How does currency diversification explain banks' leverage procyclicality?*

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ABSTRACT:

The amplitude and dynamics of the leverage procyclicality are heterogeneous across banks and across countries. This paper explores whether currency diversification of bank's balance sheet is a factor of this observed heterogeneity. The theoretical model predicts that the impact of currency diversification on bank's leverage procyclicality depends on the relative performance of economies, the global business cycle and the exchange rate regime. Using novel micro data on banks located in France, I show that the pre-crisis currency diversification of banks increases banks' leverage procyclicality during the 2008-2009 crisis. Focusing on the foreign exchange rate impact, namely the valuation effect of currency diversification, my results suggest that it had a negative effect on leverage procyclicality during this period. These findings confirm the theoretical prediction and draw attention to the specific role of balance sheet currency diversification in financial stability risk.

JEL classification: F36, G15, G21, G32

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1 Introduction

The procyclical dimension of banks' leverage defined by Shin [2012] and Adrian and Shin [2014] has been a subject of keen interest, especially in the wake of the crisis. In this framework, banks' leverage is the ratio of total assets to equity and leverage procyclicality refers to the cyclical variations of their leverage according to the value of their assets that are used as collateral. The higher the collateral value, the larger the banks' capacity to raise funds and extend leverage. Extending their leverage, banks strengthen the value of assets and create an endogenous mechanism similar to the financial accelerator ([Danielsson. et al., 2012]). Because of the amplification of booms and bursts, the procyclicality of banking activities is a major source of economic instability: the identification of the determinants of leverage procyclicality is then a matter of general interest.

Focusing on US, European and Canadian banks, Adrian and Shin [2008], Kalemli-Ozcan et al. [2012], Baglioni et al. [2013], Damar et al. [2013] confirm the general procyclicality of banks' leverage: there is a strong and positive correlation between the growth rate of assets and the growth rate of leverage. However, their results raise the question of heterogeneity in leverage procyclicality as banks located in different geographic areas show different level of leverage procyclicality. Especially, Kalemli-Ozcan et al. [2012] show that European banks exhibit less procyclical leverage than their American counterpart, leaving the source of this heterogeneity unexplained. Acknowledging the global architecture of international banking, Bruno and Shin [2015] define a general framework with a global and a regional representative bank. While this framework provides a first insight on the role of international banking by capturing the aggregate leverage procyclicality as a function of a common risk factor, it does not explain the observed heterogeneity mentioned in Kalemli-Ozcan et al. [2012] either.

Milesi-Ferretti et al. [2011] confirm high heterogeneity in the impact of the crisis and suggest that the extent of international financial integration and banking involvement could play a role. Banks having different exposures to different markets and risks may then exhibit distinct leverage procyclicality. Comparing Americain and euro area (EA) banks, Baba et al. [2009] highlight a transatlantic asymmetry in international banking: assets of EA banks denominated in US dollars account for about \$4.5 trillion in 2008, while the assets of US banks denominated in European currencies only amount to \$1.5 trillion. This specific international involvement of European banks makes them crucial intermediates in cross-border credit (Cerutti et al. [2017]). To some extent, it could also explain the observed heterogeneity in their cyclical variations of leverage. Focusing on aggregate data on European banks, Krogstrup and Tille [2017] introduce the heterogeneity in banks' balance sheet as an additional variable to explain the heterogeneous responses to global risk factor. They show that foreign currency mismatch in banks' balance sheet has a significant impact on the responses to global shock. Using microdata for emerging markets, Baskaya et al. [2017] show that banks' funding heterogeneity is the main driver of aggregate credit growth.

This paper contributes to the recent literature which focuses on banking heterogeneity by analyzing the impact of bank's currency diversification on bank's leverage procyclicality. Currency diversification is the share of assets (or liabilities) denominated in one specific currency. By identifying the currency denomination of assets and liabilities, I pay attention to the fact that not all foreign currencies are alike, especially when it is associated to financial stability risk (Krogstrup and Tille [2016]). The contributions of this paper are twofold. The first contribution is theoretical while the second is empirical.

The first contribution can be found in the capacity of the model to depict two main channels of international banking, namely the risk diversification and the valuation effect of foreign exchange rate. In this paper, I use a contract model a la Holmström and Tirole [1997] between the bank and the creditor to micro-found the Value-at-Risk (VaR) rule. The VaR rule stipulates that banks maintain a stable probability of failure, implying an increase in leverage when the economy is booming and a decrease in leverage when the economy is bursting. Banks' leverage is procyclical due to the VaR rule. Because the VaR measures the tail risk of banks, it is also determinant for banks' systemic risk and relevant for economic stability.[1] The main difference with Adrian and Shin [2014] where a contract model is also used to micro-found the VaR is the distribution of bank's asset returns. Here, the distribution of bank's portfolio depends on a mixture of distributions between the different asset returns and is especially compatible with the global involvement of banks. It allows to capture and depict two main channels of international banking, namely the diversification of risk and the valuation effect due to foreign exchange rate. My model also differs from the general theoretical framework presented in Bruno and Shin [2015] for three reasons. First, it micro-founds the VaR instead of applying it to the cross-border network. Second, it captures the currency diversification of banks and addresses more globally the international banking issue by fitting the stylized facts on European banks detailed above.[2] Third, it makes the exchange rate fluctuations endogenous to relative economic performances.

I focus in this paper on the diversification between domestic and foreign assets but the simplicity of the framework may allow researchers to use it for different purposes, like a diversification between different sectors or different types of assets. Regarding currency diversification, the model shows that introducing foreign asset and debt in foreign currency does not remove the micro-foundation of the VaR but it impacts the

[1] As supported by Benoit et al. [2013], the systemic risk of banks captured by $\Delta CoVaR$ is proportional to the VaR, under certain conditions.

[2] The model defined in Bruno and Shin [2015] includes an exogenous exchange rate, a global bank, a regional bank, and a local firm. Both the global and the regional bank carry out their financial operations in foreign currency, therefore there is no currency diversification in their balance sheets. In contrast, the local firm invests in local currency and raises debt from the regional bank in foreign currency. Thus, currency risk is only borne by the local firm and banks' portfolio only consists of one common risk factor.

adjustment of leverage, i.e the leverage procyclicality, through the tail risk of banks. When the foreign economic condition is more volatile than the domestic one under a fixed exchange rate regime, leverage becomes more procyclical with currency diversification than without. Similarly, currency diversification reduces leverage procyclicality when the foreign economic condition is less volatile than the domestic one. Valuation effect aside, the generalized conclusions of the model also support previous results from Kwok and Reeb [2000] which visit the upstream downstream hypothesis of internationalization. A floating exchange rate regime then introduces a valuation effect on converted asset and debt which impacts leverage adjustment. Assuming that currency appreciates when its economy outperforms others, a floating exchange rate decreases the tail risk and expands the bank's capacity to raise funds. Compared to a fixed exchange rate regime, valuation effect increases procyclicality during booms and decreases it during burst. This model then implies two distinct components explaining the heterogeneous leverage procyclicality: a diversification of risks between the two countries and a valuation effect due to floating exchange rate regime.

The second contribution is an empirical one. Using novel micro data on banks, this paper is then the first one to measure currency diversification of banks balance sheet and its implication on leverage procyclicality. These granular data allow me to dig deeper compared to Krogstrup and Tille [2017] and to measure the two components of heterogeneous leverage procyclicality. By focusing on both the leverage procyclicality of banks and on the currency diversification of their balance sheet, this paper not only captures activities associated to foreign exposures but also purely domestic activities. It then provides a complete picture of banks' activities (domestic and foreign) and draws attention to the specific role of balance sheet currency diversification in financial stability risk. Following theoretical predictions, banks with exposures to the US and the US dollar are supposed to show different leverage procyclicality during the 2008-2009 crisis than banks with low diversification. Considering banks located in France and the 2008-2009 crisis coming from the US, an increase in leverage procyclicality due to currency diversification is then to be expected during this period. Focusing on the valuation effect of currency diversification; however, one can expect that it had a negative impact on leverage procyclicality because of the floating exchange regime. Especially, did the pre-crisis currency diversification of assets in 2007 affect the large adjustment of banks' balance sheet during the crisis between 2008 and 2009? If it is the case, how did it affect it? My results yield supporting evidences to my theoretical predictions: currency diversification had increased leverage procyclicality during the 2008-2009 crisis; however, the valuation effect itself had a negative impact on leverage procyclicality.

The rest of the paper is organized as follows. Section 2 introduces the theoretical model while section 3 develops the quantitative analysis using innovative micro-data. Section 4 concludes.

2 Model

2.1 Setting

The model is based on a representative bank's balance sheet. The bank invests in assets and raises funds from its creditor. Here, though, there are two currency denominations for assets and debts, corresponding to two different countries (domestic and foreign). The economic state of nature corresponding to each economy is known publicly and determine the distribution of asset returns. There are two periods T=0,1. The state of nature and the distribution of returns are known at T=0.

The representative bank is domestic in the sense that its equity and its balance sheet are in domestic currency. The bank is risk neutral and equity E is exogenous.[3] The second agent is the creditor of the bank, generally a Money Market Fund or another investment bank. The creditor lends money to the bank in both currencies (domestic and foreign). The creditor is also risk neutral. The exchange rate S is defined as the number of domestic units per unit of foreign currency.

At T=0, the bank raises funds backed by collateral in domestic and foreign currency (A and $A^\star$, respectively). Total assets expressed in domestic currency are equal to $A+SA^\star$. I denote by a the share of assets in domestic currency and $(1-a)$ the share of assets in foreign currency. a will vary depending on S. In this section, I consider S as fixed. Section 2.4 covers the case of a flexible exchange rate regime. Funds are in domestic and in foreign currency (D and $D^\star$, respectively). Thus, total funding from the creditor expressed in domestic currency is equal to $D+SD^\star$. This debt is defaultable, implying that the creditor receives a defaultable debt claim at T=0.

At T=1, the bank receives a total expected return from its investments $a(1+\bar{r})+(1-a)(1+\bar{r}^\star)$, where $\bar{r}$ and $\bar{r}^\star$ are the expected returns from the domestic and the foreign asset, respectively. Returns depend on the state of nature specific to each currency area, θ and $\theta^\star$, respectively. θ and $\theta^\star$ are known publicly from T=0 and they do not change between the two periods. At T=1, the bank also reimburses its domestic and foreign debts, $\bar{D}$ and $S\bar{D}^\star$ respectively. As θ and $\theta^\star$ are known for the two periods, there is no macroeconomic risk. It is assumed that $\bar{D}>D$ and $S\bar{D}^\star>SD^\star$ to remunerate the creditor for the default risk.

The bank's balance sheets at each period are given in table 1 where $\bar{E}$ is the equity at notional value.

[3] An exogenous equity is in line with the theory of procyclical leverage put forward by Shin.

T=0, at market value:	
Assets	Liabilities
A	E
$SA^\star$	D
	$SD^\star$

T=1, at notional value:	
Assets	Liabilities
$(1+\bar{r})A$	$\bar{E}$
$(1+\bar{r}^\star)SA^\star$	$\bar{D}$
	$S\bar{D}^\star$

Table 1: Bank's balance sheet at T=0 and T=1

Four debt ratios are defined relative to each funding currency and each period. The debt ratios at T=0 are:

$$d = \frac{D}{A+SA^\star} \quad \text{and} \quad d^\star = \frac{SD^\star}{A+SA^\star} \tag{1}$$

Alternatively, the corresponding ratios of notional values of debt at T=1 to total assets at the market value are:

$$\bar{d} = \frac{\bar{D}}{A+SA^\star} \quad \text{and} \quad \bar{d}^\star = \frac{S\bar{D}^\star}{A+SA^\star} \tag{2}$$

$\bar{E}$ is the equity at the notional value that sets the two sides of the balance sheet equal. The bank is expected to make profits such that $E < \bar{E}$ and $a(1+\bar{r}) + (1-a)(1+\bar{r}^\star) > (\bar{d}+\bar{d}^\star)$.

The leverage λ is defined as the ratio of total assets to equity, at market value:

$$\lambda = \frac{A+SA^\star}{E} = \frac{A+SA^\star}{(A+SA^\star)-(D+SD^\star)} = \frac{1}{1-(d+d^\star)} \tag{3}$$

Following Adrian and Shin [2014], I use a contract model from Holmström and Tirole [1997] to micro-found the Value-at-Risk rule and define bank's leverage. Knowing the states of nature at T=0,1 and the asset distributions, the bank and the creditor identify at T=0 the potential reimbursement at T=1 which satisfies the VaR Rule. This potential reimbursement $(\bar{d}+\bar{d}^\star)$ is part of the participation constraint of the creditor and it defines the total debt the creditor is willing to lend to the bank at T=0 and the leverage. The rest of the section is devoted to the development of the contract model and the detailed theoretical results.

2.2 Investment strategy

To introduce the contract model between the creditor and the bank as in Holmström and Tirole [1997], the bank makes an indivisible choice between two types of portfolio: a good portfolio indexed by $\{H, H^{\star}\}$ and a less good portfolio $\{L, L^{\star}\}$. Each portfolio is composed of an asset in domestic currency and an asset in foreign currency, where an asterisk indicates foreign assets. The weight of each type of asset is given by a and $(1-a)$. The portfolio's distribution comes from a mixture distribution of the two asset return distributions. Assuming that each asset return follows a General Extreme Value (GEV) distribution, the portfolio's return is also defined by a GEV distribution. The first portfolio $\{H, H^{\star}\}$ is a "good" portfolio with a total expected return of $[ar_H + (1-a)r_{H^{\star}}]$, where r_H denotes the expected return from the good domestic asset and $r_{H^{\star}}$ the expected return from the good foreign asset. The second portfolio $\{L, L^{\star}\}$ is not as good. Its total expected return $[ar_L + (1-a)r_{L^{\star}}]$ is reduced through a parameter k ($k > 0$) and its volatility is increased by a parameter m ($m > 1$) compared to the good portfolio.

The Cumulative Distribution Functions (CDF) of portfolio return when the bank invests in the good portfolio or in the less good portfolio are respectively: [4]

$$\begin{aligned} F_{H,H^\star}(z) &= a\ F_H(z) + (1-a)\ F_{H^\star}(z) \\ &= a\ exp\left\{-\left(1+\xi\left(\frac{z-\theta}{\sigma}\right)\right)^{-\frac{1}{\xi}}\right\} + (1-a)\ exp\left\{-\left(1+\xi\left(\frac{z-\theta^\star}{\sigma}\right)\right)^{-\frac{1}{\xi}}\right\} \end{aligned} \tag{4}$$

$$\begin{aligned} F_{L,L^\star}(z) &= a\ F_L(z) + (1-a)\ F_{L^\star}(z) \\ &= a\ exp\left\{-\left(1+\xi\left(\frac{z-(\theta-k)}{\sigma m}\right)\right)^{-\frac{1}{\xi}}\right\} + (1-a)\ exp\left\{-\left(1+\xi\left(\frac{z-(\theta^\star-k)}{\sigma m}\right)\right)^{-\frac{1}{\xi}}\right\} \end{aligned} \tag{5}$$

Thus, the total expected return of the portfolio depends on the state of nature in the domestic country (θ) and in the foreign one ($\theta^\star$).

The CDF defines the probability of default α when the bank invests in the good portfolio. Default appears if the realized total return falls below the total debt ratio at the notional value ($(\bar{d} + \bar{d}^\star) \geq z$). Thus, the probability of default α is defined by the

[4]Where: $F_H(z) = exp\left\{-\left(1+\xi\left(\frac{z-\theta}{\sigma}\right)\right)^{-\frac{1}{\xi}}\right\}$, $F_{H^\star}(z) = exp\left\{-\left(1+\xi\left(\frac{z-\theta^\star}{\sigma}\right)\right)^{-\frac{1}{\xi}}\right\}$
$F_L(z) = exp\left\{-\left(1+\xi\left(\frac{z-(\theta-k)}{\sigma m}\right)\right)^{-\frac{1}{\xi}}\right\}$, and $F_{L^\star}(z) = exp\left\{-\left(1+\xi\left(\frac{z-(\theta^\star-k)}{\sigma m}\right)\right)^{-\frac{1}{\xi}}\right\}$
Where θ, σ and ξ are respectively the location parameter, the scale parameter and the shape parameter. Note that this framework using a mixture distribution is still compatible with a Second Order Stochastic Dominance, as in the reference model.
See Reiss and Thomas [2007] for more details on GEV distributions.

cumulative distribution function such that:[5]

$$\alpha(\bar{d}+\bar{d}^{\star}) = F_{H,H^{\star}}(\bar{d}+\bar{d}^{\star})$$
$$= a\ exp\left\{-\left(1+\xi\left(\frac{(\bar{d}+\bar{d}^{\star})-\theta}{\sigma}\right)\right)^{-\frac{1}{\xi}}\right\}$$
$$+ (1-a)\ exp\left\{-\left(1+\xi\left(\frac{(\bar{d}+\bar{d}^{\star})-\theta^{\star}}{\sigma}\right)\right)^{-\frac{1}{\xi}}\right\} \qquad (6)$$

Since the creditor is uninsured, he/she holds a defaultable debt claim with respect to the funds lent to the bank at T=0. According to Merton [1974], the value of this defaultable debt claim with strike price $(\bar{D}+S\bar{D}^{\star})$ can be divided into two components: cash $(\bar{D}+S\bar{D}^{\star})$ and a short position on a put option π. Thereby, the value of a defaultable debt claim is lower than its expected payoff $(\bar{D}+S\bar{D}^{\star})$ because of its induced risk. Since the risk differs between the two types of portfolio, the put option is specific to each investment choice. If the bank invests in the good portfolio, the following put option price is given by:[6]

$$\pi_{H,H^{\star}}(\bar{D}+S.\bar{D}^{\star}, A+SA^{\star}) = (A+SA^{\star}).\pi_{H,H^{\star}}(\bar{d}+\bar{d}^{\star},1) \equiv (A+SA^{\star}).\pi_{H,H^{\star}}(\bar{d}+\bar{d}^{\star})$$

If the bank invests in the bad portfolio, the price of the put option is:

$$\pi_{L,L^{\star}}(\bar{D}+S.\bar{D}^{\star}, A+SA^{\star}) = (A+SA^{\star}).\pi_{L,L^{\star}}(\bar{d}+\bar{d}^{\star},1) \equiv (A+SA^{\star}).\pi_{L,L^{\star}}(\bar{d}+\bar{d}^{\star})$$

[5]Alternatively, the probability of default when the bank invests in the "less good" portfolio can be defined through $F_{L,L^{\star}}(\bar{d}+\bar{d}^{\star})$. However, I focus on the good portfolio since the contract between the bank and its creditor leads to this portfolio in section 3.

[6]The price of the put option depends on the total amount reimbursed at the end of the period - $\bar{D}+S.\bar{D}^{\star}$ - and on the total value of assets $A+SA^{\star}$. Assuming that there is a constant returns to scale of option price because of competitive markets, the value of the option on total portfolio $A+SA^{\star}$ with strike price$\bar{D}+S\bar{D}^{\star}$ can be recover by bundling together $A+SA^{\star}$ options on one dollar's worth of portfolio with strike price $(\bar{D}+S\bar{D}^{\star})/(A+SA^{\star})$.

2.3 Incentive constraints

The creditor of the bank is risk neutral. He maximizes his utility U^C defined as his total net expected payoff. His net expected payoff is the difference between the value of his defaultable debt claim and the total funds provided to the bank. If the bank invests in the good portfolio, the net expected payoff is given by:

$$U^C_{H,H^\star}(A + SA^\star) = (A + SA^\star)\left[(\bar{d} + \bar{d}^\star) - \pi_{H,H^\star}(\bar{d} + \bar{d}^\star) - (d + d^\star)\right] \tag{7}$$

The requirement that utility is equal to or higher than 0 provides the first Participation Compatibility (PC) constraint of the creditor. This constraint binds in the optimal contract:

$$0 \leq (\bar{d} + \bar{d}^\star) - \pi_{H,H^\star}(\bar{d} + \bar{d}^\star) - (d + d^\star) \tag{8}$$

$$(d + d^\star) = (\bar{d} + \bar{d}^\star) - \pi_{H,H^\star}(\bar{d} + \bar{d}^\star) \tag{9}$$

Similarly for an investment in the bad portfolio:

$$(d + d^\star) = (\bar{d} + \bar{d}^\star) - \pi_{L,L^\star}(\bar{d} + \bar{d}^\star) \tag{10}$$

The PC constraint (9) defines the total debt ratio at market value relative to the total debt ratio at notional value. The latter should be large enough to form an incentive for the creditor to participate. The higher the reimbursement offered by the bank, the more the creditor is tempted to lend money at T=0.

The bank is risk neutral and maximizes its expected utility U^B defined as its total net expected payoff. In this framework, returns come from assets both in domestic and in foreign currency. Thus the net expected payoff when the bank invests in the good portfolio is equal to:

$$U^B_{H,H^\star} = (A + SA^\star)\left[a.r_H + (1-a)r_{H^\star} + (d + d^\star) - (\bar{d} + \bar{d}^\star) + \pi_{H,H^\star}(\bar{d} + \bar{d}^\star)\right] \quad (11)$$

When the bank invests in the bad portfolio the net expected payoff is equal to:

$$U^B_{L,L^\star} = (A + SA^\star)\left[a.r_L + (1-a)r_{L^\star} + (d + d^\star) - (\bar{d} + \bar{d}^\star) + \pi_{L,L^\star}(\bar{d} + \bar{d}^\star)\right] \quad (12)$$

Assuming that $U^B_{H,H^\star} \geq U^B_{L,L^\star}$, the Incentive Compatibility (IC) constraint is given by:

$$a(r_H - r_L) + (1-a)(r_{H^\star} - r_{L^\star}) \geq \pi_{L,L^\star}(\bar{d} + \bar{d}^\star) - \pi_{H,H^\star}(\bar{d} + \bar{d}^\star) \quad (13)$$

Following the definition of asset distributions, the expected return differentials $(r_H - r_L)$ and $(r_{H^\star} - r_{L^\star})$ are equal and independent on economic conditions.[7] Thus, the left hand side (lhs) of the IC constraint defined in equation (13) can be simplified, as if the bank only held assets in the domestic currency.

$$r_H - r_L \geq \Delta\pi(\bar{d} + \bar{d}^\star) \quad (14)$$
$$\text{Where}: \ \Delta\pi(\bar{d} + \bar{d}^\star) = \pi_{L,L^\star}(\bar{d} + \bar{d}^\star) - \pi_{H,H^\star}(\bar{d} + \bar{d}^\star)$$

The IC constraint simplified in equation (14) stipulates that there is a solution $(\bar{d}+\bar{d}^\star)$ that satisfies this inequality. The unique solution illustrated in figure 1 comes from the Second Order Stochastic Dominance (SOSD) between the two mixture distributions and the differential in volatility. The surface area $\Delta\pi(z)$ increases until $F_{H,H^\star}(z) = F_{L,L^\star}(z)$ and decreases after the junction. As shareholders receive returns, $(\bar{d} + \bar{d}^\star) < a(1 + \bar{r}) +$

[7] See the appendix.

$(1-a)(1+\bar{r}^{\star})$, there is a unique solution $\bar{z}=(\bar{d}+\bar{d}^{\star})$ which satisfies the IC constraint.

$$r_H - r_L = \Delta\pi(\bar{d}+\bar{d}^{\star}) \tag{IC}$$

{ *Insert Figure 1 here* }

The IC constraint also represents the moral hazard trade-off from Holmström and Tirole [1997]. The lhs of IC represents the bank's private benefit from investing in the good portfolio while the right hand side (rhs) is equal to the private benefit from investing in the bad portfolio (e.g. low effort in the moral hazard model of Holmström and Tirole [1997]). With the added PC constraint from the creditor, the bank necessarily invests in the good portfolio where the put option induces lower prices. However, additional assumptions are needed to obtain a closed form solution for $(\bar{d}+\bar{d}^{\star})$.

2.4 Value at Risk rule

As in Adrian and Shin [2014], I assume that $\xi=-1$ and $m\mapsto 1$, implying that $F_{L,L^{\star}} = e^{\frac{k}{\sigma}}F_{H,H^{\star}}$.[8] These assumptions allow the rhs of IC in equation (14) to be simplified as follows[9]

$$\begin{aligned} r_H - r_L &= \Delta\pi(\bar{d}+\bar{d}^{\star}) \\ &= (e^{\frac{k}{\sigma}}-1)\sigma F_{H,H^{\star}}(\bar{d}+\bar{d}^{\star}) \end{aligned} \tag{15}$$

Because $F_{H,H^{\star}}$ is the bank's probability of default when it invests in the good port-

[8] $\xi=-1$ implies that the $F_{H,H^{\star}}(z)$ distribution has an upper bound: the support of the distribution is $\left(-\infty\ ,\ -\sigma ln\left(a.exp\left\{-\left(\frac{\sigma+\theta}{\sigma}\right)\right\}+(1-a)exp\left\{-\left(\frac{\sigma+\theta^{\star}}{\sigma}\right)\right\}\right)\right)$. As the VaR rule focuses on the left side of the distribution, this assumption is not a problem. $m\mapsto 1$ makes the volatility between the good and the bad asset comparable. It allows an approximation of a closed form solution.

[9] See the appendix.

folio, the following VaR rule is extracted from equation (15):

$$\alpha = F_{H,H^\star}(\bar{d} + \bar{d}^\star) = \frac{r_H - r_L}{(e^{k/\sigma} - 1)\sigma} \tag{16}$$

As the rhs of (16) does not depend on θ or $\theta^\star$, the probability of default α is maintained at the same level for any state of nature and any level of diversification. Especially, equation (16) defines the VaR rule where the bank adjusts the notional value of its debt ratio $(\bar{d} + \bar{d}^\star)$ in order to satisfy a constant α. Note that the VaR rule focuses on the tail of the distribution. If the tail is thickened by a change in the states of nature, the bank has to decrease its total debt ratio in order to maintain a constant α that only depends on k, σ and the spread $r_H - r_L$.

Proposition 1 *Currency diversification does not affect the VaR rule. The bank adjusts its balance sheet to the state of nature in both currency areas:* $(\bar{d} + \bar{d}^\star)$ *adjusts to* θ *and* $\theta^\star$ *in order to satisfy a constant* α.

Hence, after some straightforward algebra, I obtain the following:[10]

$$\alpha = \underbrace{exp\left\{\frac{(\bar{d} + \bar{d}^\star) - \theta}{\sigma} - 1\right\}}_{Baseline} \underbrace{\left[a + (1-a)exp\left\{\frac{\theta - \theta^\star}{\sigma}\right\}\right]}_{\Omega} = \frac{r_H - r_L}{(e^{k/\sigma} - 1)\sigma} \tag{17}$$

The VaR rule determines bank's debt ratio $(\bar{d} + \bar{d}^\star)$ and its adjustment to the states of nature. Without diversification $a = 1$ or with similar economies $\theta = \theta^\star$, the left hand side of the VaR is reduced to the *Baseline* component and the bank's debt ratio $(\bar{d} + \bar{d}^\star)$ follows the domestic state of nature as in Adrian and Shin [2014]. As the probability of default is constant, an increase in θ leads to a similar increase in the national value of bank's debt. When diversification is introduced and $\theta \neq \theta^\star$, the VaR rule includes a factor Ω to the *Baseline* component. Ω measures the impact of currency diversification on the tail of the portfolio distribution. When $\theta > \theta^\star$, $\Omega > 1$ and diversification implies

[10]Where $F_{H^\star} = F_H \,.\, exp\left\{\frac{\theta - \theta^\star}{\sigma}\right\}$

a thickening of the tail of the portfolio distribution: the diversified portfolio becomes riskier than the baseline portfolio. In return, when $\theta < \theta^\star$, $\Omega < 1$ and the tail of the portfolio distribution becomes thinner than the tail of the portfolio distribution at the baseline, implying a safer portfolio than the baseline portfolio.

Proposition 2 *Under a fixed exchange rate, currency diversification increases the tail risk of banks ($\Omega > 1$) when the domestic economic condition outperforms the foreign one ($\theta > \theta^\star$), while it decreases it ($\Omega < 1$) when the foreign economic condition becomes better than the domestic one ($\theta < \theta^\star$).*

The VaR rule (17) then defines the adjustment of the bank's debt ratio at the notional value $(\bar{d} + \bar{d}^\star)$ to the states of nature $\{\theta, \theta^\star\}$, such that:

$$(\bar{d} + \bar{d}^\star) = \underbrace{\theta + \sigma + \sigma ln\left(\frac{r_H - r_L}{(e^{k/\sigma} - 1)\sigma}\right)}_{Baseline} - \sigma ln\left(\underbrace{a + (1-a)exp\left\{\frac{\theta - \theta^\star}{\sigma}\right\}}_{\Omega}\right) \qquad (18)$$

When $\theta = \theta^\star$, $\Omega = 1$ implying an unchanged tail risk: during booms the baseline $(\bar{d}+\bar{d}^\star)$ increases while it decreases during burst. It defines the baseline leverage procyclicality. When $\theta > \theta^\star$, $\Omega > 1$ and the tail risk increases: the increase in bank's debt ratio at the notional value is then less pronounced during booms than the baseline framework would predict. $(\bar{d} + \bar{d}^\star)$ is less procyclical than the baseline. Similarly during burst, the decrease in $(\bar{d} + \bar{d}^\star)$ is then less pronounced than the baseline framework would predict: procyclicality increases. When $\theta^\star > \theta$, $\Omega < 1$ and the tail risk decreases: during booms, currency diversification increases the procyclicality of $(\bar{d}+\bar{d}^\star)$, but it decreases it during burst.

Proposition 3 *Valuation effect aside, leverage is more procyclical with currency diversification than without when the foreign economic condition is more volatile than the domestic one. When the foreign state of nature becomes less volatile than the domestic one, leverage procyclicality then decreases.*

Following equation (9), the debt ratio $(d + d^\star)$ is a positive function of $(\bar{d} + \bar{d}^\star)$, implying that previous conclusions on $(\bar{d} + \bar{d}^\star)$ are applied to leverage procyclicality given that:

$$\lambda = \frac{1}{1 - (d + d^\star)} \tag{19}$$

When the foreign economy outperforms the domestic economy, leverage procyclicality is increased by currency diversification during booms but decreased by it during bursts. When the domestic economy outperforms the foreign economy, leverage procyclicality is then decreased by currency diversification during booms but increased by currency diversification during bursts. Valuation effect aside, leverage is then more procyclical with currency diversification than without when the foreign economic condition is more volatile than the domestic one, that is when it outperforms the domestic economic condition during booms but falls behind it during bursts. Conversely, leverage procyclicality decreases when the foreign state of nature is less volatile than the domestic one. Those generalized conclusions support previous results from Kwok and Reeb [2000] which visit the upstream downstream hypothesis of internationalization.

2.5 Introducing a floating exchange rate

In previous sections, the foreign exchange rate is assumed to be fixed. Floating exchange rate regime affects the weight of assets in the bank's portfolio since $a = \frac{A}{A+SA^\star}$. Depending on the correlation between the exchange rate and asset returns, a floating exchange rate will impact the portfolio distribution and the leverage adjustments.

The extensive empirical literature on the relationship between foreign exchange rates and the state of nature of the economy or between foreign exchange rates and interest rates suggests that domestic macroeconomic performances or relative domestic return performances are associated with domestic currency appreciation. [11]

Hypothesis 1 *The domestic currency appreciates when the domestic return rises with respect to the foreign one.*

As θ and $\theta^{\star}$ are known for both periods T=$\{0,1\}$, the exchange rate S does not change between T=0 and T=1. The process of S relative to good portfolios is given by equation (20) where returns depend on the state of nature of both economies and on a function of the shape parameter $H(\xi)$:

$$S = 1 + \frac{r_{H^{\star}} - r_H}{1 + r_H} \tag{20}$$

$$\begin{aligned} \text{Where :} & \\ r_{H^{\star}} =& \theta^{\star} + \sigma H(\xi) \\ r_H =& \theta + \sigma H(\xi) \\ \lim_{r_H \to \infty} S(r_H) =& 0 \ \ , \ \ \text{and} \ \ S = 1 \ \leftrightarrow \ r_H = r_{H^{\star}} \end{aligned}$$

As θ and $\theta^{\star}$ are known for both periods, the exchange rate does not change between T=0 and T=1. Implicitly, I also assume that the bank does not change the composition of its portfolio, notwithstanding small changes in states of nature.[12] When the domestic

[11] Using high frequency data and macroeconomic announcements in the U.S or in Germany in the 1990s, Andersen et al. [2003, 2007], Faust et al. [2007] show that the foreign exchange rate is linked to macroeconomic fundamentals: a stronger than expected release appreciates the domestic currency. Regarding interest rates, Engel [1996] shows that the currency with the higher interest rate typically appreciates. Using structural VAR with daily data from 1988 to 2004, Ehrmann et al. [2011] show that the euro is also positively affected by shocks on short rates where a rise in euro area short rates leads to a euro appreciation. Finally, Itskhoki and Mukhin [2017] define a theoretical model reproducing the different foreign exchange rate puzzles identified in the literature, including the Engel [1996] result.

[12] This implicit assumption seems to be reasonable regardless of the time horizon because of both the transaction costs and the international dimension of the foreign currency. Odean [1998], Liu and Strong [2008] justify the "buy and hold" strategy for short term horizon because of the transaction costs implied in rebalancing strategies. Following Liu and Strong [2008], a monthly rebalancing strategy is then unrealistic. In addition, the foreign currency included in the model is considered as an international currency. Because of the international involvement of global banks, there is an incompressible share of assets and liabilities denominated in foreign currency. A complete re-allocation from one currency to another would then imply a complete change in the bank's business model, going from global to national and vice-versa, or a complete change in the definition of the international monetary system. It seems reasonable to think that such adjustments are rare and sluggish.

currency appreciates, the converted value of the foreign asset declines, which leads to a larger share of domestic assets relative to total assets: a goes up at T=$\{0, 1\}$. Consequently, the changes in a and $(1 - a)$ only reflect the exchange rate effect on converted value, so called the valuation effect of currency diversification. This makes it possible to identify the impact of currency diversification on leverage.

Hypothesis 2 *Changes in a only reflect valuation effects due to variations in the exchange rate, that is $\frac{da(S)}{dS} < 0$.*

One can rewrite equation (18) where a is a function of S such that:

$$(\bar{d} + \bar{d}^{\star}) = \theta + \sigma + \sigma ln \left(\frac{r_H - r_L}{(e^{k/\sigma} - 1)\sigma} \right) - \sigma ln \left(\underbrace{a(S) + (1 - a(S))\ exp \left\{ \frac{\theta - \theta^{\star}}{\sigma} \right\}}_{\Omega_S} \right) \tag{21}$$

$$\text{With } \frac{da(S)}{dS} < 0$$

Because a floating exchange rate always promotes the asset which offers a better return in the portfolio, S directly affects the tail of the portfolio distribution through Ω_S. Compared to a fixed exchange rate regime, the introduction of S as defined in equation (20) always decreases the thickness of the distribution tail. As the bank still follows the VaR rule, the floating exchange rate regime increases its capacity to raise funds compared to its debt capacity in a fixed exchange rate regime.

Proposition 4 *Introducing a floating exchange rate, the valuation effect decreases the tail risk of banks and increases their fund-raising capacity as long as the two economies are different, that is $\frac{d(\bar{d}+\bar{d}^{\star})}{dS} > 0$ when $\theta^{\star} > \theta$ or $\frac{d(\bar{d}+\bar{d}^{\star})}{dS} < 0$ when $\theta^{\star} < \theta$.*

The valuation effect, or the effect of a floating exchange rate regime on $(\bar{d}+\bar{d}^{\star})$ compared to the fixed exchange rate regime is observed through the derivative of $(\bar{d} + \bar{d}^{\star})$ relative to S when θ and $\theta^\star$ are constant:

$$\frac{d(\bar{d}+\bar{d}^\star)}{dS} \mid \theta, \theta^\star = -\sigma \frac{\left(\frac{da_{(S,\theta,\theta^\star)}}{dS} \mid \theta, \theta^\star\right)\left(1 - exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}\right)}{a + (1-a)exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}} \tag{22}$$

When the exchange rate regime is floating, S does not affect $(\bar{d}+\bar{d}^\star)$ when $\theta = \theta^\star$. An appreciation of the foreign currency (i.e S increases) leads to an increase in $(\bar{d}+\bar{d}^\star)$ when:

$$\left(\frac{da_{(S,\theta,\theta^\star)}}{dS} \mid \theta, \theta^\star\right)\left(1 - exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}\right) < 0 \tag{23}$$

Because $\left(\frac{da_{(S,\theta,\theta^\star)}}{dS} \mid \theta, \theta^\star\right) < 0$, then the condition becomes $\theta^\star > \theta$. Foreign currency appreciates when the the foreign economy outperforms the domestic one, leading to an increase in the fund raising capacity. Alternatively, an appreciation of the domestic currency (i.e S decreases) leads to an increase in $(\bar{d}+\bar{d}^\star)$ when $\theta > \theta^\star$ because $\left(\frac{da_{(S,\theta,\theta^\star)}}{dS} \mid \theta, \theta^\star\right) < 0$. Domestic currency appreciates when the domestic economy outperforms the foreign one and leads to an increase in the bank's fund raising capacity. The conditions allowing an increase in fund raising capacities depend on the definitions of the model. The difference in the states of nature defines the exchange rate adjustment while $\left(\frac{da_{(S,\theta,\theta^\star)}}{dS} \mid \theta, \theta^\star\right) < 0$ defines the portfolio adjustment relative to the exchange rate. In this framework, a floating exchange rate regime always increases the bank's fund raising capacity compared to a fixed exchange rate regime when $\theta \neq \theta^\star$.

Combining both the diversification and the valuation effects introduces conditions for leverage counter-cyclicality. When the domestic economy outperforms the foreign one during a burst, $\theta > \theta^\star$, leverage procyclicality is increased by the diversification effect but decreased by the valuation effect due to the floating exchange rate. Similarly, when the foreign economy outperforms the domestic one during a burst, $\theta^\star > \theta$, leverage procyclicality is decreased by both the diversification effect and the valuation effect. If the valuation effect is strong enough during economic bursts, leverage may then become counter-cyclical if the initial currency diversification satisfies a given threshold.[13] When $\theta > \theta^\star$, the condition for a counter-cyclical leverage relative to the foreign economic condition is such that:

$$\underbrace{(1-a)\left(\frac{da_{(S,\theta,\theta^\star)}}{d\theta^\star} \mid \theta\right)^{-1}}_{Portfolio\ adjustment} < \sigma \underbrace{\left(\frac{1}{exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}} - 1\right)}_{\Delta Economic\ condition} \tag{24}$$

The counter-cyclical condition in equation (24) compares the portfolio adjustment due to the valuation effect to the relative economic performance going from $\theta = \theta^\star$ to $\theta > \theta^\star$ with θ being constant. As $\left(\frac{da_{(S,\theta,\theta^\star)}}{d\theta^\star} \mid \theta\right) < 0$, the higher the initial share of foreign asset, the more the bank benefits from the valuation effect and the more validated the condition would be. Because the foreign economy is bursting, the domestic currency appreciates and the valuation effect promotes the domestic asset in bank's portfolio: the valuation effect decreases the tail risk and offsets the economic burst.

When the domestic economy contracts ($\theta < \theta^\star$), a counter-cyclical leverage relative to the domestic economic condition is observed when the valuation effect is larger than the decline in economic condition. With $\left(\frac{da_{(S,\theta,\theta^\star)}}{d\theta} \mid \theta^\star\right) > 0$, the condition becomes:

$$\underbrace{a\left(\frac{da_{(S,\theta,\theta^\star)}}{d\theta} \mid \theta^\star\right)^{-1}}_{Portfolio\ adjustment} < \underbrace{\sigma\left(1 - exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}\right)}_{\Delta Economic\ condition} \tag{25}$$

The lower the initial share of domestic asset in the bank's portfolio, the more beneficial the valuation effect is and the more validated the condition would be.

Table 2 summarizes the theoretical predictions from the model. The impact of cur-

[13] See the appendix for more details.

rency diversification on leverage procyclicality then depends on the relative performance of the two economies, the business cycle, and the exchange rate regime.

Table 2: **Impact of currency diversification on leverage procyclicality.** The comparative is the baseline leverage procyclicality (i.e without diversification), or the leverage procyclicality under the fixed exchange rate regime for the impact of floating exchange rate regime.

Generalized conclusions with fixed FX and positive correlation between θ and $\theta^\star$:
$\sigma_{\theta^\star} < \sigma_\theta$: Less procyclical
$\sigma_{\theta^\star} > \sigma_\theta$: More procyclical
$\sigma_{\theta^\star} = \sigma_\theta$: Unchanged

	During booms:	During bursts:
Similar economies: $\theta^\star = \theta$		
Fixed FX	Unchanged	Unchanged
$\hookrightarrow$ *Introducing floating FX*	*Unchanged*	*Unchanged*
Foreign economy outperforms: $\theta^\star > \theta$		
Fixed FX	More procyclical	Less procyclical
$\hookrightarrow$ *Introducing floating FX*	*Procyclicality* $\nearrow$	*Procyclicality* $\searrow$ *(Potentially counter-cyclical)*
Domestic economy outperforms: $\theta > \theta^\star$		
Fixed FX	Less procyclical	More procyclical
$\hookrightarrow$ *Introducing floating FX*	*Procyclicality* $\nearrow$	*Procyclicality* $\searrow$ *(Potentially counter-cyclical)*

2.6 Discussion

Following theoretical conclusions, the only driving force of leverage fluctuations is the portfolio distribution which depends on both states of nature and the foreign exchange rate: the composition of bank's debt is not determinant to the definition of leverage procyclicality. In other terms, currency mismatch does not affect leverage procyclicality. There is a threefold explanation for this phenomenon.

First, the contracting problem introduces a participation constraint and an incentive constraint that micro-found the VaR rule. The only source of adjustment of banking leverage comes from the asset side: total converted debt adjusts to changes in total converted asset. In this framework, introducing an exogenous debt interest rate would change the definition of the two constraints that defined the VaR rule. Similarly, a risk-free interest rate removes the contracting model and fails to micro-found the VaR rule. Considering a potential monetary policy interest rate, the framework defined in this paper is still compatible as long as the interest rate defined by the contracting model stays above the monetary policy interest rate.[14]

Second, the bank supports foreign exchange rate fluctuations only through its total portfolio returns. The impact of foreign exchange rate fluctuations on bank's debt is supported by the creditor of the bank. Assuming that the bank only invests in domestic asset while it raises debt in foreign currency. An improvement of the foreign economic condition does not change the portfolio return distribution as it only contains domestic asset. According to the VaR rule, the bank's leverage is unchanged, implying similar total converted debt and reimbursement. Implicitly, it means that the appreciation of the foreign currency is internalized by the bank's creditor. The total converted debt and reimbursement stay unchanged, but the total debt and reimbursement in foreign currency decrease.

Third, as the states of nature are known for the two periods, S is fixed for $T = 0, 1$, removing the traditional risk implied by currency mismatch. For each state of nature, a new contract is defined where the foreign exchange rate is known.

[14]In Bruno and Shin [2015], Coimbra and Rey [2017], the VaR rule is directly implemented to constrain banks' leverage. The interest rate on deposits is then riskfree or exogenous, introducing a second source of adjustment for banking leverage on the liability side: the monetary policy. However, this framework does not enable the microfoundations of the VaR rule as in Adrian and Shin [2014].

3 Quantitative analysis

Focusing on the 2008-2009 crisis, the theoretical model predicts that banks with exposures to the US and the US dollar are supposed to show different leverage procyclicality. Considering banks in France and the major economic and financial negative shock coming from the US during the 2008-2009 crisis, currency diversification is expected to increase leverage procyclicality during this period. Focusing on the valuation effect of currency diversification, however; one can expect that it has a negative impact on leverage procyclicality. This section is devoted to the quantitative analysis of the theoretical predictions using micro-data on banks located in France during the 2008-2009 crisis.

3.1 Data

I use a unique micro-data from the French banking supervision authority ACPR. It consists of foreign and French banks located in France and it provides yearly information on consolidated banks' balance sheet and derivatives relative to foreign exchange rate operations, and on a proxy of the currency diversification of assets.[15] Additionally, it provides information on banks' characteristics such as the nationality of banks and the sub-category the banks are attached to (banks, cooperative banks, financial and investment firms).

Focusing on the 2008-2009 crisis, the sample consists of 26 banks composed of 18 and 8 French and foreign banks, respectively. Table 3 provides descriptive statistics on all banks focusing on banks' size defined as the logarithm of total assets, leverage defined as the ratio of total assets to equity, US dollar diversification defined as the share of assets denominated in US dollar FX_{2007}, US dollar diversification with euro area counterparties $FX(EA)_{2007}$ and derivatives relative to foreign exchange operations defined as the ratio of those derivatives to total assets $Deriv_{2007}$. The general decrease

[15] See the appendix for more details on data

in leverage and total assets between 2008 and 2009 is confirmed, where leverage and total assets decreased by 15% and 8% on average, respectively.

{ *Insert Table 3 here* }

Following table 3, banks had an average US dollar diversification of 12% of total assets in 2007, while the FX derivative ratio reached 0.54 on average for the same year. Focusing on standard deviations, minimum and maximums, heterogeneity is observed in all variables reported in table 3. Tables 4 and 5 provide additional descriptive statistics focusing on French or foreign banks. Comparing the two tables, foreign banks are more diversified in 2007 than French banks. They also manifest stronger decline in leverage and size during the financial crisis than their French counterparts.

{ *Insert Table 4 5 here* }

3.2 Empirical model

I focus on the impact of currency diversification on leverage procyclicality during the 2008-2009 crisis. Especially, I want to test whether the pre-crisis currency diversification of assets, i.e in 2007, affects the large adjustment of banks' balance sheet during the crisis, i.e between 2008 and 2009. My quantitative analysis is thus based on cross-section heterogeneity between banks.

I follow previous empirical strategies used in Adrian and Shin [2008], Kalemli-Ozcan et al. [2012], Baglioni et al. [2013], Damar et al. [2013] where the growth rate of leverage between 2008 and 2009 is the dependent variable and the value of leverage in 2008 and the growth rate of assets between 2008 and 2009 are the main explanatory variables.[16] Leverage procyclicality is then measured with the coefficient β_2 in equation (26). I extend the specification by introducing an interaction term between the growth rate of

[16] Δ stands for the first-difference of the logarithm.

assets between 2008 and 2009 and the level of currency diversification in 2007 $FX_{i,2007}$. The coefficient β_3 then measures the effect of currency diversification on leverage procyclicality.[17] I add the level of currency diversification and the FX derivative ratio in 2007 $Deriv_{i,2007}$ as control variables. Finally, to control for unobserved heterogeneity between banks I introduce several dummy variables δ_i including a French nationality dummy variable and dummy variables capturing the category of banks. Banking categories cover general banks, cooperative banks, specialized banks (i.e ECS) and specialized financial institutions (i.e IFS). ECS are specialized in specific financial activities including consumer loans and mortgage financial leases, while IFS are credit institutions with a specific mandate defined by public authorities. I believe that these dummy variables for banks' category and nationality may then avoid issues related to omitted factors that potentially co-determine both the choice of currency diversification prior the financial crisis as well as the movement of leverage afterward.[18]

$$\begin{aligned}\Delta Leverage_{i,2008-09} = \alpha &+ \beta_1\ ln(Leverage_{i,2008}) + \beta_2\ \Delta Asset_{i,2008-09} \\ &+ \beta_3\ (\Delta Asset_{i,2008-09} \text{ x } FX_{i,2007}) + \beta_4\ FX_{i,2007} \\ &+ \beta_5\ Deriv_{i,2007} + \sum_{j=6}^{10} \beta_j \delta_{j,i} + u_i \end{aligned} \tag{26}$$

The variable FX_{2007} captures both the diversification and the valuation effects. In order to capture the valuation effect of currency diversification I extend the analysis by

[17] I believe that the risk of reverse causality between the crisis leverage adjustment and the pre-crisis currency diversification is limited because of the unexpected nature of the financial crisis. The idea of reverse causality implies that the choice of currency diversification is determined by future leverage adjustment (or targeted leverage adjustment). Applying this hypothesis to the financial crisis, it would mean that banks have chosen their pre-crisis currency diversification in order to achieve their crisis leverage adjustment. As financial crisis are by definition unexpected, then the risk of reverse causality seems to be reduced.

[18] Because of their specific activities, then ECS and IFS are not expected to show either large currency diversification or large leverage procyclicality compared to general banks. Similarly, foreign banks located in France are expected to have more currency diversification than French banks; but they are also expected to be more procyclical than French banks as they are the first adjustment variable for foreign global banks during financial crisis.

replacing the share of assets denominated in US dollar by the share of assets denominated in US dollar with euro area counterparties $FX(EA)$.[19] Considering the euro area counterparty as a resident counterparty, this new measure of currency diversification only captures the valuation effect of diversification. An alternative to test the robustness of my results might be to replace the currency diversification measure by the FX derivative measure as it focuses on derivatives relative to foreign exchange operations only. This last specification implies to introduce the currency diversification measure as a control variable.

3.3 Quantitative results

Table 6 reports results from the different specifications of (26). For all specifications, results confirm previous conclusions from the literature: leverage is a mean reverting process and it is procyclical. However, my results also show that leverage prcyclicality depends on currency diversification.

{ *Insert Table 6 here* }

Focusing on currency diversification with all conterparties FX_{2007}, the results show that currency diversification had increased leverage procyclicality during the crisis. This first conclusion is robust even when the pre-crisis currency diversification is defined in 2006 instead of 2007. However, the measure of currency diversification FX captures the two effects of currency diversification. Because of the floating exchange rate regime, the theoretical model predicts a decrease in leverage procyclicality due to the valuation effect. Therefore, results reported in column (1) and (3) suggest that the diversification effect dominates the valuation effect. To capture the valuation effect, I introduce the variable $FX(EA)$ in column (2) and (5). The results confirm this prediction where

[19] The share of assets denominated in euro with US counterparties or with non-euro area counterparties may capture the pure diversification effect. However, that information is not available in the current database.

currency diversification relative to euro area $FX(EA)$ captures this valuation effect: valuation effect reduces leverage pro-cyclicality. Using the ratio of the FX derivative $Deriv$ as an alternative measure of the valuation effect supports my conclusions at least when the measure is taken in 2007. Comparing the different results between column (1) and (2), my results suggest that the diversification effect, apart from the valuation effect, increases leverage procyclicality. They also support the implicit assumption that banks do not change their portfolio allocation at each period.[20]

Figure 2 illustrates the previous results and reports the predicted leverage procyclicality for different levels of 2007 pre-crisis currency diversification. The total currency diversification effect increases leverage procyclicality when currency diversification goes from 0 to the average value (i.e 0.12). When the maximum pre-crisis currency diversification is assumed (i.e 0.71), the slope of the line is even more stronger than previously, translating the large sensitivity to foreign economic choc.

{ *Insert Figure 2 here* }

Focusing on the valuation effect, we observed that the predicted leverage pro-cyclicality is lower for average value of pre-crisis currency diversification (i.e. 0.03) than for 0 currency diversification, even if this average pre-crisis currency diversification is quite low. Interestingly, our results also supports the theoretical prediction which suggests a counter-cyclical leverage due to the valuation effect and a significant pre-crisis currency diversification.

[20]If banks re-allocate their portfolio at each period, then the number of lags used for currency diversification would be determinant to capture the effect of pre-crisis currency diversification on leverage procyclicality during the crisis.

4 Conclusion

By introducing currency diversification in both sides of bank's balance sheet, this paper provides an adjusted framework to European banks with two currency denominations for assets and debts, corresponding to two different countries. It implies a diversification of risks between the two countries and a valuation effect from floating exchange rate.

The international dimension of banking activities associated to the Value-at-Risk rule offer a new framework to explain the heterogeneous procyclicality of leverage where the currency diversification of balance sheet plays a key role. When the foreign economy outperforms the domestic one, a currency diversification reduces risk in bank's portfolio. Currency diversification then increases leverage procyclicality during booms but decreases it during bursts as it expands the bank's capacity to raise funds. Inversely, risk in bank's portfolio gets larger with currency diversification when the domestic economy outperforms the foreign one: currency diversification decreases leverage procyclicality during booms but increases it during bursts. More broadly, currency diversification increases leverage procyclicality when it implies a foreign economic condition that is more volatile than the domestic economic condition. Introducing a floating exchange rate then expands the bank's capacity to raise funds, since currency appreciates when its associated economy outperforms others. The bank's leverage procyclicality then depends on the relative performance of countries, the business cycle, the level of currency diversification and the exchange rate regime.

As this framework introduces currency diversification heterogeneity as an additional variable to explain the heterogeneous cyclical variations of leverage, it allows me to make use of cross-sectional data on banks' balance sheet. Focusing on banks located in France during the 2008-2009 crisis, my results show that leverage procyclicality positively depends on bank's pre-crisis currency diversification. The higher the currency diversification before the crisis, the stronger the leverage response to assets variations during the 2008-2009 crisis. Focusing on the valuation effect of currency diversification, my results show that it reduces leverage procyclicality during the crisis. Therefore, the empirical results yield supporting evidence to the theoretical predictions where the domestic economy outperforms the foreign economy during a burst.

This paper underlines the specific role of balance sheet currency diversification in financial stability risk and economic stability. As not all foreign currencies and foreign economies are alike, this paper shows that the impact of currency diversification would differ according to which currency denomination is included. Therefore, policy recommendations on international banking activities need to be identified in respect to the characteristics of foreign exchange rates and the relative economic and financial performances.

This paper offers a large range of potential extensions. First, a major advantage of this model is its flexibility, especially regarding the definition of exchange rate and the portfolio rebalancing behavior. Changing the bank's strategy from a "buy and hold" strategy to an active rebalancing strategy can be described simply by changing the assumption on the portfolio adjustments to economic conditions. Then, this paper suggests that the amplification of economic booms and bursts due to leverage cyclical variations depends to the extent of international banking activities. Applying this model to a general equilibrium model may then provide an interesting framework for future research. Finally, this paper raises the question of asymmetries between booms and burst, especially if the volatility of the economic conditions is time varying. Extending the quantitative analysis to both a panel data analysis and a broader currency portfolio is a subject of keen interest than I plan to cover in future research.

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Appendix

A The model

A.1 Constant spreads

As assets only differ in their location parameters, the spread between the good and the bad investment returns is equal for domestic as for foreign currency assets:

$$
\begin{aligned}
r_H - r_L &= \theta + \sigma H(\xi) - (\theta - k) - m\sigma H(\xi) \\
&= k - \sigma(m-1)H(\xi) \\
\text{And :} & \\
r_{H^\star} - r_{L^\star} &= \theta^\star + \sigma H(\xi) - (\theta^\star - k) - m\sigma H(\xi) \\
&= k - \sigma(m-1)H(\xi)
\end{aligned}
$$

Therefore:

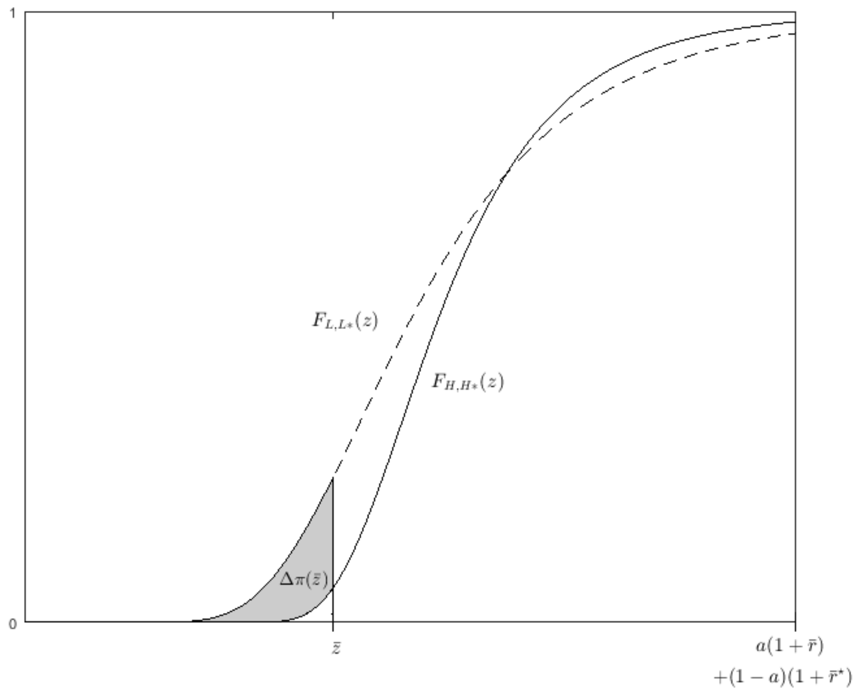
$$
\begin{aligned}
& a(r_H - r_L) + (1-a)(r_{H^\star} - r_{L^\star}) \\
& = a.\left(\theta + \sigma H(\xi) - (\theta - k) - m\sigma H(\xi)\right) + (1-a)\left(\theta^\star + \sigma H(\xi) - (\theta^\star - k) - m\sigma H(\xi)\right) \\
& = a.\left(k - \sigma(m-1)H(\xi)\right) + (1-a)\left(k - \sigma(m-1)H(\xi)\right) \\
& = \left(k - \sigma(m-1)H(\xi)\right) \\
& = Cst
\end{aligned}
$$

A.2 IC development

The simplifying assumptions give the following IC constraint:

$$
\begin{aligned}
(r_H - r_L) &= \Delta\pi(\bar{d} + \bar{d}^\star) \\
&= \int_0^{\bar{d}+\bar{d}^\star} F_{L,L^\star}\,\mathrm{d}z - \int_0^{\bar{d}+\bar{d}^\star} F_{H,H^\star}\,\mathrm{d}z \\
&= e^{\frac{k}{\sigma}} \int_0^{\bar{d}+\bar{d}^\star} F_{H,H^\star}\,\mathrm{d}z - \int_0^{\bar{d}+\bar{d}^\star} F_{H,H^\star}\,\mathrm{d}z \\
&= (e^{\frac{k}{\sigma}} - 1) \int_0^{\bar{d}+\bar{d}^\star} F_{H,H^\star}\,\mathrm{d}z \\
&= (e^{\frac{k}{\sigma}} - 1)\sigma F_{H,H^\star}(\bar{d} + \bar{d}^\star)
\end{aligned}
\tag{A.1}
$$

Figure 1: **The incentive compatibility constraint from the bank expected pay-off:** a unique solution $\bar{z}$. This chart plots the distribution functions $F_{H,H^\star}$ and $F_{L,L^\star}$ for ξ= 0.1, θ=$\theta^\star$=0.5, σ= 0.1, k= 0.05, and m= 1.4. The dark line indicates $F_{H,H^\star}$ and the dash line indicates $F_{L,L^\star}$.



A.3 Combining valuation and diversification effects

When both the diversification and the valuation effects are included, the total ratio of notional values of debt $(\bar{d}+\bar{d}^\star)$ is defined by:

$$(\bar{d}+\bar{d}^\star) = \theta + \sigma + \sigma ln\left(\frac{r_H - r_L}{(e^{k/\sigma}-1)\sigma}\right) - \sigma ln\left(a_{(S,\theta,\theta^\star)} + (1-a_{(S,\theta,\theta^\star)})\; exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}\right)$$

Assuming that θ is constant, the adjustment of $(\bar{d}+\bar{d}^\star)$ relative to a change in $\theta^\star$ is derived such that:

$$\frac{d(\bar{d}+\bar{d}^\star)}{d\theta^\star} \mid \theta = \underbrace{1 - \frac{a}{a+(1-a)exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}}}_{Diversification} \underbrace{- \sigma\frac{\left(\frac{da_{(S,\theta,\theta^\star)}}{d\theta^\star} \mid \theta\right)\left(1-exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}\right)}{a+(1-a)exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}}}_{Valuation} \quad \text{(A.2)}$$

Where the derivative is composed of two effects, the diversification effect and the valuation effect. When the exchange rate is fixed (i.e $\frac{da_{(S,\theta,\theta^\star)}}{d\theta^\star} = 0$), the derivative is limited to the diversification effect. It is equal to 0, 1 and $(1-a)$ when $a = 1$, $a = 0$ and $\theta = \theta^\star$, respectively. When the states of nature become different $\theta \neq \theta^\star$ with θ being fixed, a currency diversification implying that $a > 0$ reduces the procyclicality of $(\bar{d}+\bar{d}^\star)$ relative to the foreign state of nature: the stability of the domestic state of nature anchors the tail risk of asset portfolio.

A floating exchange rate introduces a valuation effect as long as $\theta \neq \theta^\star$. Its impact on the adjustment of $(\bar{d} + \bar{d}^\star)$ relative to a change in $\theta^\star$ depends on the adjustments of the foreign state of nature. When the foreign economy is booming ($\theta^\star > \theta$), the valuation effect is positive and increases the procyclicality of $(\bar{d} + \bar{d}^\star)$ relative to $\theta^\star$. The foreign economic condition implies a depreciation of the domestic currency and a decrease in the share of the domestic asset in the bank's portfolio: the tail risk is reduced. Similarly, when the foreign economy is bursting, $\theta^\star < \theta$, the valuation effect is negative and reduces the procyclicality of $(\bar{d}+\bar{d}^\star)$ relative to the foreign state of nature. The floating exchange rate promotes the domestic asset which performs relatively better than the foreign one because of domestic currency appreciation. In both cases, a floating exchange rate increases the fund raising capacity of banks. However, the adjustment of $(\bar{d} + \bar{d}^\star)$ relative to $\theta^\star$ may become counter-cyclical if the valuation effect is large enough to compensate the diversification effect when the foreign economy is bursting. A counter-cyclical $(\bar{d} + \bar{d}^\star)$ is observed when $\theta^\star < \theta$ and:

$$\underbrace{(1-a)\left(\frac{da_{(S,\theta,\theta^\star)}}{d\theta^\star} \mid \theta\right)^{-1}}_{Portfolio\,adjustment} < \sigma \underbrace{\left(\frac{1}{exp\left\{\frac{\theta-\theta^\star}{\sigma}\right\}} - 1\right)}_{\Delta Economic\,condition} \tag{A.3}$$

The counter-cyclical condition in equation (A.3) compares the portfolio adjustment due to the valuation effect to the relative economic growth starting from $\theta = \theta^\star$. Because $\left(\frac{da_{(S,\theta,\theta^\star)}}{d\theta^\star} \mid \theta\right) < 0$, the higher the initial share of foreign asset, the more validated the condition.

Inversely when $\theta^\star$ is constant, the adjustment of $(\bar{d} + \bar{d}^\star)$ relative to a change in θ

can be derived such that:

$$\frac{d(\bar{d}+\bar{d}^{\star})}{d\theta} \mid \theta^{\star} = \underbrace{\frac{a}{a+(1-a)exp\left\{\frac{\theta-\theta^{\star}}{\sigma}\right\}}}_{Diversification} - \sigma\underbrace{\frac{\left(\frac{da_{(S,\theta,\theta^{\star})}}{d\theta} \mid \theta^{\star}\right)\left(1-exp\left\{\frac{\theta-\theta^{\star}}{\sigma}\right\}\right)}{a+(1-a)exp\left\{\frac{\theta-\theta^{\star}}{\sigma}\right\}}}_{Valuation} \tag{A.4}$$

The derivative is equal to 0, 1 and a if $a = 0$, $a = 1$ and $\theta = \theta^{\star}$, respectively. The procyclicality of $(\bar{d}+\bar{d}^{\star})$ relative to a change in θ decreases when $\theta \neq \theta^{\star}$ with $\theta^{\star}$ and S being fixed, a currency diversification implying that $(1-a) > 0$ reduces the procyclicality of $(\bar{d}+\bar{d}^{\star})$ relative to the domestic state of nature: the stability of the foreign state of nature anchors the tail risk of asset portfolio. Similarly to equation (A.2), a floating exchange rate with $\theta \neq \theta^{\star}$ introduces a valuation effect which depends on economic conditions. When $\theta > \theta^{\star}$, the domestic economy outperforms the foreign one and the domestic currency appreciates, implying that $\left(\frac{da_{(S,\theta,\theta^{\star})}}{d\theta} \mid \theta^{\star}\right) > 0$. The share of domestic asset in bank's portfolio raises and the bank fund raising capacity increases: the valuation effect increases the procyclicality of $(\bar{d}+\bar{d}^{\star})$ relative to θ. Inversely, the foreign economy outperforms the domestic one when $\theta < \theta^{\star}$, leading to an increase of the bank's fund raising capacity and a decrease in the procyclicality of $(\bar{d}+\bar{d}^{\star})$ relative to θ. When the valuation effect is strong enough to compensate the domestic burst, the adjustment of $(\bar{d}+\bar{d}^{\star})$ relative to θ may become counter-cyclical if:

$$\underbrace{a\left(\frac{da_{(S,\theta,\theta^{\star})}}{d\theta} \mid \theta^{\star}\right)^{-1}}_{Portfolio\,adjustment} < \underbrace{\sigma\left(1-exp\left\{\frac{\theta-\theta^{\star}}{\sigma}\right\}\right)}_{\Delta Economic\,condition} \tag{A.5}$$

The lower the initial share of domestic asset in the bank's portfolio, the more the bank benefits from the valuation effect and the more validated the condition would be.

B Quantitative analysis

The final database I use is a combination different databases collected by the French banking supervision authority (ACPR) including the following eSurfi tables: {SITUATION, BILA_CONS, F_01.00, F_11.01, DEVI_SITU}. Accounting data total assets, leverage and derivatives are collected at the book value for the highest level of consolidation. For large international banks, data are consolidated using the IFRS accounting standard and collected in Finrep tables {F_01.00, F_11.01}. Smaller parent banks provide consolidated data using the French accounting standards (FRGAAP) in {BILA_CONS}, while stand-alone banks provide unconsolidated data reported in the {SITUATION} table. Data on currency exposures (from DEVI_SITU) are collected at the book value and at an individual level for all banks (unconsolidated data). The proxy of asset currency diversification adds up currency exposures of all affiliates in the same banking group. Currency diversification is then an aggregate measure of the currency exposure at the banking group level.

Table 3 provides descriptive statistics on banks focusing on bank's size defined as the logarithm of total assets, leverage defined as the ratio of total assets to equity, US dollar diversification FX defined as the share of total assets denominated in US dollar, US dollar diversification with euro area counterparties $FX(EA)$ defined as the share of total assets denominated in US dollar and including a euro area counterparty and, derivatives relative to foreign exchange operations defined as the ratio of those derivatives to total assets.

Table 3: Summary statistics: all banks

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Leverage_{2008}	14.82	11.79	1.16	50.88	26
$\ln(\text{Asset})_{2008}$	9	2.72	5.64	14.5	26
$\Delta \ln(\text{Leverage})_{2008-2009}$	-0.15	0.24	-0.89	0.21	26
$\Delta \ln(\text{Asset})_{2008-2009}$	-0.08	0.21	-0.47	0.42	26
FX_{2007}	0.12	0.18	0	0.71	26
FX(EA)_{2007}	0.03	0.04	0	0.14	26
Deriv_{2007}	0.54	1.26	0	5.74	26

Δ stands for the first difference of variable between t and $t-1$.

Table 4: Summary statistics: French banks

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Leverage_{2008}	13.91	10.23	1.16	37.01	18
$\ln(\text{Asset})_{2008}$	9.49	2.9	5.64	14.5	18
$\Delta \ln(\text{Leverage})_{2008-2009}$	-0.11	0.19	-0.46	0.21	18
$\Delta \ln(\text{Asset})_{2008-2009}$	-0.02	0.2	-0.47	0.42	18
FX_{2007}	0.05	0.07	0	0.27	18
FX(EA)_{2007}	0.03	0.04	0	0.14	18
Deriv_{2007}	0.73	1.47	0	5.74	18

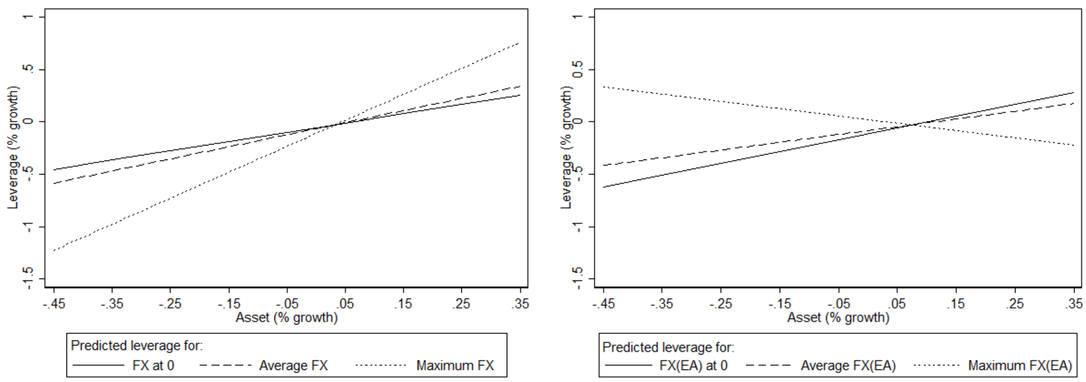
Δ stands for the first difference of variable between t and $t-1$.

Table 5: Summary statistics: foreign banks

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Leverage_{2008}	16.89	15.34	5.66	50.88	8
$\ln(\text{Asset})_{2008}$	7.89	2.01	6.24	12.49	8
$\Delta\ \ln(\text{Leverage})_{2008-2009}$	-0.25	0.33	-0.89	0.09	8
$\Delta\ \ln(\text{Asset})_{2008-2009}$	-0.19	0.2	-0.47	0.04	8
FX_{2007}	0.28	0.25	0.02	0.71	8
FX(EA)_{2007}	0.05	0.04	0	0.11	8
Deriv_{2007}	0.1	0.2	0	0.55	8

Δ stands for the first difference of variable between t and $t-1$.

Figure 2: **Predicted leverage procyclicality and currency diversification:** pre-crisis currency diversification is measured in 2007 based on our sample data detailed in table 3



(a) Total diversification: FX

(b) Valuation effect:$FX(EA)$

Table 6: Leverage procyclicality with pre-crisis currency diversification

Dependent variable : $\Delta Leverage_{2008-09}$

	(1)	(2)	(3)	(4)	(5)	(6)
$ln(Leverage_{2008})$	-0.06*	-0.05**	-0.07**	-0.07*	-0.06**	-0.08*
	(0.02)	(0.01)	(0.02)	(0.03)	(0.01)	(0.03)
$\Delta Asset_{2008-09}$	0.88**	1.13***	1.15***	0.84**	1.03***	1.09***
	(0.17)	(0.06)	(0.08)	(0.18)	(0.07)	(0.11)
$\Delta Asset_{2008-09}$ x FX_{2007}	2.25*					
	(0.86)					
$\Delta Asset_{2008-09}$ x $FX(EA)_{2007}$		-13.07**				
		(2.93)				
$\Delta Asset_{2008-09}$ x $Deriv_{2007}$			-0.16**			
			(0.05)			
$\Delta Asset_{2008-09}$ x FX_{2006}				1.83*		
				(0.58)		
$\Delta Asset_{2008-09}$ x $FX(EA)_{2006}$					-10.09**	
					(2.93)	
$\Delta Asset_{2008-09}$ x $Deriv_{2006}$						-0.22
						(0.16)
FX_{2007}	-0.08		-0.13			
	(0.15)		(0.13)			
$FX(EA)_{2007}$		0.96**				
		(0.18)				
$Deriv_{2007}$	0.01	0.04***	-0.01			
	(0.01)	(0.00)	(0.01)			
FX_{2006}				-0.12		-0.21
				(0.19)		(0.19)
$FX(EA)_{2006}$					0.75**	
					(0.17)	
$Deriv_{2006}$				0.01	0.01**	-0.04
				(0.01)	(0.00)	(0.04)
Constant	0.15	-0.02	0.16	0.18	0.00	0.19
	(0.15)	(0.06)	(0.11)	(0.20)	(0.07)	(0.17)
Observations	26	26	26	23	23	23
R-squared	0.78	0.76	0.72	0.79	0.74	0.73

† $p < 0.11$; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Standard errors are clustered at the sub-category level. Control variables including the dummy variable for banks' nationality or the sub-category dummy are reported in this table.