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NOTE

A NOTE ON CREDIT RISK TRANSFER AND THE MACROECONOMY

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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 Recycling

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. Prior to the crisis securitization and credit risk-transfer (CRT) techniques expanded at an unprecedented scale. In normal times, this business model provided insurance and liquidity to the intermediation sector and contributed to stabilize the business cycle. In the presence of nonperforming loans, however, the possibility of transferring credit risk in opaque markets can impair banks' commitment to monitor clients. This channel amplifies the business cycle impact of financial and liquidity shocks, like those occurred in 2007. Against this background, the macroeconomic consequences of the securitization process on macroeconomic and financial stability are largely unknown and unexplored. Many papers now address the interaction between banking and the macroeconomy, none considered the role of CRT.

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My paper fills this gap by embedding a microfounded originate to distribute business model of banking into a standard macromodel. CRT in my model helps banks to insure against liquidity shocks but can have detrimental effects on ex-ante monitoring incentives and on the efficient price of risk. Banks are delegated monitors of firms' projects but can off-load risk in markets for CRT. Although monitoring prevents firms' shirking, it also allows banks to acquire proprietary information as they learn about the firms' project success. This induces asymmetric information between them and uninformed investors in CRT markets. Banks indeed trade in credit derivatives either to insure against liquidity shocks or when they intend to recycle toxic loans. Investors hold subjective beliefs about the probability of banks' liquidity shortage but cannot discern the presence of toxic loans, hence a *pooling* price emerges. Two opposing effects emerge. CRT improves banks' ability to redeploy capital in the face of liquidity shortages without the need for costly project liquidation. On the other side, opacity reduces the informative content of prices and eventually impairs banks' ex-ante incentives to monitor. Misincentives affect the macroeconomy through the dynamic of investment and of banks' and firms' wealth, which in turn depend upon their rents. The latter increase with both moral hazard and asymmetric information.

Whether the beneficial or the detrimental effects of CRT prevail depends primarily on the type of shock that affects the business cycle. In the presence of traditional macroshocks (productivity or government spending), CRT helps to stabilize the business cycle as the improved liquidity management and insurance properties prevail. This effect is 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 modeled as disturbances to investors' subjective probability[1]), the model with CRT produces sharp amplification effects. With those shocks[2] the share of toxic assets increases and so do the banks' proprietary information and its incentives to recycle credit risk. Both asymmetric information and moral hazard problems become more pervasive. Banks' rents become more volatile and so do investment as well as banks' and firms' wealth. The quantitative 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). The model does well in this respect.

Section 2 briefly reviews the literature and shows some stylized facts. Section 3 describes the model. Section 4 shows the model's quantitative implications. Section 5 concludes.

2. LITERATURE REVIEW AND EMPIRICAL FACTS

The finance literature has discussed merits as well as weaknesses of CRT. Some have highlighted its beneficial risk sharing properties and have shown that, conditional on banks' retaining the junior tranche, a signaling price can emerge [see De Marzo and Duffie (1999)]. Other papers instead have stressed the monitoring misincentives associated with loan sales [see Gorton and Pennacchi (1995)], a fact

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TABLE 1. Regression: GDP volatilities (10 years rolling window) over an ABS growth index (United States and EA)

	ABS_index_US	ABS_index_EA
Coefficient	−0.59	−0.43
t-statistic	−2.72	−2.25
P-value	0.03	−0.05

well detected in the empirical literature [see for instance Dell'Ariccia et al. (2008)]. My paper is related to the literature that analyzes jointly asymmetric information in secondary markets and banks' monitoring incentives [see Dell'Ariccia and Marquez (2006)]. I employ the contractual agreement and the market design in Parlour and Plantin (2008), who introduce CRT in Holmström and Tirole (1997). Other papers have introduced Holmström and Tirole (1997) into macromodels [Chen (2001), Meh and Moran (2010)]. None considered CRT and added asymmetric information.

The OTD business model of banking spread quickly in the decade prior to the 2007 crisis [see evidence in European Central Bank (ECB) (2004) and Bank of International Settlements (2005)]. Data from SIFMA[3] show that new issuances declined after the crisis, but trading on outstanding is still very large. Prior to the 2007 crisis, several economists [see Blanchard and Simon (2001)] argued that securitization dampened the effects of productivity and demand shocks and contributed to macroeconomic stabilization (the so-called Great Moderation). Other authors [see Angeloni and Faia (2013), Brunnermeier and Sannikov (2014)] argue that banking coupled with trading in asset-backed securities (ABS) or other short-term liabilities can cushion the economy from traditional macroshocks. I test this hypothesis using data for ABS trading volume outstanding from SIFMA and time series for real gross domestic product (GDP) (data are from the OECD [Organisation for Economic Co-operation and Development]) for the United States and the euro area (EA hereafter) over the period 1990–2007. Using Hodrick–Prescott (HP) detrended GDP series, I compute standard deviations over rolling windows of 10 years.[4] Using the ABS trading volumes for different categories of assets,[5] I compute an index of ABS transaction growth. I then regress the rolling GDP volatilities over the ABS growth index. Table 1 shows that for both the United States and Europe there is a negative relation between the two (the coefficients in the regressions are significant at the 95% or the 97% level). The regression remains robust and significant also when considering different definitions of the ABS index. The negative relation confirms the link between macroeconomic stabilization and ABS growth observed prior to the 2007 crisis. Following the financial shock of 2007, as we know securitization contributed to amplify instability. My model captures well this dual role of CRT, stabilizing in the face of standard macroshocks (at normal times) and destabilizing in the face of financial and liquidity shocks.

3. THE MODEL

The economy is populated by households/workers, entrepreneurs, and a bank.[6] Following standard practice, 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. A competitive sector produces final goods using capital and labor. The sector producing physical capital acquires funds from banks, which in turn obtain funds through deposits. In the presence of CRT markets, banks can also acquire liquidity by selling credit claims. The moral hazard problems arising between firms and the bank and between the bank and uninformed investors is solved via a three-party contract. Firms can influence the probability of success of a project (high, p_h, or low, p_l) and obtain private benefits. Banks' monitoring disciplines firms' moral hazard by reducing, albeit not eliminating, private benefits. Monitoring activity is costly and induce moral hazard between banks and depositors or uninformed investors in CRT markets. Banks' stakes in the project help to discipline moral hazard; however, banks can also off-load risk onto secondary markets. They do so in the face of liquidity shortage or when they learn about nonperforming loans through firms' monitoring.[7] Uninformed investors are unable to distinguish among those two cases, hence a *pooling* price emerges. The possibility of selling claims on risky loans changes the banks' incentive compatibility constraint on monitoring.

3.1. Households and Final Good Firms

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 utility with respect to consumption, C_t, and labor hours, H_t:

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

subject to the following budget constraint, in real terms: $C_t + q_t I_t^h + D_{t+1} = (1 + r_{t-1}^d) D_t + Z_t K_t^h + w_t H_t - \tau_t$, where q_t is the price of capital, I_t^h is the capital investment done by households, $(1 + r_t^d)$ is the gross interest rate received on deposits, D_t are the 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 the real labor income, and τ_t are the 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:

$$u'(C_t) = \beta E_t \left\{u'(C_{t+1})(1 + r_t^d)\right\} \tag{2}$$

$$q_t u'(C_t) = \beta E_t \left\{u'(C_{t+1})(q_{t+1}(1 - \delta) + Z_{t+1})\right\} \tag{3}$$

$$w_t u'(C_t) = -v'(H_t). \tag{4}$$

Equation (3) is the first-order condition with respect to capital holding. Finally, equation (4) is the first-order condition with respect to labor hours. The set of first-order conditions must hold alongside with a no-Ponzi condition on wealth.

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 process, α is the share of capital in production, K_t is the rental physical capital, and H_t is the labor input. Each firm chooses production input optimally by minimizing costs. Standard optimality conditions apply.

3.2. External Finance and Banks

A continuum of entrepreneurs has access to the same technology for producing capital goods, although their returns are subject to idiosyncratic risk, R^j. 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. There exist a continuum of banks that are ex ante identical and across which the performance of the portfolio is independent and identically distributed (i.i.d). Notice that as in Holmström and Tirole (1997) projects' returns are perfectly correlated within the portfolio of a single intermediary, but not across banks. This assumption implies that idiosyncratic project returns do not turn into aggregate risk. Projects produce the same publicly visible returns but have different success probabilities high, p_h, or low, p_l, with $p_l < p_h$.[8] Projects with high success probability have zero private benefits, projects with low probability can provide private benefits high, B, or low, b, with $B > b$. 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. Private benefits are assumed to be proportional to the value of investment, $q_t I_t^j$. Assuming a linear investment technology permits easy aggregation (from now the index j is dropped). Bank monitoring has a cost, c, proportional to the project scale, I_t. Hence, a second moral hazard problem between the bank and depositors or uniformed investors arises. This problem is mitigated by the bank's capital invested in the project, BK_t. However, the possibility that banks can transfer risk onto secondary markets can impair banks' monitoring incentives ex ante. Once the cost of monitoring has been paid, the bank is able to lend an amount $L_t = \mathrm{BK}_t + D_t - cI_t$. The timing of actions is as follows. 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 project's success and/or about liquidity shocks. At last, the bank can engage in a risk-transfer transaction.

Banks engage into CRT trading to insure against liquidity shocks. As in Parlour and Plantin (2008), I assume that the bank has a stochastic discount factor,[9] which becomes indeed higher in the presence of liquidity shocks. Liquidity shocks have several interpretations, such as exogenous increases in capital regulations or liquidity shortages in interbank markets due increased counter-party risk.[10] Liquidity shortages occur with a probability ζ, which can be interpreted as a subjective market belief. Hence, the banks' stochastic discount factor is $\theta \in (0, 1)$ with probability ζ_t and 1 with probability $(1-\zeta_t)$. Such formulation captures unanticipated changes in the opportunity cost of carrying out outstanding loans. In the absence of secondary markets for CRT, the bank is unable to liquidate its investment; hence, the bank's return from the project investment is discounted by the average factor $\bar{\theta}_t = \zeta_t\theta + (1-\zeta_t)$. In the presence of secondary markets, banks can sell loans if a liquidity shock materializes; hence, ex post they enjoy a unitary discount factor. The probability ζ_t will be modeled later on as a GARCH (1) stochastic process (GARCH, generalized autoregressive conditionally heteroskedastic) with stochastic volatility to better capture uncertainty and swings in market sentiment.

3.3. Financial Contract in the Absence of CRT

In the absence of CRT markets, a three-party contract[11] among depositors, the bank, and the entrepreneurs take place. Total project return is linearly divided among depositors, R_t^h, banks, R_t^b, and entrepreneurs, $R_t^e : R_t = R_t^h + R_t^b + R_t^e$. Limited liability ensures that no agent earns a negative return. Entrepreneurs have the bargaining power; hence, the contract is designed to maximize their expected return. 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:

$$\mathrm{Max}_{\{I_t,\mathrm{BK}_t,D_t,R_t^h,R_t^b,R^e\}} q_t p_h R_t^e I_t, \tag{5}$$

subject to

$$p_h R_t^e q_t I_t \geq p_l R_t^e q_t I_t + q_t I_t b \tag{6}$$

$$\bar{\theta}_t p_h R_t^b q_t I_t - c I_t \geq \bar{\theta}_t p_l R_t^b q_t I_t \tag{7}$$

$$\bar{\theta}_t p_h R_t^b q_t I_t \geq (1 + r_t^m)\mathrm{BK}_t \tag{8}$$

$$p_h R_t^h q_t I_t \geq (1 + r_t^d) D_t, \tag{9}$$

where $I_t \leq \mathrm{NW}_t + \mathrm{BK}_t + D_t - cI_t$ and $R_t = R_t^h + R_t^b + R_t^e$. Constraint 6 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 (7) is the incentive compatibility constraint of the bank; it states that the expected returns from monitoring should be higher than the expected returns from nonmonitoring. Equations (8) and (9) are the participation constraints for the bank and the depositors[12] as they state that expected returns form this contract should at least cover market-driven returns. The time t value of the bank's expected payout depends on the average realization of the stochastic discount factor, $\bar{\theta}_t$, and affects both banks incentive and participation constraints. In equilibrium, the incentive compatibility constraints, 6 and 7, hold with equality.[13] The contract delivers the following returns' share structure:

$$R_t^e = \frac{b}{p_h - p_l};\ R_t^b = \frac{c}{\bar{\theta}_t q_t (p_h - p_l)};\ R_t^h = R_t - \frac{b}{p_h - p_l} - \frac{c}{\bar{\theta}_t q_t (p_h - p_l)}. \quad \textbf{(10)}$$

Higher private benefits, b, and higher monitoring costs, c, steepen entrepreneurs' and banks' moral hazard problems and increase their rent extraction, R_t^e and R_t^b. The higher the expected value of the stochastic discount factor, $\bar{\theta}_t$, the lower the returns accruing to the banker, R_t^b. Merging the optimal returns with depositors' participation constraint, 9, delivers the optimal investment schedule: $I_t = \frac{\mathrm{NW}_t + \mathrm{BK}_t}{1 + c - \frac{q_t p_h}{1 + r_t^d}\left(R_t - \frac{b}{p_h - p_l} - \frac{c}{\bar{\theta}_t q_t (p_h - p_l)}\right)}$. The larger the size of an investment the larger are entrepreneurs' and bankers' stakes 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 asset price boom, q_t, increases investment, whereas an increase in the value of alternative risk-free assets, r_t^d, reduces the scale of investment. The bank's reservation value is determined by the market driven rate, which from the banks' participation constraint reads as follows: $(1 + r_t^m) = \frac{\bar{\theta}_t q_t p_h R_t^b I_t}{\mathrm{BK}_t}$. Substituting the banker's return, R_t^b, into the market returns, $(1 + r_t^m)$,delivers the optimal amount of bank capital $\mathrm{BK}_t = \frac{p_h c I_t}{(p_h - p_l)(1 + r_t^m)}$. Higher monitoring costs steepen banks' moral hazard, and in turn, bank capital increases acting as a 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. Finally, the optimal amount of deposits is determined using the participation constraint, 9, combined with the optimal deposit return, R_t^h, and reads as follows: $D_t = \frac{q_t p_h I_t \left(R_t - \frac{b}{p_h - p_l} - \frac{c}{\bar{\theta}_t q_t (p_h - p_l)}\right)}{(1 + r_t^d)}$. Intuitively, the latter is positively related to depositors' returns and negatively related to the risk free rate, r_t^d, which proxies alternative investment opportunities.

3.4. Financial Contract with CRT

If CRT markets are available, the bank can sell claims on loans' cash flows to confront a liquidity shock or to off-load a toxic loan. Investors know that the bank sells claims in the presence of nonperforming loans [with probability $(1 - p_h)$] or alternatively in the face of a liquidity shock (with probability $\zeta_t p_h$). Given this, the following pooling price emerges:

$$r_t = \frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h}. \quad \textbf{(11)}$$

If the probability of a liquidity shock, ζ_t, is zero, the price is also zero as investors know for sure that the bank will sell only bad loans. When $\zeta_t = 1$, the price approaches the unconditional probability of success p_h. Overall ζ_t can be interpreted as the subjective probability that investors assign to liquidity shortages.

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In the presence of CRT, the three-party contract (described in the preceding section) shall be adapted by changing the bank's participation and the incentive compatibility constraints as follows:

$$p_h(1-\zeta_t)R_t^{b,s}q_t I_t^s + (1-p_h+p_h\zeta_t)r_t R_t^{b,s}q_t I_t^s \\ \geq cI_t^s + p_l(1-\zeta_t)R_t^{b,s}q_t I_t^s + (1-p_l+p_l\zeta_t)r_t R_t^{b,s}q_t I_t \quad \textbf{(12)}$$

$$q_t p_h R_t^{b,s} I_t^s \geq (1+r_t^{m,s})\text{BK}_t^s, \quad \textbf{(13)}$$

where the index s denotes equilibrium values in the presence of CRT. Since the bank can sell loans in the face of liquidity shortages, it is no longer forced into early project liquidations; hence, $\bar{\theta}_t$ is equal to 1. When the bank monitors [the left-hand side of equation (12)], it retains the loan when the project is successful or there is no liquidity shortage [joint events with probability $p_h(1-\zeta_t)$], while it decides to sell the loans' claims at a price r_t when the loan is not performing or in face of liquidity shortage [events with probability $(1-p_h+p_h\zeta_t)$]. When the bank does not monitor [the right-hand side of equation (12)], it retains the loan's claims with probability $p_l(1-\zeta_t)$, and it sells them with probability $(1-p_l+p_l\zeta_t)$. Notice that the bank's IC constraint, which captures banks' ex-ante incentives to monitor, changes compared to the case with no CRT. Whether the IC constraint is relaxed or tightened in the presence of CRT depends on the evolution of ζ_t and r_t. With this new contract the return's shares are derived as follows:

$$R_t^{e,s} = \frac{b}{p_h - p_l};\ R_t^{b,s} = \frac{c}{q_t\,[p_h - p_l(1-\zeta_t) - (1-p_l+p_l\zeta_t)r_t]};\ R_t^{h,s} \\ = R_t - R_t^{e,s} - R_t^{b,s}. \quad \textbf{(14)}$$

Notice that now banks' rents, a proxy for banks' misincentives, increase with c but also with r_t. As the price of CRT derivatives increase, it is easier for banks to off-load credit risk; hence, they extract higher rents. Given the above optimal returns' shares, we obtain as before the optimal investment, bank capital, and deposit schedules: $I_t^s = \frac{\text{NW}_t^s + \text{BK}_t^s}{1+c-\frac{q_t p_h}{1+r_t^d}(R_t^s - R_t^{e,s} - R_t^{b,s})}$, $\text{BK}_t^s = \frac{q_t p_h R_t^{b,s} I_t^s}{(1+r_t^m)}$; $D_t^s = \frac{q_t p_h I_t^s R_t^{h,s}}{(1+r_t^d)}$.

Before closing notice that following Parlour and Plantin (2008) I assume that investors in CRT claims do not take into account fluctuations in future cash flows. This would introduce reputational mechanisms, since future defaults and/or future cash flows can be used as a signal on whether the bank has been monitored or not. The possibility of signaling would effectively enlarge the region in which 12 is satisfied.

Households Portfolios with Secondary Markets. In the presence of CRT, households can invest in deposits, physical capital, or in credit derivatives. Based on the Euler 2 the risk-free return is equated to the stochastic discount factor: $\frac{1}{(1+r_t^d)} = \beta E_t\{\frac{u'(C_{t+1})}{u'(C_t)}\}$ and from the investors' participation constraint 9 projects' returns, $R_t^{h,s}$, are linked to $(1+r_t^d)$. Returns from CRT claims, which we call

$(1+r_t^c)$, are given by loans' cash flows; hence $p_h q_t R_t^{h,s} I_t^s$. Moreover, due to arbitrage CRT returns shall equalize gross deposit returns (the household invests in either of the two up to the indifference point); hence $(1+r_t^c) = \frac{p_h q_t R_t^{b,s} I_t^s}{D_t} = (1+r_t^d)$. The arbitrage condition is also consistent also with the contractual condition 9.

Consumption and Asset Accumulation for Bankers and Entrepreneurs. Bankers and entrepreneurs are finitely lived agents and risk neutral with γ^e and γ^b being their respective survival probabilities. Surviving entrepreneurs and bankers receive the contract proceeds in the form of capital goods; hence, $K_t^e = p_h R_t^e I_t$ and $K_t^b = p_h R_t^b I_t$. Those proceeds generate revenues as capital can be rented to the production sector. Both agents consume all available resources at the end of their life according to fractions $(1-\gamma^e)$ and $(1-\gamma^b)$; hence, aggregate consumption schedules are $C_t^e = (1-\gamma^e) q_t p_h R_t^e I_t$; $C_t^b = (1-\gamma^b) q_t p_h R_t^b I_t$. Entrepreneurial and bankers' wealth accumulates according to the returns from renting capital goods, multiplied by the end of period capital. After substituting for the optimal investment schedule, wealth accumulations read as follows:

$$\mathrm{NW}_{t+1} = \gamma^e \left[Z_{t+1} + q_{t+1}(1-\delta)\right] p_h R_t^e \left(\frac{\mathrm{NW}_t + \mathrm{BK}_t}{\Gamma_t}\right) \quad \textbf{(15)}$$

$$\mathrm{BK}_{t+1} = \gamma^b \left[Z_{t+1} + q_{t+1}(1-\delta)\right] p_h R_t^b \left(\frac{\mathrm{NW}_t + \mathrm{BK}_t}{\Gamma_t}\right), \quad \textbf{(16)}$$

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

Equilibrium Conditions. Aggregate capital, $K_t = K_t^h + K_t^e + K_t^b$, evolves according to the following law of motion, $K_{t+1} = (1-\delta) K_t + p_h R_t I_t$. The resource constraint in this economy is given by $Y_t - c I_t = C_t + C_t^e + C_t^b + I_t + G_t$, where G_t is an exogenous government expenditure shock. Government spending is financed through lump sum taxation. The term $-c I_t$ is the resource cost induced by moral hazard.

3.5. Secondary Markets: Liquidity, Efficiency, and Bank Capital

Remark 1 (steady-state properties of CRT). Under CRT banks with liquidity needs are willing to sell their loans in the secondary markets when $\theta \le \frac{\zeta p_h}{1 - p_h + \zeta p_h}$ (liquidity threshold). Aggregate investment is larger under CRT when $\theta \le \frac{p_h}{(p_h - p_l)} - \frac{(1-\zeta) p_l}{(p_h - p_l)} - \frac{(1 - p_l + p_l \zeta)\zeta p_h}{(1 - p_h + \zeta p_h)(p_h - p_l)}$ (efficiency condition).

The CRT market is liquid when the pooling price is higher than the illiquid bank selling price. For given, θ, higher credit rating, as proxied by p_h, makes easier to pass the liquidity threshold. Comparing investment scheduled with and without CRT, we find that the first is higher when $\bar{\theta}(p_h - p_l) \le [p_h - p_l(1-\zeta) - (1 - p_l + p_l \zeta)\frac{\zeta p_h}{1 - p_h + \zeta p_h}]$. Rearranging the latter delivers the efficiency condition above. Without CRT, the bank requires a liquidity premium to hold the loan until maturity, $\frac{1}{\bar{\theta}(p_h - p_l)}$, which is inversely related to θ. Higher premia by draining resources reduce investment.

In models with dual hazard, bank capital has a discipline role. Expansionary shocks, by increasing asset prices, relax the bank's incentive compatibility constraint, reduce the severity of the moral hazard and, in turn, lower capital ratios. In this context, banks' capital ratios behave procyclically (with respect to bank risk and countercyclically with respect to the business cycle). The capital ratio is $bk_t = \frac{\mathrm{BK}_t}{\mathrm{BK}_t + D_t} = \frac{c(1+r_t^d)}{c(1+r_t^d) + R_t^h q_t (p_h - p_l)(1 - r_t^m)}$ in the absence of CRT and is $bk_t^s = \frac{\mathrm{BK}_t^s}{\mathrm{BK}_t^s + D_t^s} = \frac{c(1+r_t^d)}{c(1+r_t^d) + R_t^{h,s} q_t (p_h - \frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h})(1 - r_t^{m,s})}$ in the presence of CRT.

Remark 2. For given ζ_t, to the extent that $R_t^{h,s}(p_h - \frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h})(1 - r_t^{m,s}) > R_t^h (p_h - p_l)(1 - r_t^m)$, an expansionary shock reduces capital ratios, the more so in the presence of CRT.

The condition in Remark 2 is met when $R_t^{h,s} > R_t^h$, $\frac{\zeta_t p_h}{1 - p_h + \zeta_t p_h} \leq p_l$ and $r_t^{m,s} \leq r_t^m$. First, if investors' returns are higher under CRT, it follows that banks' rents, $R_t^{b,s}$, are lower, a signal that bankers' moral hazard is less pervasive. If so it shall be easier to meet bankers' incentive constraint and bank capital can fall by more in the face of expansionary asset price shocks. 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 get easily refinanced, there is less need to raise bank capital. At last, lower market returns (investors' outside option) increase investors' incentives to buy CRT claims, making this market more liquid.

3.6. Calibration and Shock Estimation

Parameters. The time unit is the quarter. Households' utility is $U(C_t, H_t) = \frac{C_t^{1-\sigma} - 1}{1 - \sigma} + \nu \log(1 - H_t)$, where $\sigma = 2$ as in most RBC studies and $\nu = 6$ so that steady-state employment $H \approx 0.3$. The discount factor is $\beta = 0.99$. The share of capital in production, α, is set to 0.3. The quarterly aggregate capital depreciation rate δ is 0.025. The parameters characterizing the banking sector $(p_h, p_l, c, R, b, \gamma^e, \gamma^b)$ are chosen so that both models deliver realistic long-run values for financial variables. p_h, is set equal to 0.97 to reproduce the firms' quarterly failure rate in industrialized countries. The remaining parameters, p_l, c, R, b, are set so as to match the following steady-state values: a de-facto capital ratio, bk, between 7% and 15%[14]; a ratio of investment to output, $\frac{I}{Y}$, around 0.20, and a capital-to-output ratio, $\frac{K}{Y}$, between 9 and 10 like in most RBC studies; an investment to entrepreneurial wealth ratio, $\frac{I}{\mathrm{NW}}$, between 2 and 2.5 in line with firms' data; a quarterly return on bank equity (ROE), $\gamma^b[Z_{t+1} + q_{t+1}(1 - \delta)] p_h R_t^b$, between 5% and 10% in line with ROE data during the period of rapid CRT growth expansions [see references ECB (2007) and Federal Reserve (2008)]; banks' operating costs (labeled as BOC), $\frac{\mu I}{\mathrm{NW}}$, between 4% and 5% of investment. Table 2 below shows parameters and steady-state values in the models with and

TABLE 2. Parameters and steady-state values in the model with and without CRT

No CRT	$c = 0.025$	$R = 1.21$	$b = 0.16$	$\gamma^e = 0.85$	$\gamma^b = 0.58$	$\theta = 0.7$	$p_l = 0.6$
No CRT	$bk = 6\%$	$\frac{I}{Y} = 0.21$	$\frac{K}{Y} = 10.11$	$\frac{I}{\text{NW}} = 2.8$	ROE = 3.8%	BOC = 5.6%	
CRT	$c = 0.011$	$R = 1.21$	$b = 0.16$	$\gamma^e = 0.85$	$\gamma^b = 0.41$	$\theta = 1$	$p_l = 0.7$
CRT	$bk = 15\%$	$\frac{I}{Y} = 0.20$	$\frac{K}{Y} = 9.31$	$\frac{I}{\text{NW}} = 1.89$	ROE = 9%	BOC = 3.7%	

without CRT (notice that ζ is set equal to 0.125 in both models). Robustness checks were performed extensively.

Shocks. Standard macroshocks are calibrated as follows. Productivity shocks follow an AR(1) process (AR, auto-regressive), $A_t = A_{t-1}^{\rho_\alpha} \exp(\varepsilon_t^\alpha)$ with $\rho_{\varepsilon^\alpha} = 0.9$ and $\sigma_{\varepsilon^\alpha} = 0.008$, whereas the log-government spending shock follows the process, $\ln(\frac{g_t}{g}) = \rho_g \ln(\frac{g_{t-1}}{g}) + \varepsilon_t^g$, with g set so that $\frac{g}{y} = 0.22$, with $\rho_{\varepsilon^g} = 0.9$ and $\sigma_{\varepsilon^g} = 0.004$. Both shocks have standard calibration in the macroliterature. Financial and liquidity shocks are instead estimated through a combination of vector auto-regressive (VAR) and GARCH(1) models.[15] In the model, the asset price shock, ψ_t, follows an AR (1) process, $\psi_t = \psi_{t-1}^{\rho_\psi} \exp(\varepsilon_t^\psi)$, and enters households' first-order condition for capital investment as follows: $q_t = \frac{1}{\psi_t} \beta E_t \{\frac{u'(C_{t+1})}{u'(C_t)} (q_{t+1}(1-\delta) + Z_{t+1})\}$.The liquidity shock affects the subjective probability ζ_t through the following mean reverting process: $\zeta_t = (1-\rho_\zeta)\bar{\zeta} + \rho_\zeta \zeta_{t-1} + \sigma_t^\varsigma$, whose idiosyncratic component follows an ARCH(1) process (ARCH, autoregressive conditional heteroskedasticity).[16] To calibrate the parameter of those shocks, I first estimate a VAR, of order one, in two variables, namely the quarterly series for the S&P 500 index, which proxies the asset price, and the 3 month LIBOR_OIS spread (The difference between the London Interbank Offered Rate (LIBOR) and the Overnight Indexed Swap (OIS) rate), which proxies the liquidity shock.[17] In a second step, using the residuals from the estimated VAR, I estimate an ARCH(1) for the LIBOR_OIS spread.[18] The model correlation between ε_t^ψ and σ_t^ς is set equal to the estimated correlation of the VAR residuals (a value of 0.40). The persistence of the asset price shock in the model is set equal to the estimated VAR coefficient linking the S&P 500 index to its lagged series (a value of 0.8). The persistence of the liquidity shock, ρ_ζ, is set equal to the estimated VAR coefficient linking the LIBOR_OIS spread to its lagged series (a value of 0.85). The estimated parameters of the GARCH process are used to calibrate σ_t^ς.

Simulation Method. The presence of stochastic volatility makes even more salient the role of nonlinearities in the model. To exploit this under those shocks, I simulate the model using third-order approximations.

4. QUANTITATIVE PROPERTIES: THE ROLE OF SECONDARY MARKETS

I use impulse response analysis to compare the macrodynamic with and without CRT. Figure 1 shows impulse responses of selected variables to a 1% positive

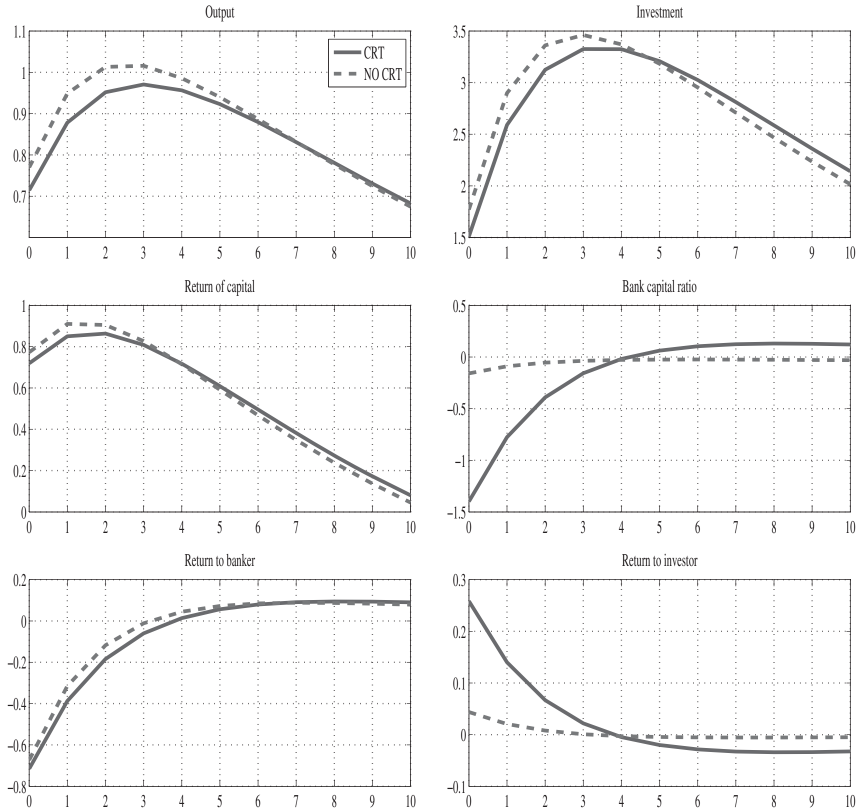

FIGURE 1. Impulse responses of selected variables to 1% (positive) productivity shock.

productivity shock. As in standard macromodel output, investment demand and the return on capital all increase. The increase in projects' returns, in turn, increase entrepreneurial and bank wealth (not shown in the figure) and also their stakes in the projects. The ensuing asset price boom makes it easier to meet all the incentive compatibility constraints. The extent of moral hazard falls, thereby reducing banks' rents and increasing investors' returns. As a result, the bank capital ratio falls (countercyclically with respect to GDP, procyclically with respect to risk and compatibly with empirical evidence during the Basel-II regulation) as discipline is less needed. The above description applies qualitatively to both models, with (solid line) and without (dashed line) CRT. In the model with CRT, however, the banks' capital ratio and rents fall by more: CRT facilitates liquidity insurance and management, which, in turn, makes easier to satisfy the banks' incentive compatibility constraint, and reduces the extent of moral hazard hence banks' rents. The beneficial insurance and liquidity properties of the CRT model prevail over the impaired monitoring abilities: As a result output and investment are more

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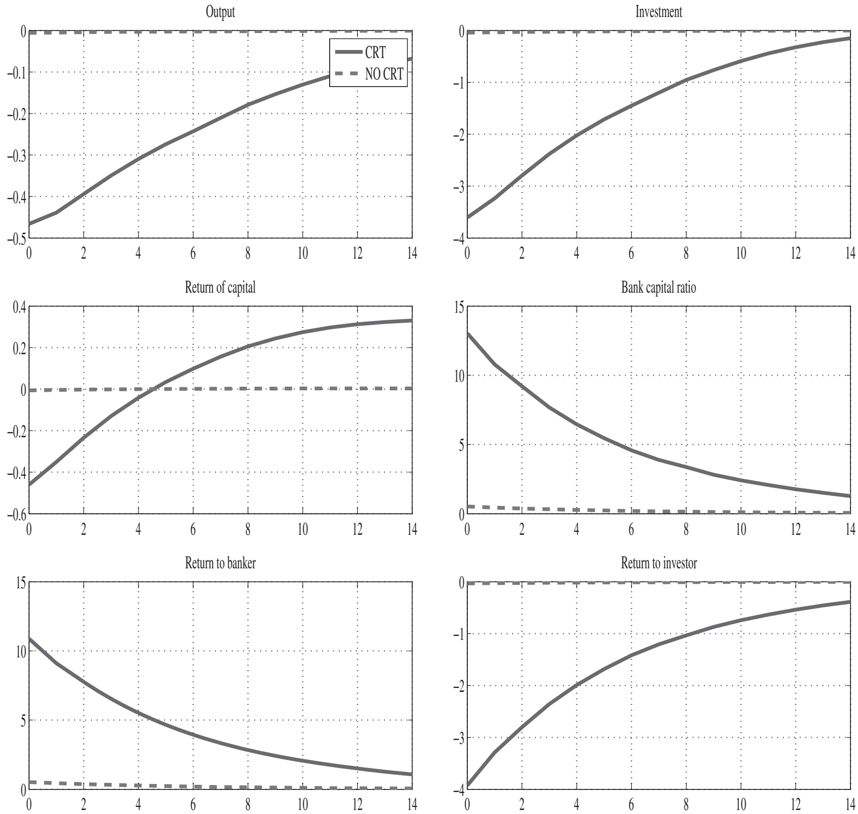

FIGURE 2. Impulse responses of selected variables to 1% (negative) combined liquidity/financial shock.

stable. Simulations to a government expenditure shock (not reported for brevity but available upon request) show similar qualitative dynamics across the two models.

Things look different under liquidity and financial shocks. Figure 2 shows impulse responses of selected variables to a 1% (negative) liquidity shock considered in combination with the asset price shock and correlated to it. The banks' liquidity shortage shrink firms' credit, which, in turn, reduces output, investment, and the return on capital. In this case and contrary to the case with standard macroshocks, the amplification under CRT (solid line) is much larger than in its absence. 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 CRT. Overall projects' returns fall (hence, also R_t^e, R_t^h, and R_t^b): This is consistent with evidence showing that in the face of liquidity shocks fire sales trigger falls in projects' returns. An increase in the pooling price also implies that it is now easier for banks to recycle toxic loans

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TABLE 3. Statistics (standard deviations and autocorrelations of order 1) in the data and the model with credit risk transfer

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	1.42	0.96
Consumption	0.87	0.71	0.86	0.87	0.61	0.91
Employment	0.79	0.64	0.91	0.91	0.52	0.88
Investment	5.3	2.9	0.87	0.91	3.15	0.97
Bank capital	1.76	1.80	0.88	0.85	3.09	0.97
Bank capital ratio	0.68	1.68	0.84	0.70	0.77	0.59

Note: St. Dev. stands for standard deviation, whereas Per. stands for the first-order autocorrelation.

as agents cannot distinguish perfectly between ζ_t and p_h. As markets are more opaque banks' ex-ante monitoring incentives are also weakened. It is now more difficult and costly to maintain banks' monitoring incentives; hence, the share of bankers' returns increases relatively to the share of investors' returns. Weakened monitoring also comes along with higher bank capital ratios.[19]

Overall, we conclude that the standard macroshocks' CRT helps to stabilize the economy since the beneficial insurance properties prevail, the opposite is true with combined financial/liquidity shocks.

4.1. Comparison of Model Statistics with the Empirical Counterpart

The quantitative assessment of the model with CRT is completed through an empirical validation. Table 3 compares a number of statistics in the model with its empirical counterpart. I use quarterly data for real GDP, consumption, employment, investment, bank capital, and the bank capital ratio for both the United States and Europe for the period 1992Q4–2009Q4.[20] 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 CRT has fallen sharply.[21] All data, except the bank capital ratio, have been detrended with HP, computed over the entire time sample. Bank capital ratios statistics are computed over quarterly changes.

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 United States and Europe. This is due to the fact that the model neglects nominal or real frictions. The standard deviation of investment (higher in the United States than in the EA) in the model is closer to the value observed for the EA. 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 are very close to the ones for the United States. 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 (the model based value is -0.29), a well-known fact during the Basel-II era.

5. CONCLUSIONS

This paper constructs a macromodel with banks that operate according to the originate to distribute business model. CRT 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 this is left for future research.

NOTES

1. This captures well the uncertainty and the swings in market sentiments that are pervasive in those markets.
2. I calibrate those shocks using estimated parameters from a VAR in the (quarterly) S&P 500 index and the 3 month LIBOR_OIS spread. The latter is subsequently estimated as GARCH(1) with an heteroskedastic component. To capture the effects of nonlinearities, I simulate the model through third-order approximations.
3. The Securities Industry and Financial Markets Association in the United States.
4. GDP data for the period 1992:Q4–2011:Q4 have been HP filtered (1,600 smoothing parameter). The GDP volatility was calculated on a rolling window starting with 1992:Q4–2000:Q4 and going forward until 2007.
5. Data on ABS are nominal in U.S. dollars: They have been deflated with the U.S. GDP deflator taken from the FRED database.
6. An index b is used to indicate bankers' variables, an index e is used for entrepreneurs' variables, and an index h is used for investors.
7. In the model, I examine a more general case than the one derived in Parlour and Plantin (2008): They assume that the investment project succeeds with probability p if the bank monitors and with probability 0 if it does not. 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.
8. Notice that I extend the Parlour and Plantin (2008) as follows. They assume that a project succeeds with probability p if the bank monitors and with probability 0 if it does not. In my model, I assume instead that projects succeed with probability p_h if the bank monitors and with probability p_l if the bank does not monitor.
9. Notice that differently from Parlour and Plantin (2008), I assume that banks do not apply any discounting between 0 and 1, but do face a stochastic discounting between 1 and 2.
10. Abrupt and large increases in liquidity hoarding by banks have been observed in the most acute phases of the financial crisis after September 2008 both in the United States and in Europe.
11. Repetition of contracts across period is consistent with recursivity due to anonymity.
12. Since households are risk averse, they discount all their expected returns by the stochastic discount factor $\Lambda_{t,t+1} = E_t\{\frac{u_{c,t+1}}{u_{c,t}}\}$. Since such a stochastic discount factor applies to both sides of the participation constraint [equation (9)] and since project returns are i.i.d., it can be canceled out.
13. See Holmström and Tirole (1997).
14. See the EU banking sector stability report of 2007 and the Profits and Balance Sheet Developments at U.S. Commercial Banks.

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15. See similar estimation strategies in Engle (2002).

16. The ARCH process takes the following form: $\sigma_t^{\zeta} = (\sqrt[2]{(c + \alpha(\varepsilon_{t-1}^{\psi})^2 + \beta(\varepsilon_{t-1}^{\zeta})^2})\varepsilon_t^{\zeta}$.

17. Data refer to the United States and cover the period Q4-2003 to Q1-2012.

18. Whose variance equation reads as: GARCH $= c + \alpha *$ (LIBOR_OIS_residual$(-1))^2 + \beta *$ (S&P500_residual$(-1))^2$.

19. Through robustness checks I have verified that the qualitative result in the text is independent from the parameterization and the stochastic process governing the shock.

20. Data for real GDP, consumption and investment in the United States are from NIPA-BEA National Income and Product Accounts–US Bureau of Economic Analysis), data for real GDP, consumption, investment and employment in the EA and for employment in the United States are from the OECD statistics. Data for bank capital and bank capital ratios in the United States are from the Federal Deposit Insurance Corporation (FDIC); data for the EA have been computed by the ECB through back casting procedures.

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

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