is actually affecting directly the incentive compatibility constraints of banks and entrepreneurs. Consider more specifically a negative shock, as the one depicted in the figure. By moderating the fall in asset prices, the policy maker can actually facilitate the fulfillment of the incentive compatibility constraints for both, banks and entrepreneurs. This stabilizes investment and output, although at the cost of higher variability in nominal interest rates and inflation. Different is the case of liquidity shocks (see Figure 7) considered in combination with asset price shocks according to the calibration provided in the main text of the paper. In this case the policy maker, by smoothing fluctuations in asset prices, limits the ability of the economy to absorb the liquidity shock, thereby causing large de-leveraging and a consistent fall in investment demand.

⁴⁰Before turning to the comparison of the effects of different monetary policy rules in the model with credit risk transfer, it is useful to confirm that the results obtained above in relation to the comparison of the models with credit and credit risk transfer are valid on this new set up. Credit risk transfers delivers more dampened cycles in response to productivity, government spending and monetary policy shocks. The opposite is true for asset price and liquidity shocks.

⁴¹This coefficient is indicative as there is no historical evidence on rules responding to asset prices.

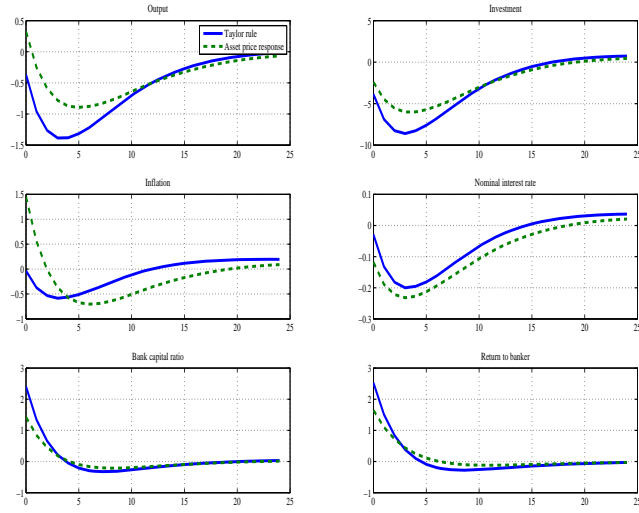


Figure 6: Impulse responses of selected variables to a 1% (negative) asset price shock in the model with credit risk transfer and sticky prices under two alternative monetary policy rules (a standard Taylor rule versus a rule targeting additionally asset prices).

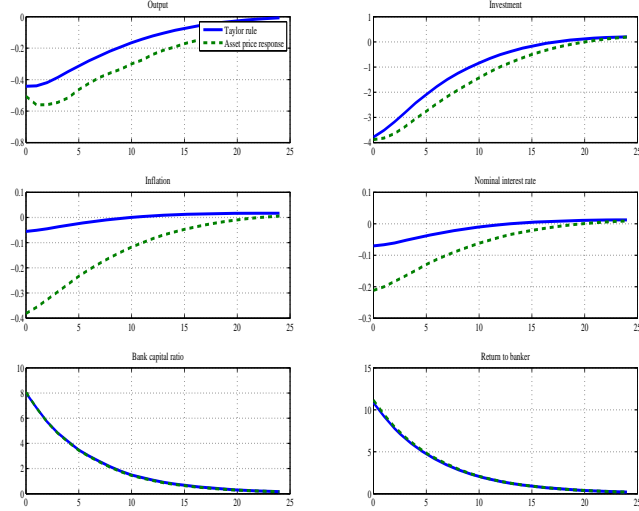


Figure 7: Impulse responses of selected variables to a 1 % (negative) liquidity shock (considered in combination with asset an asset price shock and correlated to it) in the model with credit risk transfer and sticky prices under two alternative monetary policy rules (a standard Taylor rule versus a rule targeting additionally asset prices).