Financial volatility, currency diversification and banking stability.*

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Abstract:

European global banks are mainly exposed to the US and the euro area financial markets, implying that their balance sheet captures the effects of the global financial cycle. In this paper, we identify strategies to exploit this global framework and to find conditions under which international exposure improves banking stability. We first define a theoretical model where interactions between asset returns, funding costs and exchange rate are introduced in bank’s equity volatility. To minimize equity volatility, an efficient diversification of banks’ balance sheet is defined decomposing each hedging strategy. Second, we estimate DCC-GARCH and depict the US and the euro area financial markets’ dynamics from 2000 to 2015, including conditional correlations between asset returns, funding costs and exchange rate fluctuations. Focusing on this period, our results suggest that foreign currency exposure reduces equity volatility even during large financial distresses such as 2008. In addition to the Basel III regulatory framework, the currency dimension of banks’ balance sheet then offers an interesting potential regulatory tool to improve the resilience of banks and to understand all the consequences of international exposure on banking stability.

JEL classification: F01, F3, F4, F6, G01, G1, G15

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1 Introduction

The post-crisis literature including Baba et al. [2009], Borio and Disyatat [2011], McGuire and Von Peter [2012] has drawn special attention to international activities of European banks. Baba et al. [2009] describe the transatlantic asymmetry in international banking where assets of euro area (EA) banks denominated in US dollars come to approximatively $4.5 trillion in 2008 while the assets of US banks denominated in European currencies only amount to $1.5 trillion the same year. Following Ivashina et al. [2015], 43% of EA bank lending is in US dollar between 2005 and 2007. Focusing on banks in located in France from 1999 to 2015, Pedrono and Violon [2015] attest that on average 22% of French banks’ total assets are denominated in foreign currency where the US dollar is the main foreign currency. Over the same period, on average 65% of assets denominated in US dollar imply counterparts outside the EA. As US dollar mismatch only accounts for 1% of total assets on average, results from Pedrono and Violon [2015] suggest that banks located in France are exposed to the US and the EA in both sides of their balance sheet, implying diversified asset returns and funding costs between these two currency areas.

Previous research including Evans and McMillan [2009], Bekaert et al. [2009] documents that international stock returns are positively correlated and suggests that financial comovements can be identified between international stocks. Additionally, Conovera et al. [1999] confirm that both US and foreign market stock returns are related to the US monetary environment. More generally, it also refers to the global financial cycle described by Rey [2013], Miranda-Agrippino and Rey [2015] where the US monetary policy has a major influence on credit conditions worldwide. Therefore, the different components within European banks’ balance sheet are linked all together.

1 On average 17% of banks’ total assets are denominated in US dollar between 1999 and 2015.
As long as assets are imperfectly correlated, Markowitz [1952], Levy and Sarnat [1970], Driessen and Laeven [2007], Shapiro [2013] confirm that international portfolio decreases portfolio returns’ volatility. Using CAPM definition, Reeb et al. [1998], Kwok and Reeb [2000] and Pedrono and Violon [2016] posit the benefit of introducing an international asset in portfolios by focusing on the reduction of the non-diversifiable risk and exchange rate channel. Specifically, a negative correlation between the domestic asset return and the exchange rate would help to absorb shocks according to Pedrono and Violon [2016] \(^2\). Although the volatility of financial returns increases during financial distress as documented in Evans and McMillan [2009], international exposure in European banks’ assets would improve banking stability when we focus on the asset side of banks’ balance sheet.

However, banks’ stability depends on both assets and liabilities, implying a leverage effect and a foreign exchange rate channel on both sides of the balance sheet. To capture the complete dimension of banking stability, we focus on this paper on banks’ equity. Focusing on banks’ equity that is defined as the difference between total assets and total liabilities introduces all potential sources of risk from assets, liabilities and exchange rate. Additionally and following Diamond and Rajan [2000], the focus on banks’ equity is determinant to banking stability as it is a buffer against financial losses. Thus, the purpose of this paper is to identify banks’ equity volatility by determining each source of potential risk. We first develop a theoretical framework based on stochastic processes that defines banks’ equity volatility as a function of a constant leverage ratio and correlations between assets, liabilities and exchange rate. \(^3\) It enables to identify the specific

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\(^2\) The exchange rate is defined as the units of domestic currency per unit of foreign currency. An increase in exchange rate translates a depreciation of the domestic currency. See Andersen et al. [2003, 2007], Zettelmeyer [2004], Kearns and Manners [2006], Faust et al. [2007], Ehrmann et al. [2011], Chinn and Meredith [2004], Chinn and Quayyum [2012] for empirical evidences on the negative correlation between domestic return and exchange rate.

\(^3\) By introducing a Basel III regulatory framework, the Basel Committee on Banking Supervision wants to strengthen banks’ equity and to limit leverage procyclicality. Basel III instruments are fully
impact of foreign exchange rate on equity volatility, including all potential correlations
with other components of the bank’s balance sheet: whether a floating exchange rate is
stabilizing or destabilizing would then depend on foreign exchange rate behavior with re-
gard to shocks on asset return and financing cost. Interestingly, the model also provides
clear and identifiable conditions on exchange rate and correlations to minimize equity
volatility using balance sheet diversification. For a given level of international exposure
of liability, the efficient share of foreign asset positively depends on the asset-side risk
explained by the domestic asset, the need to cover foreign exchange rate fluctuations
because of liability exposure, the foreign liability capacity to cover shocks on foreign
asset and the domestic liability capacity to cover shocks on foreign asset. Depending on
the weight of each determinant, currency mismatch may offer new hedging strategies.

The second part of our analysis consists of estimating financial markets’ characteris-
tics between the US and the EA using daily data on exchange rate, international stock
indices and funding costs proxied by Shadow Short Rates (SSR). Regarding international
stock indices, we focus on the S&P500 and the Eurostoxx50 to capture asset returns
in the US and the EA respectively. As mentioned by Longin and Solnik [1993], Evans
and McMillan [2009], Silvennoinen and Terasvirta [2009], correlations and volatility of
financial returns are not constant, justifying estimation of bi-variate DDC GARCH.
Therefore, we first provide a detailed analysis on conditional volatility and conditional
correlations between international asset returns, funding costs and exchange rates from
2000 to 2015. Our analysis extends the previous empirical analysis of financial market
correlations by introducing foreign exchange rate and funding costs, completing the cur-
rent identification of the global financial cycle. We then calibrate the theoretical model
with our estimates of volatility and correlations in order to define equity volatility and
the efficient international diversification. Our results confirm the benefits from interna-
tional exposure: introducing foreign currency exposure in assets and liabilities decreases equity volatility even during large financial distresses such as 2008. It also provides a detailed explanation of large and efficient currency mismatch between 2009 and 2012, pointing out the necessity to decompose equity volatility with all components. Finally, and in addition to the Basel III regulatory framework, the currency dimension of banks’ balance sheet then offers an interesting potential regulatory tool to understand banks’ external positions and to improve the resilience of banks.

The remainder of the paper is organized as follows. Section 2 explains briefly the general framework and provides some descriptive statistics on financial markets and exchange rate. Section 3 develops the theoretical framework based on a simplified definition of a bank’s balance sheet. The volatility of equity as a function of financial integration is then introduced, allowing for the definition of an efficient diversification. Section 4 first provides estimates of conditional volatilities and correlations from 2000 to 2015 based on bi-variate DCC-GARCH. We then study the impact of international diversification on banking stability.

2 General framework and descriptive statistics

We consider two international currencies, domestic and foreign. We define a global bank as a bank with a diversified balance sheet between the two currencies. The portfolio of the bank includes a domestic and a foreign asset denominated in domestic and foreign currency, respectively. Similarly, the global bank has domestic and foreign debts denominated in domestic and foreign currency, respectively.

Foreign asset and debt introduce a foreign exposure to risks in both sides of the banks’ balance sheet. Depending on correlations between returns on financial markets,
funding costs and exchange rate fluctuations, foreign currency exposure may allow a decrease of equity volatility through spontaneous hedge against risks. Assuming that asset returns are imperfectly correlated, an international asset introduces a risk diversification on the asset side of the balance sheet. Similarly, banks would benefit from a risk diversification in funding if funding costs are imperfectly correlated. Additionally, as bank’s equity is defined as the deference between assets and liabilities, a positive correlation between asset returns and funding costs leads to more financial stability. As long as the bank’s balance sheet is expressed in domestic currency, risk hedging would be improved or altered depending on exchange rate fluctuations. Section 3 provides detailed theoretical conditions of each source of risks in the definition of equity volatility.

Defining the euro as the domestic currency and the US dollar as the foreign currency, we proxy domestic and foreign assets with the Eurostoxx50 and the S&P500 stock market indices respectively. We then use the euro area shadow short rate (EA SSR) and the US shadow short rate (US SSR) to identify domestic and foreign funding costs respectively. SSR are estimations of monetary policy interest rate adjusting for unconventional monetary policy. According to Aizenman et al. [2015] they provide a good representation of liquidity availability, especially when monetary interest rates are at the zero bound.

Figure 1 illustrates these four variables plus the exchange rate between US dollar and euro. Over the period 2000-2015, we observe a common trend on both international stock market indices and shadow short rates, suggesting the financial comovements between international stocks from Evans and McMillan [2009], Bekaert et al. [2009] and the global financial cycle from Rey [2013], Miranda-Agrippino and Rey [2015]. Concern-
ing the foreign exchange rate, the euro appreciates against the US dollar from 2001 to 2008 while the second half of the period is characterized by more stagnation and some depreciation of the euro. Finally, figure 1 also suggests that international stocks have larger volatility than both the US and the EA SSR.

Table 1 reports descriptive statistics of variable first differences. The low mean of returns associated with large standard deviations and excess kurtosis translate the traditional characteristics of daily financial variables. Although figure 1 suggests some notions of correlations between variables - especially for stock market indices and SSR - we need to implement specific empirical analysis to identify properly the correlations and volatilities. Section 4 is devoted to this exercise with estimations of bivariate Dynamic Conditional Correlation GARCH (DCC GARCH).

3 Theoretical model

3.1 Definition of equity

3.1.1 Assets

Bank’s total asset $A$ is composed of domestic asset $C$ and foreign asset converted in domestic currency $SC^*$ where $S$ is the exchange rate. The share of domestic and foreign asset are given by $(1 - \psi)$ and $\psi$ respectively.

$$A = C + SC^*$$
$$\frac{C}{A} = (1 - \psi) \quad ; \quad \frac{SC^*}{A} = \psi$$
The exchange rate and both asset returns follow stochastic processes with marginal variations defined as:

\[ d\tilde{C} = \frac{dC}{C} = r \, dt + \sigma_C dZ_C \]  
\[ d\tilde{C}^* = \frac{dC^*}{C^*} = r^* \, dt + \sigma_{C^*} dZ_{C^*} \]  
\[ d\tilde{S} = \frac{dS}{S} = \mu \, dt + \sigma_S dZ_S \]  

\( r, r^* \) and \( \mu \) are the deterministic parts of the returns, and \( \sigma_C, \sigma_{C^*} \) and \( \sigma_S \) are the stochastic part. White noises are denoted \( dZ \) such that \( dZ_C \sim N(0; \, dt) \), \( dZ_{C^*} \sim N(0; \, dt) \) and \( dZ_S \sim N(0; \, dt) \).

### 3.1.2 Liabilities

Bank’s total debt \( D \) consists of domestic liability \( L \) and foreign liability converted in domestic currency \( SL^* \). Denote \( (1 - \lambda) \) and \( \lambda \) the share of domestic and foreign liabilities respectively.

\[ D = L + SL^* \]  
\[ \frac{L}{D} = (1 - \lambda) ; \quad \frac{SL^*}{D} = \lambda \]

Introducing stochastic processes, we get the following Stochastic Differential Equations (SDE) for each liability:

\[ d\tilde{L} = \frac{dL}{L} = i \, dt + \sigma_L \, dZ_L \]  
\[ d\tilde{L}^* = \frac{dL^*}{L^*} = i^* dt + \sigma_{L^*} dZ_{L^*} \]

\(^6\text{For more details on Stochastic Differential Equations, see Oksendal 2003}\)
Where $dZ_L$ and $dZ_L^\star$ are white noises, and $i$ and $i^\star$ are the constant drifts of the marginal variation of domestic liability and foreign liability respectively. \( \sigma_L \) and \( \sigma_L^\star \) are the volatility of the marginal variation of domestic liability and the foreign liability, respectively.

### 3.1.3 Equity

Bank’s equity is defined through $E$ such that:

$$E = A - D$$

Bank’s leverage $l$ is the ratio of total debts over equity.

$$l = D/E$$

Following the Basel III framework, we assume that leverage is defined by authorities. Using definitions of $l$ and $E$, we obtain the bank’s equity SDE:

$$d\tilde{E} = \frac{dE}{E} = (1 + l) \frac{dA}{A} - l \cdot \frac{dD}{D}$$

$$= (1 + l) \left[ ((1 - \psi)r + \psi(r^\star + \mu)) \, dt + (1 - \psi)\sigma_C dZ_C + \psi(\sigma_C^\star dZ_C^\star + \sigma_S dZ_S) \right]$$

$$- l \left[ ((1 - \lambda)i + \lambda(i^\star + \mu)) \, dt + (1 - \lambda)\sigma_L dZ_L + \lambda(\sigma_L^\star dZ_L^\star + \sigma_S dZ_S) \right]$$

(10)

If $\psi = \lambda = 0$, $d\tilde{E} = (1 + l) (r \, dt + \sigma_C dZ_C) - l (i \, dt + \sigma_L dZ_L)$

In absence of foreign currency exposure (e.g. $\psi=0$ and $\lambda=0$), the marginal variation of equity does not depend on foreign components. The contribution of total assets on equity returns is larger than the contribution of total liabilities because of the leverage multiplier effect $(1 + l)$.

In absence of foreign currency exposure, the volatility of equity is composed of the
volatility of the domestic asset and liability and of the covariance between these two components. It is thus defined as:

\[
\text{Var}\left(\frac{d\tilde{E}}{dt}\right) = (1 + l)^2 \sigma_C^2 + l^2 \sigma_L^2 - 2l(1 + l)\sigma_{LC}
\]  

(11)

Where \(\sigma_{LC}\) is the covariance between the domestic liability and the domestic asset (i.e. \(\text{Cov}(z_L, z_C)\)). A positive correlation between returns on domestic asset and funding costs on domestic liability then decreases the volatility of equity: shocks on asset returns are hedged by shocks on funding costs.

### 3.2 Volatility of equity with foreign currency exposure

#### 3.2.1 Volatility of equity

Assuming that shocks are not orthogonal, the volatility of equity includes all possible correlations between the different components of the bank’s balance sheet \(\{C, C^*, L, L^*, S\}\). Therefore, \(\sigma_{CC^*}, \sigma_{LL^*}, \sigma_{LC}, \sigma_{L^*C^*}, \sigma_{L^*C}, \sigma_{LC^*}\), denote the covariance between assets, the covariance between liabilities, the covariance between domestic asset and liability, the covariance between foreign asset and liability, the covariance between domestic asset and liability, and the covariance between the domestic liability and the foreign asset respectively. Additionally, \(\sigma_{SC^*}, \sigma_{SC}, \sigma_{SL^*}\) and \(\sigma_{SL}\) illustrate the covariance between exchange rate and foreign asset, the covariance between exchange rate and domestic asset, the covariance between exchange rate and foreign liability and the covariance between the exchange rate and domestic liability respectively. Considering all potential covariances, the variance of equity marginal variation \(\Phi^2\) can be decomposed
as:

\[
\Phi^2 = \text{Var}\left(\frac{d\tilde{E}}{dt}\right)
\]

\[
= \left((1 + l)(1 - \psi)^2 \sigma_C^2 + \left((1 + l)\psi}\right)^2 \sigma_{C^*}^2 + (\psi + l(\psi - \lambda))^2 \sigma_S^2 + (l(1 - \lambda))^2 \sigma_L^2 + (l\lambda)^2 \sigma_{L^*}^2\right)
\]

with orthogonal shocks

\[
+ 2(1 + l)^2 \psi(1 - \psi) \sigma_{CC^*} + l^2 \lambda(1 - \lambda) \sigma_{LL^*}
\]

global financial cycle risk, asset global financial cycle risk, liability

\[
- 2(1 + l)l \left[(1 - \psi) \left((1 - \lambda)\sigma_{LC^*} + \lambda\sigma_{L^*C^*}\right) + \psi \left(\lambda\sigma_{L^*C^*} + (1 - \lambda)\sigma_{LC^*}\right)\right]
\]

A–D hedging strategies

\[
+ 2(\psi + l(\psi - \lambda)) (1 + l) \left[(1 - \psi)\sigma_{SC} + \psi\sigma_{SC^*}\right]
\]

FX channel, asset

\[
- 2(\psi + l(\psi - \lambda)) l \left[(1 - \lambda)\sigma_{SL} + \lambda\sigma_{SL^*}\right]
\]

FX channel, liability

(12)

The first line of \(\Phi^2\) summarizes the volatility of equity when all shocks are orthogonal. Then, it depends positively on risks from \(C\), \(C^*\), \(L\), \(L^*\) and \(S\). When \(\psi = \lambda \neq 0\) (no currency mismatch), the exchange rate still impacts equity volatility because of the leverage multiplier: a currency match does not remove exchange rate risk. The exchange rate risk is removed if and only if \(\frac{\psi}{\lambda} = \frac{l}{1 + l}\): as long as \(l > 0\), it implies that \(\psi \neq \lambda\) when \(\psi > 0\).

The second line of \(\Phi^2\) introduces the risk added by global financial cycle on both sides of the balance sheet. A positive correlation between \(C\) and \(C^*\) raises the variance of equity through \(\sigma_{CC^*}\): it translates the global financial cycle risk coming from the asset side. Similarly, the global financial cycle risk related to the liability side is introduced with the covariance \(\sigma_{LL^*}\).

The third line of \(\Phi^2\) introduces hedging strategies between assets and liabilities, exchange rate movements aside. A positive correlation between funding costs and asset
returns makes equity more resilient to shocks. Equity volatility is thus reduced by this spontaneous mechanism. Notice that domestic asset can be used to hedge foreign liability if $\sigma_{LC^*} > 0$. Similarly, foreign asset can be used to hedge domestic liability if $\sigma_{LC^*} > 0$. Therefore, equation (12) suggests that currency mismatch can reduce the volatility of equity.

The fourth line of $\Phi^2$ introduces the foreign exchange rate channel on the asset side. This channel is removed either when $\psi = \lambda = 0$, or when $\frac{\psi}{\lambda} = \frac{l}{1+l}$. Following previous empirical studies including [Andersen et al. 2003, 2007], Ehrmann et al. [2011], there is a negative correlation between asset returns and exchange rate, implying that $\sigma_{SC^*} > 0$ and $\sigma_{SC} < 0$. Assuming that $\sigma_{SC} = -\sigma_{SC^*}$ with $\sigma_{SC^*} > 0$, the introduction of foreign exchange rate correlations leads to different conclusions depending on foreign currency exposure. When $\psi = 0.5$, the two covariances $\sigma_{SC}$ and $\sigma_{SC^*}$ have similar weight, translating a neutrality in exchange rate fluctuations relative to shocks on asset returns. Thus, there is no additional impact on equity volatility when $\psi = 0.5$. When $\psi > 0.5$, the weight associated to $\sigma_{SC^*}$ increases: a simultaneous and positive shock on domestic and foreign asset returns is associated with an increase in converted asset returns due to foreign currency appreciation. The FX channel on assets then amplifies equity volatility. However, with foreign currency exposure on the liability side, the foreign currency appreciation also increases converted funding costs, compensating the increase in converted asset returns due to foreign currency appreciation. When $\frac{\psi}{\lambda} = \frac{l}{1+l}$, fluctuations in converted funding costs completely cancel out the fluctuations in converted returns due to FX channel. When foreign currency exposure on liability is large enough (i.e $\frac{\psi}{\lambda} < \frac{l}{1+l}$), the increase in converted funding costs also compensated for the initial positive shock on asset returns, reducing equity volatility. When $\psi < 0.5$, the weight associated to $\sigma_{SC}$ increases: a positive shock on domestic and foreign asset returns is associated with a domestic currency appreciation. The latter lowers the increase in foreign asset returns:
increase in total asset returns is moderate and equity volatility is stabilized. The decrease in converted funding costs implied by a relatively low foreign currency exposure of liability (i.e. $\frac{\psi}{\lambda} > \frac{1}{1+\lambda}$) still enables a reduction in equity volatility. However, when the foreign currency exposure of liabilities is relatively high (i.e. $\frac{1+\lambda}{1+\lambda} \psi < \lambda$), then the induced decrease in converted funding costs exceeds the decrease in converted returns from foreign asset: the gap between total returns and total funding costs widens and the variance of equity increases. Thus, equity volatility increases when $\frac{\psi}{\lambda} < \frac{1}{1+\lambda}$ and decreases when $\frac{\psi}{\lambda} > \frac{1}{1+\lambda}$.

The last line of $\Phi^2$ introduces the foreign exchange rate channel on the liability side. Following empirical evidences, $\sigma_{SL} < 0$ and $\sigma_{SL^*} > 0$. Assuming that $\sigma_{SL} = -\sigma_{SL^*}$ with $\sigma_{SL^*} > 0$, the introduction of correlations between foreign exchange rate and funding costs also leads to different conclusions depending on foreign currency exposure. Similarly to the FX channel on assets, there is no additional impact on equity volatility when $\lambda = 0.5$. However, when $\lambda \neq 0.5$, the introduction of correlations relative to exchange rate and funding costs impacts the volatility of equity. When $\lambda > 0.5$ and $\psi$ is relatively low (i.e. $\frac{\psi}{\lambda} < \frac{1}{1+\lambda}$), the introduction of correlations relative to foreign exchange rate and funding costs increases the volatility of equity. When $\psi$ becomes relatively large (i.e. $\frac{\psi}{\lambda} > \frac{1}{1+\lambda}$), the introduction of correlations relative to foreign exchange rate and funding costs decreases the volatility of equity. Conversely, when $\lambda < 0.5$, a relatively low $\psi$ (i.e. $\frac{\psi}{\lambda} < \frac{1}{1+\lambda}$) decreases equity volatility while a relatively large $\psi$ (i.e. $\frac{\psi}{\lambda} > \frac{1}{1+\lambda}$) increases it. Combining with the FX channel on the asset side, the leverage effect extends the impact of correlations linked to assets relative to those linked to liabilities.

3.2.2 Efficient currency diversification

We derive from the variance of equity marginal variation an "efficient" share of asset denominated in foreign currency $\hat{\psi}$ where $\psi$ is defined so as to minimize the volatility of
Considering all potential correlations between each component \( \{C, C^*, L, L^*, S\} \), the "efficient" level of asset diversification \( \hat{\psi} \) is defined such as:

$$
\frac{\partial \Phi^2}{\partial \psi} = 0 \mid \lambda \text{ constant}
$$

$$
\hat{\psi} = \frac{\sigma_C^2 - \sigma_{CC^*} - \sigma_{SC}}{\sigma_C^2 + \sigma_{C^*}^2 + \sigma_S^2 - 2(\sigma_{CC^*} + \sigma_{SC} - \sigma_{SC^*})} \tag{13}
$$

The first component of equation (13) is the share of \( C \) in asset-side risk. In other terms, it is the share of total assets volatility driven by domestic asset volatility. The higher this share, the higher the efficient asset diversification. The second component introduces the risk reduction related to part of the liability side being also in foreign currency: it depends on \( \lambda \) and \( l \). If \( \lambda \neq 0 \) \( \sigma_S^2 \neq 0 \), the share of assets denominated in foreign currency can be used to hedge foreign risk introduced by foreign liability. If \( \lambda = 0 \) (i.e. no liability foreign currency exposure), exchange rate volatility \( \sigma_S^2 \) is as important as the foreign asset volatility \( \sigma_{SC^*}^2 \) in the determination of efficient asset diversification.

The last two components of equation (13) link efficient asset diversification with the foreign currency exposure of liability. First, it introduces the share of foreign asset risk...
that can be hedged with foreign liability. The higher the liability exposure, the larger
the efficient asset exposure. Second, it introduces the share of foreign asset risk that
can be hedged with domestic liability: a larger efficient asset exposure can be justified
if domestic liability is a good instrument to hedge against shocks on foreign asset (i.e
\((\sigma_{SL} + \sigma_{LC^*} - \sigma_{LC}) > 0\)). In this case, the lower the liability exposure, the larger the
efficient asset exposure.

Turning on the "efficient" level of liabilities denominated in foreign currency, the
complete framework with all potential correlations implies a \(\hat{\lambda}\) such that:

\[
\frac{\partial \Phi^2}{\partial \lambda} = 0 \mid \psi \text{ constant} \\
\hat{\lambda} = \frac{\sigma_{LL^*}^2 - \sigma_{LL^*} - \sigma_{SL}}{\sigma_{LL}^2 + \sigma_{LL^*}^2 + \sigma_S^2 - 2(\sigma_{LL^*} + \sigma_{SL} - \sigma_{SL^*})}
\]

\[\text{share of } L \text{ in liability-side risk}\]

\[+ \psi \left(\frac{1 + l}{l}\right) \frac{\sigma_{LL^*}^2 + \sigma_{SL^*}^2 - \sigma_{SL}}{\sigma_{LL}^2 + \sigma_{LL^*}^2 + \sigma_S^2 - 2(\sigma_{LL^*} + \sigma_{SL} - \sigma_{SL^*})}
\]

\[\text{share of } L^* \text{ to hedge FX risk due to } C^*\]

\[+ \psi \left(\frac{1 + l}{l}\right) \frac{\sigma_{LL^*}^2 + \sigma_{SL^*}^2 - \sigma_{LC^*}}{\sigma_{LL}^2 + \sigma_{LL^*}^2 + \sigma_S^2 - 2(\sigma_{LL^*} + \sigma_{SL} - \sigma_{SL^*})}
\]

\[\text{share of } L^* \text{ risk that can be hedged with } C^*\]

\[(1 - \psi) \left(\frac{1 + l}{l}\right) \frac{\sigma_{SC} + \sigma_{LC} - \sigma_{LC}}{\sigma_{LL}^2 + \sigma_{LL^*}^2 + \sigma_S^2 - 2(\sigma_{LL^*} + \sigma_{SL} - \sigma_{SL^*})}
\]

\[\text{share of } L^* \text{ risk that can be hedged with } C\]

As for \(\hat{\psi}\), \(\hat{\lambda}\) decomposes each share of liability-side risk that can be hedged either
with risk diversification within liabilities, or with the foreign exchange rate exposure
included in asset exposure, or because foreign asset is a potential instrument to hedge
against foreign funding costs, or on the contrary, because domestic asset is potentially a
good instrument to hedge against risks associated to foreign funding costs.
4 Efficient diversification: an application to US and EA financial markets

4.1 Conditional variance and correlations of assets, liabilities and exchange rate

To identify variances of \{C, C^*, L, L^*, S\} and correlations between the different components, we implement 10 bivariate DCC GARCH(1,1) using daily data from 2000 to 2015\(^8\). The log returns of the S&P500 index and the log returns of the Eurostox50 are used to proxy foreign \((C^*)\) and domestic \((C)\) returns respectively. Concerning funding costs, we use the US SSR changes and the EA SSR changes to proxy monetary tightening in the foreign economy \((L^*)\) and in the domestic economy \((L)\) respectively\(^9\). Compared to cointegration analysis, conditional variance and correlation provided by bivariate GARCH analysis capture the potential change in financial integration as mentioned by Evans and McMillan \([2009]\). In fact, the period 2000-2015 includes different phases of financial integration starting with the introduction of the euro at the beginning of 2000’s, then followed by a systemic financial crisis in 2008-2009, to finally express an increasing divergence in international stock indices and SSR since 2013\(^10\).

Figure 2 illustrates conditional variances of each component while table 2 provides details on average conditional variances per year. For both assets and liabilities, the period from 2004 to 2007 is characterized by low conditional variances while we observe high volatility in 2001-2002 and in 2008-2009, corresponding to the bursting of the dot-com bubble and the subprime crisis respectively. For each variable, US and euro area

\(^8\) A definition of DCC GARCH is developed in the appendix.

\(^9\) Bloomberg is the main source for data on stock index while data on SSR are estimated by the Reserve Bank of New Zealand.

\(^10\) Divergences are observed in figure 1,a) and figure 1,b). In 2013, the S&P 500 exceeds its pre-crisis level and continue to increases until 2015, while the Eurostox50 stays below its pre-crisis level. Regarding SSR, US SSR increases since 2013 while EA SSR declines.
counterparts show similar volatility movements between 2004 and 2011. As reported in table 2, the euro area stock index displays larger volatility on average than the US stock index except in 2008: $\sigma_C^2 > \sigma_C^{*2}$. Regarding SSRs, the results vary more than for the stock indices: on average, the EA SSR volatility is higher than the US SSR volatility in 2000 and 2003, during the financial crisis in 2009 and since 2011, implying that $\sigma_L^2 > \sigma_L^{*2}$. Comparing both sides of the bank’s balance sheet from 2000 to 2015, stock returns are on average more volatile than changes in SSR: $\sigma_C^2 > \sigma_L^2$, $\sigma_C^{*2} > \sigma_L^{*2}$, $\sigma_C^{*2} > \sigma_L^2$ and $\sigma_C^2 > \sigma_L^{*2}$. The exchange rate exhibits large increase in volatility at the beginning of the euro and during financial distresses from the end of 2008 to 2011. However, the average volatility of the exchange rate is lower than the volatility of stock returns but larger than the volatility of SSR changes over the period. The difference in volatilities between stock returns, foreign exchange rate and SSR changes translates the different degree of uncertainty for each category where stock index imply more uncertainty than monetary policy. Finally, 2015 presents several episodes of increased volatility for all component of the balance sheet except US SSR.

Figure 3 displays the conditional correlations between stock returns and SSR changes. The average conditional correlations per year are reported in table 3. Over the period 2000-2015, $\rho_{LL^{*}}$ and $\rho_{CC^{*}}$ are mainly positive. However, on average $\rho_{CC^{*}}$ is higher than $\rho_{LL^{*}}$, translating a stronger financial cycle on stock returns than on SSR changes. $\rho_{LC}$ and $\rho_{L^{*}C^{*}}$ are also mainly positive over the period and they exhibit similar trends until 2010, expressing potential common behaviors among stock returns and SSR changes for a given currency area. Additionally, the similarity between shocks on stock returns and SSR changes is larger in the US and in the EA until 2013 ($\rho_{LC} \geq \rho_{L^{*}C^{*}}$). In 2014 and 2015 $\rho_{LC}$ decreases and becomes lower than $\rho_{L^{*}C^{*}}$. The last two correlations $\rho_{L^{*}C}$ and $\rho_{LC^{*}}$ suggest potential hedging strategies among assets and liabilities in different currencies. In 2003 and between 2009 and 2012, $\rho_{LC^{*}} > \rho_{L^{*}C^{*}}$, implying that domestic
liability offers more hedging capability than foreign liability regarding risks on foreign asset. Similarly, $\rho_{LC^*} > \rho_{LC}$ in 2005 and since 2014, offering some potential gains from a currency mismatch.

Figure 4 pictures correlations associated to the exchange rate. The average conditional correlations per year are reported in table 3. One interesting fact from the estimation of conditional correlations is that the four correlations $\{\rho_{SL}, \rho_{SL^*}, \rho_{SC}, \rho_{SC^*}\}$ have similar patterns with three distinct trends. First, they are mainly increasing from 2000 to 2003. Then, they are decreasing until 2011, before increasing again after 2012. The dynamic behavior of correlations makes them switch from positive to negative value over the period. From 2000 to 2003, all correlations are positive, meaning that a negative shock on stock returns or SSR changes in both currency areas is generally associated with a euro appreciation. Similarly, $\{\rho_{SC}, \rho_{SC^*}\}$ are negative on average from 2009 to 2013. Therefore, negative shocks on stock returns in both currency areas are mainly associated with US dollar appreciation during this period. This specific exchange rate behavior from 2009 to 2013 can be explained by the safe haven status of the US dollar during financial distresses. Finally, 2008 is the only year where both $\rho_{SL^*}$ and $\rho_{SC^*}$ are positive while $\rho_{SL}$ and $\rho_{SC}$ are negative, suggesting that positive shocks on one currency area is associated with an appreciation of its currency.

4.2 Efficient diversification from 2000 to 2015

To close our estimation of efficient diversification, we need to define leverage ratio. Following the Basel III framework, a minimum leverage ratio ($E/A$) is fixed at 3%, implying a leverage of 32.33. Then, we use the yearly average conditional variances and correlations reported in table 2 and 3 to identify efficient portfolios. Assuming that the bank is resident in the EA, figure 5 then illustrates efficient currency diversification on both sides of bank’ balance sheet.
From 2001 to 2003, $\lambda > \psi$ in order to benefit from risk reduction in equity related to correlations with foreign exchange rate $\{\rho_{SL}, \rho_{SL^*}, \rho_{SC}, \rho_{SC^*}\}$. Are they are all positive, a currency mismatch where $\lambda > \psi$ implies that correlations between stock returns and foreign exchange rate reduce equity volatility, while correlations between SSR changes and foreign exchange rate increases it to a lesser extend because of the leverage effect. However, the currency mismatch is relatively limited as $\rho_{L^*C^*} > \rho_{LC}$ and $\sigma_{C}^2 > \sigma_{C^*}^2$ over this period.

Unsurprisingly, 2008 is characterized by large degree of volatility in all components of the bank’s balance sheet: stock returns in both currency areas reach their highest level of volatility, and we observe the second largest volatility of foreign exchange rate and EA SSR. 2008 is also the only year where the US asset return volatility is larger than the volatility of EA asset returns. Therefore, the efficient diversification of assets $\psi$ reaches its lowest point that year. Despite of the financial crisis, the model still predicts a large currency exposure in both sides of bank’s balance sheet where almost half of the bank’s balance sheet is in foreign currency. As mentioned previously, $\rho_{SL^*}$ is positive and $\rho_{SL}$ is negative but they share similar magnitudes. Therefore, an equally diversified liability cancels out impact of correlations. Similarly, $\rho_{SC}$ is negative and $\rho_{SC^*}$ is positive, and their magnitude are alike. A exposure of asset close to 0.5 is also justified. Finally, the large values of $\rho_{L^*C^*}$ and $\rho_{LC}$ support the currency match between assets and liabilities in order to absorb shocks from both sides of the balance sheet, foreign exchange rate risk aside. Currency exposure is thus compatible with large episodes of financial distress.

From 2009 to 2012, the model predicts a large decline in liability exposure with significant currency mismatch where $\lambda \leq 0.1$ and $\psi \geq 0.6$. During this period, several episodes of financial distress are observed in both the US and the EA financial markets.
Despite the large volatility in both financial markets, the US stock index still offers lower volatility than its EA counterparts, promoting large $\psi$. Additionally, the large volatility of foreign exchange rate observed during this period does not prevent from a currency mismatch because of the negative and strong correlation $\rho_{SC^*}$. Positive shocks on US asset returns are associated with euro appreciation while negative shocks are associated with US dollar appreciation: foreign exchange rate shocks and shocks on US asset returns balance one another. This stabilizing effect of $\rho_{SC^*}$ on equity volatility is maximized for relatively low value of $\lambda$, promoting then a currency mismatch. Finally, the US liability is not the best instrument to hedge against shocks on asset returns, foreign exchange rate fluctuations aside. As $\rho_{LC^*} > \rho_{L^*C^*}$, banks in the EA have an incentive to use domestic liability to cover foreign assets. Interestingly, this period of large currency mismatch where $\lambda \rightarrow 0$ corresponds to the period where European banks faced difficulties to fund themselves in US dollar, especially in 2011. This result points out the necessity to decompose completely equity volatility in order to understand all the consequences of banks’ external position.

After 2012, $\rho_{SC^*}$ increases and becomes positive, and the foreign liability turns back to be the best instrument to hedge against shocks on assets, foreign exchange rate aside. The previous currency mismatch where $\psi > \lambda$ is no more efficient. Additionally, it is more efficient to use $L^*$ to hedge shocks on both $C^*$ and $C$ than $L$ (i.e $\rho_{L^*C^*} > \rho_{LC^*}$), explaining that $\lambda > \psi$ in 2014 and 2015.

More generally, our results show that introducing currency exposure on both total assets and liabilities allows an improvement in equity stability, even during financial crisis such as 2008. Our estimations also explain the appearance of currency mismatch and it highlights the fact that risks can complement one another.

\textsuperscript{11}See Ivashina et al. [2015] for more details on this specific period.
Conclusion

The financial crisis of 2008 has drawn special attention to international activities of European banks. Especially, European banks are largely exposed to the US financial markets, implying diversified balance sheets. This exposure of banks’ balance sheet captures the effects of the global financial cycle where international stock indices are positively correlated, and where the US monetary policy is a major influence on credit conditions worldwide. Additionally, because assets and liabilities are denominated in foreign currency, the exchange rate fluctuations would alter or widen financial shocks depending on correlations.

The financial crisis has also expressed the need for more resilient banks. Therefore, this paper tries to find a way to exploit this global framework and to find some conditions under which currency exposure improves banking stability. To do so, we develop a theoretical model based on bank’s balance sheet definition. Interactions between asset returns, funding costs and exchange rate are introduced with stochastic processes, capturing the effect of the global financial cycle. The theoretical model then expresses clear conditions under which balance sheet diversification can improve equity stability.

Using daily data covering the US and the euro area financial markets, we first depict financial market dynamics from 2000 to 2015, including conditional correlations between asset returns, funding costs and exchange rate fluctuations. Thus it extends the previous analysis on financial market correlations and the identification of the global financial cycle. These estimations are then used to analysis efficient diversification between 2000 and 2015. Our results suggest that currency exposure reduces equity volatility even during large financial distresses such as 2008. Furthermore, our results point out the potential benefit of foreign exchange rate fluctuations depending on correlations between asset
returns and financing costs. Finally, and in addition to the Basel III regulatory framework, the currency dimension of banks’ balance sheet then offers an interesting potential regulatory tool to improve the resilience of banks and to understand the consequences of banks’ external positions.
Appendix

Descriptive statistics:

Table 1: Summary statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Skew</th>
<th>Kurt.</th>
<th>ADF</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>FX</td>
<td>-0.00001</td>
<td>0.00663</td>
<td>-.02090</td>
<td>4.42408</td>
<td>-1.422</td>
<td>3934</td>
</tr>
<tr>
<td>US SSR</td>
<td>-0.00001</td>
<td>.00019</td>
<td>-.67017</td>
<td>17.11876</td>
<td>-0.410</td>
<td>3934</td>
</tr>
<tr>
<td>EA SSR</td>
<td>-0.00001</td>
<td>.00019</td>
<td>.98390</td>
<td>19.19070</td>
<td>-0.791</td>
<td>3934</td>
</tr>
<tr>
<td>S&amp;P500</td>
<td>0.0001</td>
<td>0.01279</td>
<td>-.18733</td>
<td>10.82903</td>
<td>-0.879</td>
<td>3934</td>
</tr>
<tr>
<td>Euro Stoxx 50</td>
<td>-0.00009</td>
<td>0.01551</td>
<td>.01291</td>
<td>7.14403</td>
<td>-2.231</td>
<td>3934</td>
</tr>
</tbody>
</table>

Note: summary statistics are calculated using the first difference of log-level data (except for SSR which are initially in level instead of log-level) and unit root tests concern level data. ADF lags chosen by AIC.
Figure 1: Financial markets:
Sources: Bloomberg, The Reserve Bank of New Zealand.
DCC GARCH and conditional correlations

For each bivariate DDC GARCH, the estimation goes into two steps. First, it estimates
the conditional volatility of each one of the two series \( \{i, j\} \) from univariate GARCH(1,1).
Then, the bivariate DCC GARCH captures from the first step the dynamic correlation
between the two series. Suppose \( r_t \) a 2x1 vector of returns of 2 assets at time \( t \), \( H_t \) a
2x2 matrix of conditional variances of \( r_t \) at time \( t \) and \( z_t \) a 2x1 vector of iid errors such
that \( E[z_t] = 0 \) and \( E[z_t z_T^T] = I \). Then, univariate GARCH is such that:

\[
r_t = H_t^{1/2} z_t
\]  

(15)

Decomposing the covariance matrix \( H_t \) into conditional standard deviation \( D_t \) from
univariate GARCH, and a correlation matrix \( R_t \) capturing the dynamic correlation \( \{i, j\} \),
the DCC GARCH introduces the following extension:

\[
H_t = D_t R_t D_t
\]  

(16)

Where the varying conditional correlation matrix \( R_t \) is defined as:

\[
R_t = (I \circ Q_t)^{-1/2} Q_t (I \circ Q_t)^{-1/2}
\]  

(17)

\[
Q_t = (1 - a - b) \bar{Q} + a \epsilon_{t-1} \epsilon_{t-1}^T + b Q_{t-1}
\]  

(18)

Therefore, the dynamic matrix process \( Q_t \) is a function of \( \bar{Q} \), the unconditional corre-
lation matrix of the standardized errors \( \epsilon_t \). Our results suggest that all correlations are
mean-reverting process where \( (a + b) < 1 \). Additionally, all Wald tests reject the null
hypothesis where \( a = b = 0 \): conditional correlations are dynamic.
\begin{align*}
\sigma^2_{C^*} & \quad 2.12e-04 & \quad 5.72e-05 & \quad 2.47e-08 & \quad 2.91e-08 \\
\sigma^2_C & \quad 1.80e-04 & \quad 6.17e-05 & \quad 1.14e-07 & \quad 4.83e-08 \\
\sigma^2_{S^*} & \quad 2.81e-04 & \quad 4.53e-05 & \quad 3.32e-08 & \quad 3.61e-08 \\
\sigma^2_S & \quad 1.24e-04 & \quad 9.75e-05 & \quad 2.87e-08 & \quad 2.66e-08 \\
\sigma^2_{L^*} & \quad 3.11e-04 & \quad 7.09e-05 & \quad 2.23e-08 & \quad 1.83e-08 \\
\sigma^2_L & \quad 2.73e-05 & \quad 3.63e-05 & \quad 3.43e-08 & \quad 2.44e-08 \\
\sigma^2_{C^*} & \quad 1.05e-04 & \quad 1.67e-05 & \quad 3.43e-08 & \quad 8.33e-08 \\
\sigma^2_C & \quad 5.84e-04 & \quad 6.22e-05 & \quad 9.43e-08 & \quad 8.33e-08 \\
\sigma^2_{S^*} & \quad 3.34e-04 & \quad 7.61e-05 & \quad 3.74e-08 & \quad 4.59e-08 \\
\sigma^2_S & \quad 2.98e-04 & \quad 6.59e-05 & \quad 3.93e-08 & \quad 2.76e-08 \\
\sigma^2_{L^*} & \quad 2.30e-04 & \quad 5.77e-05 & \quad 4.05e-08 & \quad 6.08e-08 \\
\sigma^2_L & \quad 3.28e-04 & \quad 3.38e-05 & \quad 2.25e-08 & \quad 3.54e-08 \\
\sigma^2_{C^*} & \quad 1.95e-04 & \quad 3.38e-05 & \quad 2.25e-08 & \quad 3.54e-08 \\
\sigma^2_C & \quad 6.29e-05 & \quad 1.71e-05 & \quad 3.87e-08 & \quad 4.92e-08 \\
\sigma^2_{S^*} & \quad 1.29e-04 & \quad 1.70e-05 & \quad 2.43e-08 & \quad 2.71e-08 \\
\sigma^2_S & \quad 1.01e-04 & \quad 2.24e-05 & \quad 2.23e-08 & \quad 8.39e-08 \\
\end{align*}

Table 2: Conditional variances. $S$, $C$, $C^*$, $L$ and $L^*$ refer to the exchange rate, the eurostoxx 50 index, the S&P500 index, the euro Shadow Short Rate and the US Shadow Short Rate respectively.
Figure 2: Conditional variances from DCC GARCH(1,1)
Figure 3: Assets and liabilities: conditional correlations from bivariate DCC GARCH (1,1) estimations
Figure 4: Exchange rate: conditional correlations from bivariate DCC GARCH (1,1) estimations
\begin{table}
\centering
\begin{tabular}{cccccccccc}
\hline
 & $\rho_{LL^*}$ & $\rho_{CC^*}$ & $\rho_{LC}$ & $\rho_{L^*C^*}$ & $\rho_{PL^*C}$ & $\rho_{PL^*C^*}$ & $\rho_{PSL}$ & $\rho_{SL}$ & $\rho_{SC}$ & $\rho_{SC^*}$ \\
\hline
2000 & 0.44 & 0.52 & 0.20 & 0.20 & 0.04 & 0.14 & 0.15 & 0.21 & 0.00 & 0.02 \\
2001 & 0.48 & 0.58 & 0.33 & 0.28 & 0.26 & 0.25 & 0.27 & 0.28 & 0.20 & 0.21 \\
2002 & 0.43 & 0.60 & 0.49 & 0.32 & 0.27 & 0.26 & 0.14 & 0.22 & 0.31 & -0.07 \\
2003 & 0.45 & 0.60 & 0.44 & 0.30 & 0.32 & 0.28 & 0.36 & 0.40 & 0.41 & 0.36 \\
2004 & 0.50 & 0.57 & 0.25 & 0.20 & 0.13 & 0.22 & 0.41 & 0.37 & 0.14 & -0.07 \\
2005 & 0.43 & 0.58 & 0.20 & 0.20 & 0.14 & 0.21 & 0.18 & 0.10 & 0.17 & -0.04 \\
2006 & 0.47 & 0.62 & 0.23 & 0.14 & 0.11 & 0.16 & 0.32 & 0.03 & 0.01 & -0.12 \\
2007 & 0.51 & 0.61 & 0.40 & 0.35 & 0.27 & 0.28 & 0.22 & 0.04 & 0.00 & -0.11 \\
2008 & 0.50 & 0.59 & 0.45 & 0.40 & 0.37 & 0.33 & 0.13 & -0.16 & -0.01 & 0.05 \\
2009 & 0.50 & 0.64 & 0.34 & 0.26 & 0.28 & 0.25 & 0.08 & -0.07 & -0.35 & -0.44 \\
2010 & 0.44 & 0.64 & 0.36 & 0.27 & 0.33 & 0.24 & 0.04 & -0.27 & -0.36 & -0.44 \\
2011 & 0.42 & 0.65 & 0.45 & 0.34 & 0.37 & 0.30 & -0.06 & -0.42 & -0.44 & -0.52 \\
2012 & 0.43 & 0.63 & 0.37 & 0.28 & 0.31 & 0.26 & -0.07 & -0.35 & -0.49 & -0.46 \\
2013 & 0.47 & 0.62 & 0.21 & 0.19 & 0.17 & 0.18 & 0.09 & -0.17 & -0.09 & -0.22 \\
2014 & 0.36 & 0.62 & 0.20 & 0.26 & 0.20 & 0.22 & 0.23 & -0.12 & 0.17 & 0.01 \\
2015 & 0.31 & 0.59 & 0.15 & 0.26 & 0.13 & 0.22 & 0.30 & -0.10 & 0.32 & 0.15 \\
\hline
\end{tabular}
\caption{Conditional correlations. $S$, $C$, $C^*$, $L$ and $L^*$ refer to the exchange rate, the eurostoxx 50 index, the S&P500 index, the euro Shadow Short Rate and the US Shadow Short Rate respectively.}
\end{table}
Figure 5: Efficient currency diversification of bank’s balance sheet (2000-2015): $\psi$ and $\lambda$ are defined as to minimize the volatility of bank’s equity.
References


