ASSET ENCUMBRANCE AND BANK RISK: THEORY AND FIRST EVIDENCE FROM PUBLIC DISCLOSURES IN EUROPE

2021

BANCO DE ESPAÑA
Eurosistema

Documentos de Trabajo
N.º 2131

Albert Banal-Estañol, Enrique Benito,
Dmitry Khametshin and Jianxing Wei

ASSET ENCUMBRANCE AND BANK RISK: THEORY AND FIRST EVIDENCE FROM PUBLIC DISCLOSURES IN EUROPE

ASSET ENCUMBRANCE AND BANK RISK: THEORY AND FIRST EVIDENCE FROM PUBLIC DISCLOSURES IN EUROPE [(*)]

Albert Banal-Estañol

UNIVERSITAT POMPEU FABRA AND BARCELONA GSE

Enrique Benito

CITY, UNIVERSITY OF LONDON

Dmitry Khametshin

BANCO DE ESPAÑA

Jianxing Wei

UNIVERSITY OF INTERNATIONAL BUSINESS AND ECONOMICS

(*) Authors' contacts: Albert Banal-Estañol, Universitat Pompeu Fabra and Barcelona GSE, albert.banalestanol@upf.edu; Enrique Benito, City, University of London, enrique.benito.1@city.ac.uk; Dmitry Khametshin, Banco de España, dmitry.khametshin@bde.es; Jianxing Wei, University of International Business and Economics, jianxing.wei@uibe.edu.cn. All authors equally contribute to the paper.
Jianxing Wei acknowledges financial support from National Natural Science Foundation of China (Ref. No. 72003030) and University of International Business and Economics (Ref. No. 18QN01). Dmitry Khametshin acknowledges financial support from the Spanish Ministry of Economy and Competitiveness (BES-2014-070380). An earlier version of this paper was developed through CEPR's Restarting European Long-Term Investment Finance (RELTIF) Programme funded by Emittenti Titoli. We are grateful to Thorsten Beck, Javier Suárez, Florian Heider, Toni Ahnert, Xavier Freixas, Sergio Mayordomo, Yuliyan Mitkov, Ettore Panetti, Qifei Zhu, José María Liberti, Andrea Resti, Sergio Schmukler and Mungo Wilson for helpful comments and suggestions, as well as Alexandra Cahue and Jonas Nieto for excellent research assistance. This work has also benefited from comments by participants at the 2018 China International Conference in Finance (CICF), Financial Intermediation Research Society (FIRS) 2019 Conference, ESCB Cluster 3 Financial Stability 2019 Workshop, as well as at the seminars at Saïd Business School, Cass Business School, Bank of England, Banco de España, and Deutsche Bundesbank.
The views expressed in this paper are those of the authors and should not be attributed to the Banco de España or the Eurosystem. This draft is from July, 2021.

Documentos de Trabajo. N.º 2131

August 2021

The Working Paper Series seeks to disseminate original research in economics and finance. All papers have been anonymously refereed. By publishing these papers, the Banco de España aims to contribute to economic analysis and, in particular, to knowledge of the Spanish economy and its international environment.

The opinions and analyses in the Working Paper Series are the responsibility of the authors and, therefore, do not necessarily coincide with those of the Banco de España or the Eurosystem.

The Banco de España disseminates its main reports and most of its publications via the Internet at the following website: http://www.bde.es.

ISSN: 1579-8666 (on line)

Abstract

We document that overcollateralisation of banks' secured liabilities is positively associated with the risk premium on their unsecured funding. We rationalize this finding in a theoretical model in which costs of asset encumbrance increase collateral haircuts and the endogenous risk of a liquidity-driven bank run. We then test the model's predictions using a novel dataset on asset encumbrance of the European banks. Our empirical analysis demonstrates that banks with more costly asset encumbrance have higher rates of overcollateralisation and rely less on secured debt. Consistent with theory, the effects are stronger for banks that are likely to face higher fire-sales discounts. This evidence acts in favour of the hypothesis that asset encumbrance increases bank risk, although this relationship is rather heterogeneous.

Keywords: asset encumbrance, collateral, bank risk, credit default swaps.

JEL classification: G01, G21, G28.

Resumen

En este trabajo mostramos que la sobrecolateralización de los pasivos garantizados bancarios se asocia de forma positiva con la prima de riesgo de su financiación no garantizada. Incorporamos esta idea en un modelo teórico en el que los costes derivados del gravamen de activos *(asset encumbrance)* provocan un aumento de los descuentos aplicables al colateral *(haircuts)* y aumentan el riesgo endógeno de una quiebra bancaria por riesgo de liquidez. Posteriormente comprobamos las predicciones del modelo utilizando un nuevo conjunto de datos sobre el gravamen de activos de bancos europeos. El análisis empírico demuestra que los bancos con mayores costes derivados del gravamen de activos presentan mayores tasas de sobrecolateralización y menor dependencia de la financiación garantizada. En línea con nuestro modelo teórico, estos efectos son de mayor magnitud en los bancos que se enfrentan a mayores descuentos por ventas de activos en situaciones de estrés. Los resultados apuntan a que el gravamen de activos aumenta el riesgo bancario, aunque esta relación es bastante heterogénea.

Palabras clave: gravamen de activos, colateral, riesgo bancario, *swaps* de incumplimiento crediticio (CDS).

Códigos JEL: G01, G21, G28.

1 Introduction

Asset encumbrance refers to the existence of bank balance sheet assets being subject to arrangements that restrict the bank's ability to transfer or realise them. Assets become encumbered when they are used as collateral to raise (secured) funding, for example in repurchase agreements (repos), or in other collateralised transactions such as asset-backed securitisations, covered bonds, or derivatives. In stressed situations, high levels of asset encumbrance can impede obtaining funding and affect the liquidity and solvency of a bank.[1] Since bank failures can have substantial negative externalities, understanding the effects of asset encumbrance on bank default risk is crucial for financial stability.

Policymakers have acted decisively to address what were considered excessive levels of asset encumbrance. Several jurisdictions introduced limits on the level of encumbrance (Australia, New Zealand) or ceilings on the amount of secured funding or covered bonds (Canada, US), while others have incorporated encumbrance levels in deposit insurance premiums (Canada). Several authors have proposed linking capital requirements to the banks' asset encumbrance levels or establishing further limits to asset encumbrance as a back-stop (Juks (2012), Helberg and Lindset (2014), IMF (2013)). As part of the Basel III regulatory package, the Net Stable Funding Ratio requires banks to hold higher amounts of stable funding for encumbered assets. In Europe, regulatory reporting and disclosure requirements have been introduced and institutions are required to incorporate asset encumbrance within their risk management frameworks. The Dutch National Bank (DNB) even publicly committed to "keeping encumbrance to a minimum" (De Nederlandsche Bank (2016)). This point of view presumes that asset encumbrance is detrimental to financial stability. Despite regulatory intervention, the recent outbreak of the Covid-19 pandemic has led to a significant increase in asset encumbrance. In Europe, banks have made extensive use of new and existing central bank facilities while supervisory con-

[1] In Europe, one can find several examples of bank failures precipitated by high levels of asset encumbrance. Dexia, a Franco-Belgian bank that reported a Tier 1 capital ratio of 11.4% and a buffer of €88bn in liquid securities as of June 2011, was partly nationalised by the Belgian and French governments in the course of three months despite stress tests by the European Banking Authority (EBA) confirming its relatively strong capital position. Several commentators highlighted the high levels of encumbered assets as the key factor precipitating its move into government arms (e.g., FT (2011)). More than €66bn of Dexia's €88bn buffer securities were encumbered through different secured funding arrangements, particularly with the European Central Bank (ECB), and were therefore unavailable for obtaining emergency funding. In June 2017, Spain's Banco Popular was put into resolution by the European Single Supervisory Mechanism and was acquired by Banco Santander for a symbolic amount of €1. Yet, as of year-end 2016, it reported a Tier 1 capital ratio of 12.3% and had passed that year's EBA stress tests with a solid margin. The bank's disclosures show that nearly 40% of its total balance sheet assets were encumbered.

straints on asset encumbrance may have been eased temporarily to support lending.[2] In its latest annual report on Asset Encumbrance, the European Banking Authority (EBA) noted that 2020 registered the largest yearly rise in asset encumbrance since data is available (EBA (2021)).

Asset encumbrance is the product of the level of secured funding chosen by the bank and its overcollateralisation. In a bank's private decision, optimising asset encumbrance involves a trade-off between a bank's *ex-post* ability to withstand liquidity shocks and lower *ex-ante* funding costs associated with secured finance. Thus, higher levels of asset encumbrance reduce both the amount of unencumbered assets that the bank can use to meet sudden liquidity demands and the pool of assets that become available to unsecured creditors under insolvency, an effect coined as *structural subordination* (see, for instance, CGFS (2013)).[3] But by encumbering assets, a bank may also reduce its overall cost of funds and liquidity risks because posting collateral brings in cheaper and more stable secured funding — this is the *stable funding* effect of asset encumbrance. This paper presents a theoretical model exploring this trade-off and provides empirical evidence on the determinants of asset encumbrance and its relation to the bank risk premium.

Figure 1 motivates our further analysis. It plots CDS premia on subordinated debt of European banks in 2015 against overcollateralisation levels of their secured liabilities. On its vertical axis, the left graph plots banks' CDS premia on subordinated debt. Similarly, the chart on the right plots the differential between banks' CDS premia on subordinated and senior liabilities. On the horizontal axes, we plot overcollateralisation measured as the ratio of encumbered assets to the matching liabilities using the 2014 asset encumbrance disclosures.[4] The figure illustrates that banks with higher levels of overcollateralisation of their secured liabilities tend to face higher cost of unsecured funding. The link between the bank risk premium and the drivers of asset encumbrance is a starting point of our analysis.

[Figure 1]

[2]The DNB, for example, stated: "given the current circumstances, [the] DNB may allow, on a case-by-case basis, for some temporary relaxation of asset encumbrance limits, provided that this is well substantiated by the institution concerned" (De Nederlandsche Bank (2020)).

[3]As stated by Dr Joachim Nigel, a former member of the Executive Board of the Deutsche Bundesbank, in a speech at the 2013 European Supervisor Education Conference on the future of European financial supervision: "Higher asset encumbrance has an impact on unsecured bank creditors. The more bank assets are used for secured funding, the less remain to secure investors in unsecured instruments in the case of insolvency. They will price in a risk premium for this form of bank funding", see Nagel (2013).

[4]We provide a detailed description of data construction in Section 3. To ensure that the quality of banks' assets and their capital do not drive the relationship in Figure 1, we orthogonalise both the overcollateralisation levels and CDS premia with respect to banks' credit ratings and leverage. The regression coefficient (robust standard error) on overcollateralisation is 4.34 (2.12) for the CDS premium on the subordinated debt, and 1.3 (0.57) for the excess CDS premium on the subordinated debt net of the senior premium.

We rationalize the relationship observed in Figure 1 in a theoretical model in which higher asset encumbrance costs can increase required overcollateralisation and the endogenous risk of a liquidity-driven bank run by unsecured investors. In our model, encumbered assets have higher liquidation costs. These costs may represent value destruction stemming from weaker monitoring incentives of secured investors or higher price impact in fire-sales of collateral (Duffie and Skeel (2012)).[5] Additionally, encumbrance costs may also include legal costs and transaction costs of "unencumbering" collateral or transferring assets to the secured creditors in case of default. The costs of asset encumbrance determine which of its effects — the structural subordination or stable funding — dominates and, consequently, whether bank risk increases or decreases with the level of secured financing.

We show that the stable funding effect dominates the adverse impact of structural subordination when encumbrance costs are relatively low. Indeed, in this case, secured finance reduces bank risk because, if the bank is to be liquidated, asset encumbrance does not destroy too much value and leaves plenty of liquidity to the unsecured creditors. On the contrary, when the liquidation costs associated with encumbered assets are high, the amount of liquidity available after liquidation and paying back the debts to the secured creditors is low. In this case, the structural subordination effect dominates the one of stable funding, and secured financing increases default risk. Hence, we show that, in theory, the positive relationship between bank risk and overcollateralisation of secured liabilities is not ubiquitous. Namely, our approach admits that when costs of asset encumbrance are low, a regulation that limits its levels may be counterproductive and increase bank risk.

To provide additional insights into which case is empirically relevant, we use the model to generate further predictions on the relationship between asset encumbrance costs, overcollateralisation, and the optimal choice of secured funding. We show that, in theory, when encumbrance costs are high, they affect the optimal level of secured funding both directly and indirectly via collateral haircuts.[6] Low encumbrance costs, on the contrary, matter for the optimal choice of secured debt only inasmuch as they determine the levels of overcollateralisation.

[5]In our analysis, we do not distinguish between different sources of secured funding but rather analyse the choice between secured and unsecured finance in general. However, one can extend our framework and incorporate various modes of securitisation of the same pool of assets characterised by different levels of encumbrance costs. For instance, a prevalence of asset-backed securitisation over covered bonds issuance in the U.S. can be linked to higher costs of legal complexity of the latter. From this perspective, one can further relate asset encumbrance to a more general topic of risk transferring versus risk diversification under different modes of securitisation and its implications for financial stability. We thank the anonymous referee for pointing this out. While these issues are of great relevance, we do not address them in this paper since our data does not allow us to differentiate between various sources of asset encumbrance.

[6]Haircut refers to the extent of overcollateralisation. See Gorton and Metrick (2009) and Dang et al. (2013) for more details.

Furthermore, encumbrance, effectively, is more costly when banks losses from a premature liquidation of their assets are large.

We test these predictions in a cross-section of European banks spanning more than three hundred institutions from nineteen countries. To do this, we build a novel dataset using the information provided in the asset encumbrance disclosures published in 2015 by European banks, following a set of harmonised definitions provided by the EBA (EBA (2014)). We interpret encumbrance costs from the moral hazard perspective in which secured investors have weaker incentives to monitor the bank and prevent it from value-destroying activity. From this perspective, more opaque banks acting in an environment with weaker creditor rights protection are likely to have higher encumbrance costs. Hence, we use both bank- and country-level variation and measure encumbrance costs by banks' opacity and creditors' rights for filing for bank bankruptcy.

We show empirically that the encumbrance costs affect the level of secured funding both directly and via collateral haircuts. Hence, more opaque banks or banks headquartered in countries that limit creditors' rights for bankruptcy filing tend to face higher rates of overcollateralisation. Accordingly, these banks tend to rely less on secured funding in their capital structure. Furthermore, encumbrance costs affect the chosen level of secured financing directly, including when conditioning on collateral haircuts. This evidence acts in favour of the hypothesis that asset encumbrance increases bank risk. Finally, consistent with the theory, we show that the direct effect of encumbrance costs is stronger for banks that face potentially higher fire-sales discounts. This empirical fact implies that the impact of encumbrance costs on bank risk is rather heterogeneous.

Our paper contributes to a still scarce but growing literature on bank asset encumbrance and its implications for financial stability. Ahnert et al. (2019) provide a theoretical framework to study asset encumbrance by banks subject to rollover risk, in which greater encumbrance allows the bank to attract more funding from secured creditors and increases profitable investment, but also leads to a higher probability of an unsecured debt run. Our paper also analyzes asset encumbrance with bank run risk, but differs from Ahnert et al. (2019) in several key respects. First, in our model, banks can use cheap secured finance to replace unsecured funding, which generates the stable funding effect of asset encumbrance. Thus, we predict that the levels of secured funding can be negatively correlated with the bank risk when encumbrance costs are low. Second, in our model, encumbrance cost and fire-sales discount jointly determine the overcollateralisation of secured funding. In Ahnert et al. (2019), on the contrary, overcollateralisation is only affected by the recovery rate of encumbered assets upon default. Third, we provide novel empirical results on the determinants of overcollateralisation and its relation to bank asset encumbrance and risk, consistent with our theory.[7] Our result also differs from Gai et al. (2013) and Eisenbach et al. (2014) who study the financial stability implications of bank asset encumbrance in partial equilibrium models with exogenous funding structure.

Empirical analysis of banks' asset encumbrance is scarce. In the context of interbank markets, Di Filippo et al. (2016) find that banks with low creditworthiness replace unsecured borrowing with secured loans. Garcia-Appendini et al. (2017) document a positive relationship between the costs of unsecured debt and asset encumbrance in the context of covered bonds issuers. Our paper analyses the link between bank risk and asset encumbrance and studies the determinants of overcollateralisation and secured funding. To the best of our knowledge, our paper is the first to study this relationship using a broad cross-section of banks not limited to the largest bond issuers. Finally, we contribute to the literature on law and finance (see, for instance, Beck, Demirgüç-Kunt, et al. (2003), and Beck and Levine (2008)) by analysing bank creditor rights protection and financial stability linked by banks' choice of secured financing.

More generally, our paper is related with the literature on the role of secured debt in corporate financing.[8] Our paper is close to Rampini and Viswanathan (2020), who distinguish between collateral and secured debt and argue that the use of secured debt enables higher leverage, but also entails direct and indirect costs. Unlike Rampini and Viswanathan (2020), our paper focuses on a bank's funding structure with default risk.

The rest of the paper is organized as follows. Section 2 describes the theoretical framework. Section 3 provides empirical evidence. In section 4, we discuss the policy implications of our analysis. Section 5 concludes. Appendix A provides the proofs of the mathematical results, whereas Appendix B describes the sources of asset encumbrance in the data.

[7] Hardy (2014) argues that asset encumbrance reduces liquidation costs and probability of default insofar as it makes conflict resolution less costly. In our model, this would correspond to low (or negative) encumbrance costs which would give rise to a negative relationship between secured funding and bank risk. Helberg and Lindset (2014) study the interplay between asset encumbrance, bank capital, and regulation, and find that "asset encumbrance increases financial instability from lower optimal capital." We abstract from the capital and various regulatory regimes and contribute to their discussion by formulating a simple model in which equilibrium bank risk can increase due to higher optimal levels of secured funding when the liquidation costs associated with encumbrance are sufficiently high.

[8] In the literature, the possible explanations of the use of secured debt include mitigating agency conflicts between shareholders and creditors (Smith and Warner (1979), Stulz and Johnson (1985)), addressing the information asymmetries between the lender and borrower (Chan and Thakor (1987), Berger and Udell (1990), Thakor and Udell (1991)), or preventing debt dilution (Donaldson et al. (2020)). See Berger and Udell (1990), Rauh and Sufi (2010), Luck and Santos (2019), Benmelech et al. (2020) and Lian and Ma (2021) for the empirical findings on secured debt in corporate financing. A separate line of literature studies the effects of collateral value and haircuts fluctuations but without referring to the choice of secured vs. unsecured funding. See, for instance, Brunnermeier and Pedersen (2009) and Adrian and Shin (2010).

2 Theoretical Framework

We now present a simple model of a bank to understand the decisions about asset encumbrance.

A risk-neutral bank has access to a profitable project that needs one unit of cash at $t = 0$. The bank's project generates a random return $\theta \geq 0$ at $t = 1$ and a fixed return $k < 1$ at $t = 2$. The random payoff θ is distributed on the range $[0, \bar{\theta}]$ with a continuous cumulative distribution function F with a non-decreasing hazard ratio. As $k < 1$ and θ can be zero, the bank is subject to insolvency risk. The bank is protected by limited liability.

At $t = 0$, the bank has no cash at hand, so it needs to raise funds from a competitive credit market offering fairly-priced long-term demandable debt. That is, creditors can withdraw their money at $t = 1$ before the debt matures at $t = 2$. To meet creditor withdrawals, the bank can use, in addition to θ, the proceeds from selling part of the fixed second-period returns k prematurely. The bank can sell these assets at $t = 1$ only at a fire-sales discount: the per-unit price at $t = 1$ is $\phi < 1$.[9] The bank fails if the amount of funds withdrawn at $t = 1$ exceeds its liquid assets. Thus, the bank is subject to liquidity risk.

The bank raises funding by issuing secured or unsecured debt, so as to maximize the bank's expected profits at $t = 0$. There are two types of creditors. Some are risk-neutral but demand a minimum expected gross return of $1 + \gamma$, with $\gamma > 0$. The others are infinitely risk-averse, and willing to lend only if debt is absolutely safe, but they demand a minimum return of just 1.[10] Since infinitely risk-averse investors demand a lower expected return, it is optimal for the bank to raise (safe) secured funding from this group of investors, and (risky) unsecured debt from the risk-neutral investors. This setup captures a major advantage of secure funding: it is perceived to carry lower roll-over risks and is generally cheaper than equivalent unsecured funding. In what follows, we refer to γ as risk premium or secured funding gains.

Denote by s the funds raised through secured debt to the risk-averse investors, and by $1 - s$ those raised through unsecured debt to the risk-neutral investors. To make sure risk-averse investors are repaid fully and unconditionally, the bank needs to pledge enough assets. The bank can use the project's payoff k at $t = 2$. The bank's return θ at $t = 1$, instead, cannot be pledged because it is random. Hence, from now on, we refer to k as the available collateral of the bank, part or all of which can be "encumbered", i.e., used to raise secured funding.

[9] Equivalently, at $t = 1$, there is a bond market where the bank can sell, at a price ϕ, riskless bonds which promise one unit of cash at $t = 2$. Since the project's payoff at $t = 2$ is k, the bank can sell up to k riskless bonds. Freixas and Rochet (2008), for instance, use the same setup.

[10] A possible interpretation of this assumption is that investors obtain utility directly from holding riskless assets, see Krishnamurthy and Vissing-Jorgensen (2012), Stein (2012), Caballero and Farhi (2013), W. Diamond (2020) and Magill et al. (2020) for similar modeling assumptions. Gorton, Lewellen, et al. (2012) and Krishnamurthy and Vissing-Jorgensen (2012) provide empirical evidence consistent with this assumption.

This setup captures common sources of asset encumbrance, such as repo financing, securities financing transactions, or asset-backed securities.[11]

Encumbering a bank's assets, however, can be costly. In the model, we capture these features through a proportional cost $c \geq 0$ associated with secured funding, so that the bank incurs additional losses cs in case of default.[12] We argue that this is a convenient way to capture multiple sources of costly encumbrance in a simple reduced form.[13]

The mechanisms generating costs of encumbrance are diverse. For instance, in Calomiris and Kahn (1991), demandable debt act as an instrument to prevent opportunistic behavior by the bank managers.[14] However, insurance provided by collateral can weaken creditors' incentives to monitor the issuer of secured claims. To the extent the lax monitoring by secured investors can not be easily compensated by other mechanisms, it is likely to exacerbate agency problem of bank managers and destroy value upon default.

The weaker monitoring pressure by secured investors can manifest itself, among other things, in stronger incentives of bank managers to postpone filing for bankruptcy. Apart from direct losses of this gambling for resurrection before resolution takes place, late filings can further impact fire-sales prices of the liquidated institution. Duffie and Skeel (2012) discuss these concerns in more detail. Boyd and Hakenes (2014) and Akerlof et al. (1993) discuss looting and risk shifting by managers of a bank facing likely default.

Encumbrance costs may also represent legal or transaction costs of transferring assets from the defaulting bank to the secured creditors (as specified, for instance, in ICMA's Global Master Repurchase Agreement). We think, however, that informational frictions described above are likely to be more important quantitatively.

The resulting maximum amount of secured funding available to the bank at $t = 0$ is, thus, $\phi(1+c)^{-1}k$. Indeed, for each unit of secured funding, the bank needs to encumber $\phi^{-1}(1+c) > 1$ units of the collateral k, so that the bank can sell it at the fire-sales price at $t = 1$ and recover 1 unit, once the encumbrance costs are taken into account. The overcollateralisation or "haircut", understood as the difference between the assets' value and the amount that can be used as collateral, is thus given by $h \equiv 1 - \phi(1+c)^{-1}$. Note that encumbrance costs affect the

[11] See Appendix B for further details on sources of asset encumbrance in practice.

[12] The assumption that encumbrance costs are incurred by the bank can be generalized to the assumption that encumbrance is more costly for a defaulting bank than for a surviving one.

[13] Similarly, Rampini and Viswanathan (2020) argue that the cost of encumbering assets can either be a direct cost or an indirect cost due to a loss in operating flexibility, monitoring costs, or the inconvenience of use restrictions. Tirole (2006) discusses various costs of pledging assets in corporate finance. See also Jackson and Kronman (1979), Scott (1996) and Mann (1997) for the discussions of the cost of encumbering asset in the law literature.

[14] See also D. W. Diamond and Rajan (2001).

required levels of overcollateralisation since they reduce the amount of resources available to all creditors upon default.

The encumbered assets cannot be used at $t = 1$ to meet unsecured debt holders' withdrawals. In the event of a "bank run", secured debt holders can seize the encumbered assets to meet their claim s. Because of full collateral protection, they have no incentive to withdraw money in the interim period (i.e., to run the bank). In case of bank failure, the bank distributes any of the remaining proceeds from selling the long-term assets prematurely $\phi(1+c)^{-1}k - s$, along with θ, on a pro-rata basis to the unsecured investors.

The timing of the model is illustrated in Figure 2.

[Figure 2]

Our model includes several departures from the Modigliani and Miller framework. First, as it is standard in the banking literature, in the presence of costly asset liquidation, coordination failure may give rise to bank runs. Furthermore, encumbered assets give rise to additional liquidation costs, thus reducing the amount of liquidity available to the unsecured investors *ex-post* and increasing bank risk and its total debt obligations *ex-ante*. We turn to the analysis of the trade-offs of asset encumbrance in the next section.

2.1 Effects of asset encumbrance on bank risk

This section identifies the effects of an exogenous level of secured funding s on the bank's risk of failure. Since secured debt is absolutely safe, the face value per unit of secured debt is equal to 1, which is the minimum return demanded by infinitely risk-averse investors. We first treat the face value of a unit of unsecured debt, which we denote by D, as exogenously given and identify the trade-off between structural subordination and stable funding. Thereafter we endogenise D, taking into account that the risk-neutral investors demand a minimum return of $1+\gamma$, and identify the key drivers of this trade-off. In the following section, we endogenise the level of secured funding s and thus the resulting levels of asset encumbrance.

To proceed, we introduce liquidity and solvency thresholds that determine the final outcome. Thus, the bank is insolvent at $t = 1$ if and only if the total value of the bank's assets is inferior to the total amount of debt obligations, i.e., when $\theta + k < s(1+c) + (1-s)D$. Since $k < 1$ and θ can be low, there exists a critical solvency return $\underline{\underline{\theta}}$ such that the bank is insolvent if and only if $\theta < \underline{\underline{\theta}}(s) \equiv s(1+c) + (1-s)D - k$. In case the realization of θ is low, unsecured debt holders withdraw their money, thus provoking a (fundamental) bank run. We call $\underline{\underline{\theta}}$ *solvency threshold*.

The bank is not only exposed to insolvency risk but also exposed to liquidity risk. Despite being solvent, the bank may suffer a bank run at $t = 1$ if the unsecured investors' demands are superior to the bank's available liquidity. To meet withdrawals, the bank can use its $t = 1$ proceeds θ as well as proceeds from the fire-sales of long-term assets, net of the amount recovered by secured creditors, $k\phi - s$, and encumbrance costs, cs. Hence, the bank may suffer a run if $\theta + [k\phi - s(1+c)] < (1-s)D$. Rearranging, there exists a critical *liquidity threshold* $\underline{\theta}$, such that the bank is illiquid in case all unsecured investors withdraw if and only if:

$$\theta < \underline{\theta}(s) \equiv (1-s)D - [k\phi - s(1+c)]. \tag{1}$$

The range of θ can be split into three regions.[15] If $\theta < \underline{\underline{\theta}}$, the bank is insolvent. If $\underline{\underline{\theta}} < \theta < \underline{\theta}$, the bank is solvent but possibly illiquid. If $\theta > \underline{\theta}$, the bank is solvent and liquid. The intermediate region $\underline{\underline{\theta}} < \theta < \underline{\theta}$ spans multiple equilibria. In one of them, all unsecured debt holders withdraw and the bank fails. In another equilibrium, all unsecured debt holders choose not to withdraw and the bank survives. For simplicity, we assume that the bad equilibrium prevails, so that the bank fails if it is solvent but possibly illiquid, because of the unsecured investors' self-fulfilling concern that all the other unsecured debt holders withdraw.[16] Since $\theta \sim F(\theta)$, the bank fails at $t = 1$ with probability $F(\underline{\theta})$ so that bank's default probability increases in $\underline{\theta}$. Given that F is increasing in θ, we call $\underline{\theta}$ a "liquidity threshold" and "bank default risk" or simply "bank risk" interchangeably.

Notice that an increase in the level of secured funding, s, has two effects on the bank's default risk, $\underline{\theta}$. On the one hand, as s increases $(1-s)D$ decreases, which implies that the bank needs less liquidity to face a potential liquidity shock at $t = 1$. This is the *stable funding effect* of secured financing. On the other hand, as s increases, $k\phi - s(1+c)$ decreases, which implies that the amount of net unencumbered assets available to the unsecured debt holders is lower. This is the *structural subordination effect* of secured funding. As we show next, the balance between the two effects depends on the benefits and costs of using secured funding, γ and c, respectively.

[15] Simple algebra shows that $\underline{\underline{\theta}} \leq \underline{\theta}$, with the inequality being strict if $\phi < 1$ or $c > 0$.

[16] If the good equilibrium were to be chosen, bank's liquidity risk will disappear. In this case, only solvency risk would be relevant for the bank. Our results would still hold, nevertheless, if we were to allow (more generally) for an (exogenous) positive probability of failure. In principle, we could also use the global games approach to select a unique equilibrium (e.g., Rochet and Vives (2004), Goldstein and Pauzner (2005) and Ahnert et al. (2019)). We work with an exogenously chosen equilibrium for tractability.

We endogenise D as following. The face value of the unsecured debt D is determined by the break-even condition:

$$(1-s)(1+\gamma) = \int_0^{\underline{\theta}(s)} (\theta + k\phi - s(1+c))\,\mathrm{d}F + \int_{\underline{\theta}(s)}^{\bar{\theta}} (1-s)D(s)\,\mathrm{d}F. \tag{2}$$

The first term in the right-hand side is the unsecured debt holders' expected return in the case of a bank run: unsecured debt holders share, on a pro-rata basis, the realized return at $t = 1$, θ, as well as all the value of the encumbered assets, $k\phi - s(1+c)$. The second term in the right-hand side is the unsecured debt holder's expected return when they are fully paid. The left-hand side is the opportunity cost of the unsecured debt holders' funding.

Combining (1) and (2), we get the following Proposition:

Proposition 1 *If encumbrance costs c are lower (higher) than the risk premium γ, bank risk $\underline{\theta}$ is decreasing (increasing) in the level of secured funding s.*

This result is intuitive. If encumbrance does not impose significant costs on the bank ($c < \gamma$), the amount of liquidity left after recovering the collateral in the case of a bank run is relatively large. In this case, by exploiting the stability of secured debt, the bank needs less liquidity $\underline{\theta}$ to meet the withdrawals of the unsecured investors at $t = 1$: the stable funding effect dominates the one of structural subordination. If, on the contrary, encumbrance is costly ($c > \gamma$), the amount of liquidity left to the unsecured investors in case of a bank run is small. Hence, for higher values of secured funding s, the bank is required to have more liquidity $\underline{\theta}$ to compensate the outflow of unsecured funds at $t = 1$: the structural subordination effect dominates the one of stable funding.

2.2 Optimal levels of asset encumbrance

We now examine the bank's optimal choices of secured funding an asset encumbrance. The expected profits of the bank at $t = 0$ are given by:

$$\Pi = \int_{\underline{\theta}(s)}^{\bar{\theta}} \{\theta + k - [s + (1-s)D(s)]\}\,\mathrm{d}F \tag{3}$$

Indeed, when $\theta < \underline{\theta}$, the banks fails due to a bank run at $t = 1$ and the bank (insiders) get 0. When $\theta > \underline{\theta}$, the bank survives and the payoff of the bank's assets is $\theta + k$. At $t = 2$ the bank pays s to secured debt holders and $(1-s)D$ to unsecured investors. Clearly, Π depends on $\underline{\theta}$ and D, which depend, in turn, on s, as shown in (1) and (2), respectively.

Simple algebra shows that, substituting (1) and (2) into (3), we have:

$$\frac{\mathrm{d}\Pi}{\mathrm{d}s} = \gamma - cF(\underline{\theta}(s)) - [\underline{\theta}(s) - \underline{\underline{\theta}}(s) + sc]\frac{\mathrm{d}F}{\mathrm{d}s}(\underline{\theta}(s)). \tag{4}$$

The first term shows that a marginal increase in s benefits the bank by allowing it to save γ on each additional unit of secured funding. The second term states that, for a fixed endogenous probability of bank failure, the additional unit of secured finance comes at a per-unit cost c realized upon bank run. The last term describes the effect of encumbrance coming from a change in the probability of bank run associated with a marginal shift in secured debt. As we show in the previous section, secured funding can both decrease or increase bank risk, and the direction of this effect depends on the encumbrance costs c and the funding benefits γ. The expression in the square brackets, in its turn, can be understood as exposure to this marginal change in bank risk. It consists of (i) the part of the risky payoff that may be lost due to liquidity run in excess of the losses coming with the fundamental run, $\underline{\theta} - \underline{\underline{\theta}}$, and (ii) direct encumbrance costs, sc.[17] The optimal choice of secured finance, thus, balances its marginal benefits (lower required return) with marginal costs (additional expected liquidation costs as well as the effects of encumbrance on the probability of liquidation).

To characterise optimal levels of secured funding further, we consider the two cases: low and high encumbrance costs relative to the risk premium. When the cost of encumbrance c is low ($c < \gamma$), secured funding affects the bank's expected profits positively, in two ways. First, since secured funding is a cheaper source of finance, relative to the costs it has, higher asset encumbrance reduces bank's overall funding cost: conditional on success, the bank receives larger residual payoffs (first two terms in (4)). Second, since $c < \gamma$, asset encumbrance reduces the bank's liquidity risk (third term in (4)). Thus, the bank sets the level of secured funding as high as possible.

Proposition 2 *If encumbrance costs c are lower than the risk premium γ, the bank's profits are strictly increasing in the level of secured funding s, which implies that the optimal level of secured funding for the bank is $s^* = k\phi(1+c)^{-1}$.*

Consider next the case when encumbrance costs are relatively high ($c > \gamma$). From Proposition 1 we know that in this case bank's risk is increasing in the level of secured funding. In

[17] This term can equivalently be rewritten as $kh - c(k(1-h) - s)$. Hence, when the bank uses its full collateral capacity, $s^* = k(1-h)$, the exposure to the marginal change in the bank risk can be measured by the unpledgeable part of the safe asset, kh. This exposure decreases when the bank chooses a lower level of secured funding.

this case the bank may opt not to use its full collateral capacity. In terms of the FOC condition implied by (4), the bank balances the positive effects of secured funding γ with its unambiguously negative consequences for default risk (a higher expected losses induced by encumbrance $cF(\underline{\theta})$, and a marginal increase in the default probability $\frac{\mathrm{d}F}{\mathrm{d}s}(\underline{\theta})$). The effect that dominates depends on the level of encumbrance costs c:

Proposition 3 *If encumbrance costs c are higher than the risk premium γ, there exist $\underline{c}$ and $\bar{c}$, such that $\gamma < \underline{c} < \bar{c}$ and*

(i) bank profits are strictly increasing in the level of secured funding s, so that the optimal level of secured funding is $s^* = k\phi(1+c)^{-1}$ if encumbrance costs are moderately high, $\gamma < c < \underline{c}$;

(ii) bank profits exhibit an inverted U-shaped form in the level of secured funding s, so that the optimal level of secured funding is interior, $s^* \in (0, k\phi(1+c)^{-1})$ if encumbrance costs are significantly high, $\underline{c} < c < \bar{c}$;

(iii) bank profits are strictly decreasing in the level of secured funding s, so that the optimal level of secured funding is $s^* = 0$ if encumbrance costs are too high, $c > \bar{c}$.

Note that when $\gamma < c < \underline{c}$, the bank chooses to use its full collateral capacity, $s^* = k(1-h)$. This equilibrium outcome is identical to the case when $c < \gamma < \underline{c}$. As discussed below, this result poses challenges for identifying the effect of secured funding on bank risk since the bank's optimum alone does not allow to differentiate the two cases.

2.3 Implications for empirical analysis

Propositions 2 and 3 highlight the main conceptual difficulty of empirical identification of the relationship between bank risk and secured funding. Thus, the propositions suggest that the bank chooses to use its full collateral capacity whenever encumbrance costs are relatively low, i.e., when $c < \underline{c}$. However, as suggested by the Proposition 1, this fact alone does not identify the dependence of bank risk on secured funding as the latter may have positive or negative effect on bank risk whenever $\gamma < c < \underline{c}$ or $c < \gamma < \underline{c}$, correspondingly. Similarly, one can show that, in equilibrium, the price of unsecured debt, D, is positively related to encumbrance costs c whenever $c < \underline{c}$. In this case, the bank uses its full collateral capacity, $s^* = k(1-h)$, and the cost of the unsecured debt is $D^* = \frac{\theta(k(1-h))}{1-k(1-h)}$. Taking into account that $\frac{\mathrm{d}\theta}{\mathrm{d}h} > 0$ and $\frac{\mathrm{d}h}{\mathrm{d}c} > 0$, we have $\frac{\mathrm{d}D^*}{\mathrm{d}c} > 0$.[18] It follows, that the positive relationship between the cost of the unsecured debt, D, and the level of overcollateralisation, h, can be obtained both when encumbrance costs are low, $c < \gamma < \underline{c}$, or moderately high, $\gamma < c < \underline{c}$. Hence, in our model, observing high levels of secured funding or its positive correlation with the cost of unsecured debt do not necessarily imply that, if the bank was constrained to reduce its encumbrance ratio, the default risk would have gone down.

Still, Proposition 3 suggests a way to differentiate between moderately high and significantly high encumbrance costs. This comparison, in its turn, is informative about the sign of the sensitivity of bank risk with respect to secured funding. We formulate this result as the following corollary.

Corollary 1 *An increase in encumbrance costs c when haircut h is held fixed (i) does not affect the optimal level of secured funding s^* if $c < \underline{c}$, and (ii) decreases the optimal level of secured funding s^* if $\underline{c} < c < \bar{c}$.*

In the model, encumbrance costs affect the haircut on secured funding because they reduce the amount of liquidity available to all creditors upon default. Hence, collateralisability of the safe asset decreases as encumbrance costs increase. If these costs are relatively low ($c < \underline{c}$), the bank chooses maximum available secured funding, $s^* = k(1-h(c,\phi))$: in this case, encumbrance costs propagate to the choice of funding structure only via collateral haircut.

Corollary 1 highlights that, apart from affecting the choice of secured funding via haircut, asset encumbrance has another — direct — effect on the optimal funding structure. This effect manifests itself in the bank's optimal decision whenever encumbrance costs are sufficiently high ($\underline{c} < c < \bar{c}$). In this case, the bank chooses to operate at the interior optimum below its full collateral capacity, $s^* < k(1-h)$, to reduce marginal costs of secured debt. As discussed above, lowering these costs involves reducing expected per-unit losses from encumbrance, decreasing the sensitivity of default probability to the choice of s, and lowering the bank's exposure to the changes in default probability. All three components of marginal costs depend positively on encumbrance costs, even when the collateral haircut is held fixed. In the interior optimum, this results in a negative dependence of secured funding on the costs of asset encumbrance — in addition to the effects of the latter mediated via haircut.

Corollary 1, when coupled with the Proposition 1, shows that the presence of the direct negative effect of encumbrance costs on the level secured funding is indicative of unambiguously

[18] This results holds whenever $(1+\gamma)(1-k(1-h)) > \underline{\theta}(k(1-h))(1-F(\underline{\theta}(k(1-h))))$ which holds from the break-even condition.

positive relationship between the latter and bank risk. We use this model conclusion extensively as a guidance for the empirical analysis below.

Another implication for the interpretation of empirical evidence concerns the role of fire-sales prices. Intuitively, fire-sales price determines the minimum losses of a bank's liquidity that do not depend on its funding structure. Hence, with high fire-sales discounts, even small encumbrance costs can hurt the bank by further draining its liquidity *ex-post* and increasing the probability of bank run *ex-ante*. In other words, the bank can perceive the same level of encumbrance costs as low when it does not lose too much value in fire-sales and high — if asset liquidation is exceptionally costly. We formalize this intuition in the following corollary.

Corollary 2 *The encumbrance cost threshold $\underline{c}$, that separates interior optimum from the case of full collateral utilisation, is high when fire-sales discount is low:*

$$\frac{\mathrm{d}\underline{c}}{\mathrm{d}\phi} > 0.$$

Corollary 2 suggests that conditional on the level of overcollateralisation, encumbrance costs are more likely to directly affect the chosen level of secured funding when fire-sales discounts are high. We use this conclusion in the next section, where we analyse the dependence of secured funding on encumbrance costs empirically.

3 Empirical evidence

Figure 1 that motivated our analysis so far is indicative of a positive relationship between secured funding and bank risk. Yet, as discussed above, this fact alone may not be sufficient to conclude that secured finance increases bank risk. In this section, we provide further empirical evidence on the relationship between encumbrance costs, overcollateralisation, and secured funding using a larger cross-section of European banks. Our general empirical strategy is as follows. We first analyse the determinants of overcollateralisation across banks. Having identified the variables that are likely to be related to the theoretical concept of costs of asset encumbrance, we move on to the analysis of the determinants of bank's reliance on secured funding. Following our theoretical results, we are mostly interested in the drivers of secured funding conditional on the haircuts faced by the banks. In particular, to interpret the empirical observations, we employ Corollary 1 and analyse whether proxies of encumbrance costs correlate with the choice of secured funding beyond the effects of the former on overcollateralisation. Finally, guided by Corollary 2, we analyse the heterogeneity of the relationship between encumbrance costs and secured finance in its relation to the potential magnitude of fire-sales discounts.

3.1 Data and Descriptive Statistics

Asset encumbrance, balance sheet, and macroeconomic data. Computing asset encumbrance measures at the bank level is not straightforward since standard accounting data provides limited information to infer the amount of banks' encumbered assets, unencumbered assets and matching liabilities. Accounting statements are accompanied by disclosures which try to shed light on the amount of assets that collateralise transactions but, as noted by the EBA: "existing disclosures in International Financial Reporting Standards may convey certain situations of encumbrance but fail to provide a comprehensive view on the phenomenon" (EBA (2014)). For this reason, the EBA introduced new guidelines in 2014 proposing the requirement to disclose asset encumbrance reporting templates. EBA guidelines do not constitute a regulatory requirement and, although most did, not all of the European institutions disclosed such information.

We start the empirical analysis by selecting the sample of EU banks whose total assets exceed €1 mn. as of the end of 2014. For each bank, we collect risk disclosures from its web page and extract the reported encumbrance data from the reporting templates suggested by the EBA. The data includes information on encumbered and unencumbered assets, off-balance sheet (OBS) collateral received and available for encumbrance, OBS collateral received and re-used, and matching liabilities (the liabilities or obligations that give rise to encumbered assets). The encumbrance data we use in this paper is as of year-end 2014. Our main sample includes 306 banks from 19 countries.[19]

To calculate bank-level values of secured funding and corresponding collateral haircuts, we rely on the reported values of total encumbered assets, total unencumbered assets, and matching liabilities. We include encumbered off-balance positions of the bank in calculating haircuts. Reporting of matching liabilities is of somewhat lower quality than the one of encumbered assets. Hence, about 14% of banks that disclose asset encumbrance do not disclose the value of matching liabilities. These banks are mostly small local lenders, and we do not include them in our final sample.

We calculate the haircut on bank secured lending as the difference between the total value of encumbered assets and matching liabilities divided by the former. Furthermore, we calculate

[19]Countries included in the sample are Austria, Belgium, Bulgaria, Cyprus, Germany, Denmark, Spain, France, the United Kingdom, Greece, Croatia, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Sweden, and Slovenia.

secured funding as the ratio of matching liabilities to the sum of encumbered and unencumbered assets. With these definitions, both variables are constructed using information solely from the disclosed risk reports. As an alternative definition and robustness check we use the ratio of matching liabilities to total liabilities as a measure of secured funding, where the liabilities are incurred from the Bankscope database. We get results similar to the ones reported below when using this auxiliary definition of total liabilities.

We complement this information with bank balance sheet data from Bankscope to capture known determinants of bank risk. The control variables include proxies for bank profitability (ratio of net interest revenue to total assets), quality of credit portfolio (share of non-performing loans in total loans), leverage (ratio of common equity to total assets), liquidity (deposits and short-term funding, and liquid assets, both normalized by total assets), and bank size (measured by the natural logarithm of total assets).[20] Furthermore, we include a dummy variable to identify which banks are of investment grade. We use implied ratings provided by Fitch Solutions and derived from proprietary fundamental data. These provide a forward-looking assessment of the stand-alone financial strength of a bank and are categorized according to a 10-point rating. Finally, we include dummy variables to differentiate the business model of the institution using four categories: "Commercial banks and Bank holding companies (BHC)", "cooperative banks", "savings banks", "real estate banks", and "other banks."

To account for potential sources of omitted variable bias at the country level, we expand the list of control variables to include macroeconomic indicators. In particular, we use net foreign assets of depository institutions normalized by a country's GDP to capture banking sector reliance on foreign funding (we obtain the data from International Financial Statistics of IMF). We also control for the marketability structure of financial system liabilities measured by the difference between security and loan liabilities of a country's financial corporations normalized by GDP (the data is obtained from Financial balance sheets of Eurostat). To capture the differences in deposit insurance systems across the countries, we use the Deposit Guarantee Scheme (DGS) Moral Hazard index from Demirgüç-Kunt et al. (2014). The latter aggregates multiple characteristics of a country's safety net in a way that higher values stand for "more generosity or greater government support and imply more moral hazard."[21] Finally, we add a dummy variable for banks headquartered in Greece, Ireland, Italy, Portugal, and Spain (GIIPS)

[20] Some sources of asset encumbrance, such as securitisation, involve substantial costs of a fixed nature, which may be particularly relevant for smaller banks (Adrian and Shin (2010), Carbó-Valverde et al. (2012), Panetta and Pozzolo (2018)).

[21] Ahnert et al. (2019) predict that banks have incentives to increase asset encumbrance to take advantage of deposit insurance.

dummy variable for banks headquartered in Greece, Ireland, Italy, Portugal, and Spain (GIIPS) and the Eurozone indicator to account for the heterogeneity of banks within the Euro Area and, more generally, within the EU.

Costs of asset encumbrance. Measuring potential encumbrance costs is notoriously difficult. Since no directly observable measures are available, we opt for using variables that are likely to serve as proxies for encumbrance costs from the perspective of the economic model described above. In particular, as described in the previous section, insolvency costs specific to secured financing can be related to agency problems that arise due to weaker monitoring incentives of the secured investors. Hence, we assume that encumbrance costs are higher for banks that are more difficult to monitor and use bank- and country-level variables that are likely to capture these agency frictions.

At the country level, we explore variation in bank resolution frameworks of the European countries. To do this, we rely on a "Study on the differences between bank insolvency laws and on their potential harmonisation" by the European Commission (Buckingham et al. (2019)). The Study analyses differences in the legislative regimes applicable at the national level to bank insolvency proceedings. It provides a qualitative description of resolution mechanisms in the EU member states along several dimensions, including differences in objectives of insolvency procedures, pre-insolvency activity, definitions of bank insolvency, and administrative proceedings in bank liquidation and administration.[22] We use the Study's section on "Standing to file insolvency" to identify member states that allow creditors to initiate insolvency proceedings. While in most of the countries of the EU the process can be commenced by the national competent authority, only half of the member states grant similar rights to creditors. Hence, we construct an indicator variable "Insolvency filing by creditor" equal to one for banks that are headquartered in countries where bank creditors can initiate insolvency proceedings, and zero otherwise.[23] We maintain that the right of the unsecured creditors to file for bankruptcy can serve as a threat to the bank managers preventing them from engaging in a value-destroying activity. To the extent this creditors' right of filing for insolvency can partially compensate for

[22]The legislative regimes applicable at a national level to bank insolvency proceedings can be very different from the ones applied to corporate insolvency in general. Buckingham et al. (2019) provide further details on this point. This difference in provisions governing bank insolvency and general corporate insolvency is the main reason why we opt for using the Commission's report as our source of creditors' protection classification. Also, since the report focuses on the EU, it covers all its member states in great detail, which may not be the case with other sources, such as the World Bank Doing Business database.

[23]The EU Member States that allow creditors to initiate insolvency proceedings are Belgium, Cyprus, Czech Republic, Denmark, Estonia, Spain, Finland, France, Latvia, Lithuania, Malta, Romania, and Sweden.

weaker monitoring incentives of the secured investors, it is likely to reduce the costs of reliance on secured finance and, hence, of asset encumbrance.

To proxy for potential encumbrance costs at the bank level, we use bank's reliance on non-interest generating activities in its business model. Non-interest income is typically related to a bank's complexity and its systemic risk (see, for instance, Brunnermeier, Dong, et al. (2020)). Inasmuch as these factors reduce the effectiveness of monitoring, in particular, by unsecured creditors, they may contribute to higher costs of bank insolvency. Hence, to quantify this idea, we construct an indicator variable "High share of Non-interest income" which takes the value of one for banks whose total non-interest income (in excess of the standard interest income) normalized by total assets exceeds the corresponding country-level median value. As such, the indicator captures the structure of bank revenues rather than its general profitability or size, and relates it to the bank's peers in the same country to take into account cross-country variation in complexity of the bank sectors.

[Table 1]

Table 1 reports summary statistics of the final sample of banks. The average (median) overcollateralisation of secured finance is 16.5% (3%). Secured liabilities of about one fifth of banks in our sample are undercollateralized (i.e., these banks face negative haircuts). Just above 10% of the assets of banks in our sample are financed with secured funding. The average bank has about 14.8% of assets encumbered under secured finance arrangements.

3.2 Regression analysis

We start our regression analysis first by determining the drivers of banks' levels of overcollateralisation. Table 2 reports estimates of a cross-section regression of overcollateralisation and its bank- and country-level determinants. We report both OLS and country fixed effects estimates that take into account unobserved country-level heterogeneity. The table illustrates that bank size and reliance on retail funding appear to be strongly negatively related to the magnitudes of overcollateralisation of secured funding. Furthermore, the haircuts decrease with banks' profitability (measured by Net interest revenue) and quality of their credit portfolios (measured by the ratio of Non-performing loans), although, this result is less robust statistically. Overcollateralisation levels tend to be lower in countries where depository institutions have lower net external financial assets or tend to finance themselves relatively more via securities rather than loans. Importantly, banks in the GIIPS countries tend to have higher collateral haircuts even when we condition the quality of their credit portfolios, capital, and profitability. We take this result as evidence of the positive impact of fire-sales discounts on the levels of collateralisation faced by the banks.

[Table 2]

Furthermore, variables that proxy for encumbrance costs are related to overcollateralisation, as suggested by the theory. Hence, banks that tend to rely on Non-interest income in their revenue structure appear to face overcollateralisation levels that are about 10 p.p. higher (an economic effect of 0.3 standard deviations). This is consistent with the idea that higher complexity or lower transparency of bank operations can diminish the efficiency of monitoring by unsecured investors and, hence, increase costs of bank default.

At the country-level, banks located in jurisdiction allowing for insolvency filing by creditors face lower encumbrance haircuts. The economic effect on haircuts of this form of creditors protection is comparable with the one of Non-interest income (9 p.p.), although, it is less precisely estimated. Again, this is consistent with the idea that the right to file for insolvency can streamline monitoring by the unsecured investors and, as a result, counterbalance additional default costs stemming from weaker monitoring incentives of the secured creditors. As in our theoretical model, both factors that increase the efficiency of monitoring by the unsecured creditors lower asset encumbrance costs and, hence, are taken into account by the secured investors when determining the required level of overcollateralisation.

Table 3 reports estimates of the regressions of bank secured funding on its determinants, including overcollateralisation. In column 1 we include explanatory variables similar to the ones included in Table 2, while columns 2 and 3 add collateral haircuts as an additional explanatory variable. Bank profitability, capital, and asset liquidity tend to be negatively associated with the reliance on secured funding. Interestingly, banks located in countries with more generous deposit insurance systems tend to have more secured liabilities (an economic effect of 0.3 standard deviations) and, hence, higher asset encumbrance, which is consistent with the theoretical prediction of Ahnert et al. (2019).

The variables proxying for costs of asset encumbrance have economically and statistically strong effects on the levels of bank secured liabilities. Since these effects can become (partially) operative via collateral haircuts, we include the latter in the list of explanatory variables. As a result, although the estimated effects become smaller in magnitude, they are still economically relevant. Hence, banks located in countries where creditors can file for insolvency tend to have higher secured liabilities (an economic effect of 0.7 standard deviations). Similarly, banks that rely more on Non-interest income in their operations tend to have lower levels of secured liabilities (an economic effect of 0.22 standard deviations). The latter estimate is robust to controlling for unobserved country-level heterogeneity.

[Table 3]

In the light of our theoretical model, the fact that the proxies of encumbrance costs are relevant determinants of secured funding *conditional on the levels of overcollateralisation* is an important empirical observation. Corollary 1 shows that this conditional dependence is indicative of large encumbrance costs and, hence, positive dependence of bank default risk and levels of asset encumbrance. To provide further support to this conclusion, we employ Corollary 2 and investigate the heterogeneity of secured funding determinants along the dimension of fire-sales prices. In particular, we analyse whether drivers of secured funding differ between German banks and banks located in GIIPS countries. As the European sovereign debt crisis has demonstrated, the former banks were less exposed to contagious fire-sales dynamics. In contrast, banks from the periphery countries were more likely to face higher discounts when liquidating their assets. Corollary 2 shows that the same level of encumbrance costs is likely to be more detrimental for the periphery institutions.

[Table 4]

We report the results of this exercise in Table 4. Since between-country variation is substantially smaller than in our previous regressions, we solely employ country fixed effects estimation. The results demonstrate that, conditional on overcollateralisation, the Non-interest income proxy for encumbrance costs is economically and statistically relevant only for the banks located in the periphery countries. For this subsample of banks, the economic effect on secured liabilities is more than twice as large as the one reported in Table 3. At the same time, higher reliance on Non-interest income does not appear to be a relevant driver of secured funding of the German banks. We conclude that lower fire-sales prices increase the effective costs of asset encumbrance. In the light of our theory, the periphery banks are more likely to exhibit positive dependence of bank default risk on asset encumbrance ratio.

4 Discussion

Bank defaults tend to impose significant negative externalities, which calls for regulation that internalises these costs in the bank's private optimum. We show that, in theory, secured finance increases the likelihood of a liquidity-driven bank run when asset encumbrance is sufficiently costly. We provide empirical evidence that is in line with this prediction, at least for some banks. Hence, the cost of unsecured funding of larger banks is positively related to the levels of overcollateralisation of their secured liabilities. More generally, encumbrance costs seem to matter for banks' choice of secured funding both directly and via collateral haircuts. The direct effect is indicative of a positive relationship between secured funding and bank risk, as it is only present when encumbrance is costly. Armed with this evidence, one may be willing to conclude that limits on asset encumbrance levels unambiguously decrease the chances of a liquidity-driven bank failure.

Yet, we show that, in theory, the positive relationship between bank risk and secured funding is not ubiquitous. When encumbrance costs are low relative to the gains of secured funding, the latter brings the liquidity risk down. In this situation, putting limits on asset encumbrance would be counterproductive as they would not allow minimising bank risk. While the evidence of low encumbrance costs on average is weak, Table 4 indicates that its effect on secured funding is heterogeneous. Hence, the gains of secured funding are more likely to be dwarfed by encumbrance costs if banks are exposed to high fire-sales discounts or, more generally, have illiquid assets. In this situation, conditioning encumbrance regulation on banks' asset liquidity may be necessary.

Similarly, aggregate developments in the economy may signal a deterioration of market liquidity conditions and, hence, lower fire-sales prices. Since the immediate adjustment of banks' funding structure is costly, central banks as lenders-of-last-resort may find it necessary to admit higher levels of banks' asset encumbrance to not provoke a liquidity run in the first place.

Finally, our analysis suggests that regulation of asset encumbrance should also adjust to the structural changes in the financial sector. The latter may come in the form of secured financing with lower transaction costs, better protection of unsecured creditors' rights, or higher demand for safe assets (that would further increase the gains of secured funding). Similarly, lower legal complexity and a more transparent financial accounting are likely to lower encumbrance costs, potentially changing the balance between the costs and the gains of secured funding.

5 Conclusion

Asset encumbrance has been a much-discussed subject, and policymakers have been actively addressing what some regulators considered excessive levels of asset encumbrance on the presumption that asset encumbrance is detrimental to financial stability. However, so far, theoretical and empirical studies on the subject have been scarce. The unprecedented level of liquidity support seen after the Covid-19 crisis is likely to increase asset encumbrance levels in the coming years, and therefore it is important that the trade-offs involved in constraining banks' asset encumbrance levels are better understood.

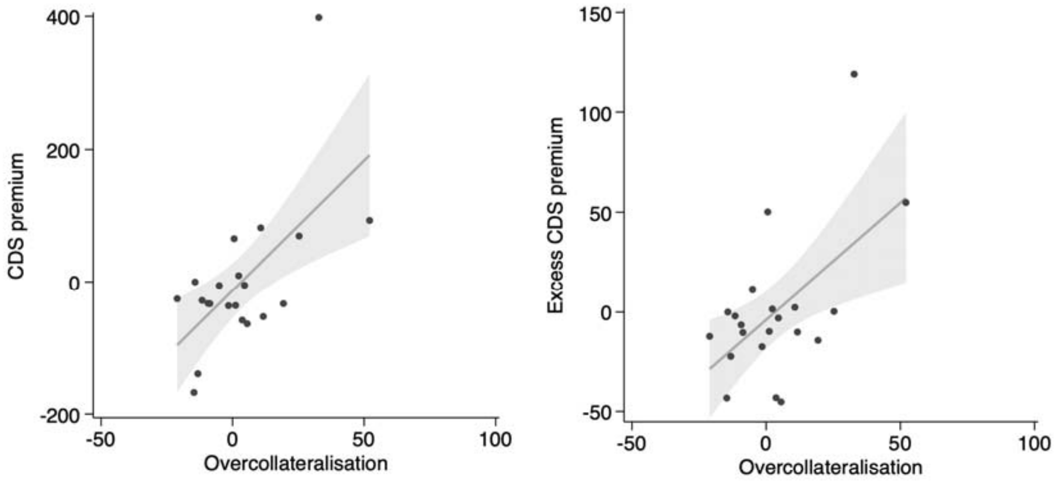
In this paper, we provide a theoretical model that captures the relationship between asset encumbrance and bank liquidity risk. According to this model, secured funding serves as a mechanism that changes a bank's exposure to liquidity risks. When encumbrance is not very costly, a bank can fully exploit the stability of secured financing and reduce its liquidity risks associated with the unsecured debt holders. Hence, secured funding and bank risk would have a negative relationship.

Alternatively, when a bank faces high encumbrance costs, secured funding can have the opposite effect on the bank's liquidity risk. In this case, the negative structural subordination effect dominates the positive impact of a run-prone secured debt. Hence, the relationship between encumbrance and bank risk premium can be positive when liquidation costs specific to secured funding are high.

We provide empirical evidence consistent with the hypothesis that bank liquidity risk increases with secured debt. We document that banks with higher levels of overcollateralisation of their secured liabilities tend to pay higher premiums on the unsecured debt. We also show that banks with more costly asset encumbrance have higher rates of overcollateralisation and rely less on secured funding. Consistent with theory, the effects are stronger for banks that are likely to face higher fire-sales discounts. The analysis suggests that a state-contingent regulation of banks' encumbrance ratios may be necessary to minimise liquidity risks.

While constraints in our data did not allow us to further explore the issue, future research could look at the implications of difference sources of secured funding such as repurchase agreements, mortgage backed securities or covered bonds, and whether using some over the others could make a difference to our results.

Figure 1. Bank CDS spreads on unsecured funding and overcollateralisation of secured debt



Vertical axes mark bank CDS spreads on subordinated liabilities (left graph) and excess CDS spreads on subordinated liabilities net of the ones on the senior liabilities (right graph). Horizontal axes mark overcollateralisation of secured funding. Both CDS spreads and overcollateralisation are centered and orthogonalised with respect to the banks' credit ratings and leverage ratios. The sample includes European banks with non-missing CDS quotes and asset encumbrance disclosures. CDS spreads (on 5 year "modified-modified" restructure Euro-denominated contracts) are from Datastream and averaged over the 2015 daily values. Overcollateralisation (net, in percents) is calculated using the 2014 asset encumbrance disclosures as the ratio of encumbered assets to the matching liabilities.

Figure 2. Model timeline

$t = 0$

Bank borrows 1 via
safe secured debt $s \leq k\phi$,
and unsecured debt $1 - s$
by promising D
to the unsecured investors

$t = 1$

Return $\theta \sim F[0, \bar{\theta}]$.
If the unsecured run,
bank may use net
unencumbered assets
$\theta + k\phi - s(1 + c)$
to pay back its debt

$t = 2$

If no run at $t = 1$:
Return $k < 1$
Debt matures with
face values of 1 (secured)
and $D > 1$ (unsecured)
Bank profits are realized

Table 1. Summary statistics

	Mean	Median	SD	p25	p75
Asset encumbrance ratio	14.8	10.1	12.5	7.0	20.1
Overcollateralisation	16.5	3.0	29.7	0	20.7
Secured funding	10.5	8.1	9.6	4.6	13.1
Bank characteristics					
Net interest revenue	2.0	2.1	0.5	1.7	2.3
NPL	6.9	3.5	8.4	1.9	8.0
Deposits & ST Funding	80.6	86.9	13.6	76.6	89.2
Equity to total assets	8.3	8.3	2.4	6.8	9.5
Liquid assets	11.7	8.9	9.6	5.8	14.9
Size	1.7	1.0	1.9	0.5	2.1
High share of Non-interest income	0.5	0	0.5	0	1
Investment grade	0.7	1	0.5	0	1
Country characteristics					
Insolvency filing by creditor	0.09	0	0.3	0	0
Eurozone	0.9	1	0.2	1	1
GIIPS	0.2	0	0.4	0	0
DGS Moral Hazard index	2.3	3.5	1.7	0.8	3.5
Bank NFA to GDP	42.5	57.4	54.2	12.7	57.4
Marketability of FS liabilities	10.0	22.1	126.8	22.1	26.4

The table reports summary statistics of banks' asset encumbrance ratios, overcollateralisation, and share of secured liabilities in total assets, as well as other bank and country characteristics. Asset encumbrance ratio is defined as the ratio of encumbered assets to total assets (including both on- and off-balance sheet positions). Overcollateralisation is defined as the net ratio of encumbered assets to matching liabilities. Secured funding is measured as the ratio of banks' matching liabilities to the sum of encumbered and unencumbered assets. The three variables are reported in percentage points. See main text for other variables' definitions. All variables are as of end-2014. The number of banks (observations) is 306.

Table 2. Determinants of overcollateralisation

	Overcollateralisation			
	(1)		(2)	
High share of Non-interest income	9.01	(3.3)***	11.4	(3.5)***
Insolvency filing by creditor	−9.23	(5.1)*		
Bank characteristics				
Investment grade	−0.48	(3.2)	−1.65	(3.5)
Net interest revenue	−7.64	(4.1)*	−5.85	(4.3)
NPL	0.37	(0.3)	0.82	(0.5)*
Deposits & ST Funding	−0.52	(0.2)***	−0.49	(0.2)***
Equity to total assets	0.12	(0.8)	0.90	(0.9)
Liquid assets	0.065	(0.1)	0.15	(0.1)
Size	−7.05	(1.6)***	−8.90	(1.8)***
Country characteristics				
Eurozone	0.70	(7.5)		
GIIPS	10.5	(5.9)*		
DGS Moral Hazard index	−1.20	(1.5)		
Bank NFA to GDP	−0.23	(0.07)***		
Marketability of FS liabilities	−0.08	(0.03)***		
Constant	13.8	(8.2)*		
Business model FE	yes		yes	
Country FE	no		yes	
R^2	0.40		0.43	
# observations	306		304	

The table reports the estimates of cross-section regressions where the dependent variable is the level of overcollateralisation of banks' secured funding. Overcollateralisation (in percentage points) is defined as the net ratio of encumbered assets to matching liabilities. See main text for other variables' definitions. All variables are as of end-2014. All continuous variables are demeaned. Robust standard errors are in parenthesis ($^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$).

Table 3. Determinants of secured funding

	Secured funding		
	(1)	(2)	(3)
High share of Non-interest income	–3.11 (1.0)***	–2.11 (0.9)**	–2.10 (1.0)**
Insolvency filing by creditor	7.89 (2.8)***	6.87 (2.6)***	
Overcollateralisation		–0.11 (0.02)***	–0.11 (0.02)***
Bank characteristics			
Investment grade	0.34 (1.1)	0.28 (1.0)	0.066 (1.0)
Net interest revenue	–1.66 (1.4)	–2.51 (1.3)*	–3.34 (1.4)**
NPL	–0.016 (0.1)	0.025 (0.10)	–0.14 (0.1)
Deposits & ST Funding	–0.11 (0.08)	–0.16 (0.08)**	–0.15 (0.1)
Equity to total assets	–0.50 (0.2)**	–0.49 (0.2)**	–0.44 (0.2)*
Liquid assets	–0.15 (0.07)**	–0.14 (0.07)**	–0.14 (0.07)**
Size	1.35 (0.5)***	0.57 (0.5)	0.60 (0.7)
Country characteristics			
Eurozone	–2.22 (3.4)	–2.15 (3.1)	
GIIPS	6.48 (2.9)**	7.65 (2.6)***	
DGS Moral Hazard index	1.80 (0.7)**	1.67 (0.7)**	
Bank NFA to GDP	–0.02 (0.05)	–0.05 (0.04)	
Marketability of FS liabilities	–0.01 (0.02)	–0.02 (0.02)	
Constant	12.4 (2.9)***	12.1 (2.7)***	
Business model FE	yes	yes	yes
Country FE	no	no	yes
R^2	0.44	0.51	0.54
# observations	306	306	304

The table reports the estimates of cross-section regressions where the dependent variable is banks' level of secured funding. Secured funding (in percentage points) is measured as the ratio of banks' matching liabilities to the sum of encumbered and unencumbered assets. See main text for other variables' definitions. All variables are as of end-2014. All continuous variables are demeaned. Robust standard errors are in parenthesis ($^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$).

Table 4. Fire-sales and determinants of secured funding

	Secured funding			
	Germany		GIIPS	
High share of Non-interest income	−0.082	(1.7)	−5.69	(2.5)**
Overcollateralisation	−0.058	(0.01)***	−0.091	(0.03)**
Bank characteristics				
Investment grade	0.012	(0.8)	−0.32	(2.3)
Net interest revenue	−1.77	(2.4)	−5.91	(2.4)**
NPL	−0.16	(0.2)	0.015	(0.2)
Deposits & ST Funding	−0.18	(0.09)*	0.24	(0.1)*
Equity to total assets	−0.23	(0.2)	−0.40	(0.5)
Liquid assets	−0.037	(0.05)	−0.091	(0.1)
Size	0.73	(1.8)	2.53	(0.9)***
Business model FE	yes		yes	
Country FE	no		yes	
R^2	0.26		0.59	
# observations	188		75	

The table reports the estimates of cross-section regressions where the dependent variable is banks' level of secured funding. Secured funding (in percentage points) is measured as the ratio of banks' matching liabilities to the sum of encumbered and unencumbered assets. See main text for other variables' definitions. All variables are as of end-2014. All continuous variables are demeaned. Robust standard errors are in parenthesis ($^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$).

A Appendix: Proofs

Proof of Proposition 1. Combine the definition of $\underline{\theta}$ (1) with the break-even condition (2):

$$
\begin{aligned}
(1-s)(1+\gamma) &= \int_0^{\underline{\theta}} (\theta + k\phi - s(1+c))\,\mathrm{d}F + \int_{\underline{\theta}}^{\bar{\theta}} (1-s)D\,\mathrm{d}F \\
&= k\phi - s(1+c) + \underline{\theta}(1-F(\underline{\theta})) + \int_0^{\underline{\theta}} \theta\,\mathrm{d}F,
\end{aligned}
\tag{5}
$$

which implicitly defines $\underline{\theta}(s)$. Apply implicit function theorem to get

$$
\frac{\mathrm{d}\underline{\theta}}{\mathrm{d}s} = \frac{c-\gamma}{1-F(\underline{\theta})} \lesseqgtr 0 \quad \Leftrightarrow \quad c \lesseqgtr \gamma.
$$

Proof of Proposition 2. Use (1) to express bank profit Π (3) as

$$
\begin{aligned}
\Pi &= \int_{\underline{\theta}}^{\bar{\theta}} (\theta + k - s - (1-s)D)\,\mathrm{d}F \\
&= \int_{\underline{\theta}}^{\bar{\theta}} (\theta + k - s - [\underline{\theta} + k\phi - s(1+c)])\,\mathrm{d}F \\
&= \int_{\underline{\theta}}^{\bar{\theta}} \theta\,\mathrm{d}F + [k(1-\phi) + sc - \underline{\theta}](1-F(\underline{\theta})),
\end{aligned}
$$

and differentiate it with respect to s:

$$
\begin{aligned}
\frac{\mathrm{d}\Pi}{\mathrm{d}s} &= \left[c - \frac{\mathrm{d}\underline{\theta}}{\mathrm{d}s}\right](1-F(\underline{\theta})) - [k(1-\phi)+sc]f(\underline{\theta})\frac{\mathrm{d}\underline{\theta}}{\mathrm{d}s} \\
&= \gamma - cF(\underline{\theta}) - [k(1-\phi)+sc](c-\gamma)H(\underline{\theta}),
\end{aligned}
$$

where $H(.)$ is the hazard function of θ. Next, $c < \gamma$ implies $cF(\underline{\theta}) < \gamma$. Then, $\frac{\mathrm{d}\Pi}{\mathrm{d}s} > 0$ for all $s \in [0, k\phi(1+c)^{-1}]$ so that at the optimum $s^* = k\phi(1+c)^{-1}$.

Proof of Proposition 3. We are in the case when $c > \gamma$ and, hence, $\frac{\mathrm{d}\underline{\theta}}{\mathrm{d}s} > 0$.

The derivative of expected profits with respect to secured funding is:

$$
\frac{\mathrm{d}\Pi}{\mathrm{d}s} = \gamma - cF(\underline{\theta}(s)) - [k(1-\phi)+sc](c-\gamma)H(\underline{\theta}),
$$

where optimal s is in $[0, k\phi(1+c)^{-1}]$. Note that the second derivative is:

$$\frac{\mathrm{d}^2\Pi}{\mathrm{d}s^2} = -cf(\underline{\theta})\frac{\mathrm{d}\underline{\theta}}{\mathrm{d}s} - c(c-\gamma)H(\underline{\theta}) - [k(1-\phi)+sc]H(\underline{\theta}) - [k(1-\phi)+sc](c-\gamma)\frac{\mathrm{d}H}{\mathrm{d}\underline{\theta}}\frac{\mathrm{d}\underline{\theta}}{\mathrm{d}s}$$

which is negative for any optimal (corner or interior) s.

We have three sub-cases:

(i) corner solution with $s^* = 0$,

(ii) positive interior solution $s^* \in (0, k\phi(1+c)^{-1})$,

(iii) corner solution with $s^* = k\phi(1+c)^{-1}$.

Consider the corner solutions first.

The sub-case (i) happens when

$$\left.\frac{\mathrm{d}\Pi}{\mathrm{d}s}\right|_{s=0} = \gamma - cF(\underline{\theta}(0)) - k(1-\phi)(c-\gamma)H(\underline{\theta}(0)) \leq 0,$$

and in this case, in equilibrium $s^* = 0$. The above condition can be rewritten as

$$c \geq \bar{c} \quad \text{where} \quad \bar{c} \equiv \gamma\frac{1+z}{F(\underline{\theta}^0)+z}, \quad z \equiv k(1-\phi)H(\underline{\theta}^0),$$

and $\underline{\theta}^0 \equiv \underline{\theta}(0)$ is determined by

$$1+\gamma-k\phi = \underline{\theta}^0(1-F(\underline{\theta}^0)) + \int_0^{\underline{\theta}^0} \theta\,\mathrm{d}F.$$

The sub-case (iii) happens when

$$\left.\frac{\mathrm{d}\Pi}{\mathrm{d}s}\right|_{s=k\phi(1+c)^{-1}} = \gamma - cF(\underline{\theta}(k\phi(1+c)^{-1})) - k[1-\phi(1+c)^{-1}](c-\gamma)H(\underline{\theta}(k\phi(1+c)^{-1})) \geq 0,$$

and in this case, in equilibrium, $s^* = k\phi(1+c)^{-1}$.

The above condition can be rewritten as $c \leq J(c)$, where $J(x)$ is defined as

$$J(x) \equiv \gamma\frac{1+Z(x)}{F(\underline{\theta}^+)+Z(x)}, \quad \text{where} \quad Z(x) \equiv k[1-\phi(1+x)^{-1}]H(\underline{\theta}^+),$$

and $\underline{\theta}^+ \equiv \underline{\theta}^+(x)$ is implicitly defined by

$$\left[1-\frac{k\phi}{1+x}\right](1+\gamma) = \underline{\theta}^+(1-F(\underline{\theta}^+)) + \int_0^{\underline{\theta}^+} \theta\,\mathrm{d}F.$$

Note that $\underline{\theta}^0$ is the value of $\underline{\theta}$ at $s=0$ (which is independent of encumbrance costs), while $\underline{\theta}^+(x)$ is $\underline{\theta}$ treated as a function of encumbrance costs x at the maximum attainable $s=k\phi(1+x)^{-1}$.

The sign of $\frac{\mathrm{d}J}{\mathrm{d}x}$ is determined by

$$\frac{\mathrm{d}Z}{\mathrm{d}x}(F(\underline{\theta}^+)+Z(x))-\left[f(\underline{\theta}^+)\frac{\mathrm{d}\underline{\theta}^+}{\mathrm{d}x}+\frac{\mathrm{d}Z}{\mathrm{d}x}\right](1+Z(x))=-\frac{\mathrm{d}Z}{\mathrm{d}x}(1-F(\underline{\theta}))-f(\underline{\theta}^+)\frac{\mathrm{d}\underline{\theta}^+}{\mathrm{d}x}.$$

Since $\frac{\mathrm{d}\underline{\theta}^+}{\mathrm{d}x}>0$ and $\frac{\mathrm{d}Z}{\mathrm{d}x}>0$ (and as long as $\frac{\mathrm{d}H}{\mathrm{d}\underline{\theta}}\geq 0$ as we have assumed), $\frac{\mathrm{d}J}{\mathrm{d}x}<0$ for all x, including $x=c$. Then the necessary condition for the sub-case (iii) can be rewritten as

$$c\leq \underline{c},\quad \text{where } \underline{c} \text{ is defined by } \underline{c}=J(\underline{c}).$$

Finally, we show that $\underline{c}<\bar{c}$. Note first, that from definition of $\underline{c}$ we have

$$\underline{c}=J(\underline{c})=\gamma\frac{1+Z(\underline{c})}{F(\underline{\theta}^+(\underline{c}))+Z(\underline{c})}>\gamma.$$

Hence,

$$\left[1-\frac{k\phi}{1+\underline{c}}\right](1+\gamma)>\left[1-\frac{k\phi}{1+\gamma}\right](1+\gamma)=1+\gamma-k\phi,$$

and using the definitions of $\underline{\theta}^0$ and $\underline{\theta}^+$ and the break-even condition (2) one gets $\underline{\theta}^+(\underline{c})>\underline{\theta}^0$. Next, $\bar{c}>\underline{c}$ whenever

$$(1+z)[F(\underline{\theta}^+(\underline{c}))+Z(\underline{c})]-(1+Z(\underline{c}))[F(\underline{\theta}^0)+z]>0,$$

or, after some rearrangement, whenever

$$\frac{1-F(\underline{\theta}^0)}{1-F(\underline{\theta}^+(\underline{c}))}>\frac{1+z}{1+Z(\underline{c})}.$$

Since $\underline{\theta}^+(\underline{c})>\underline{\theta}^0$,

$$\frac{1-F(\underline{\theta}^0)}{1-F(\underline{\theta}^+(\underline{c}))}>1>\frac{1+z}{1+Z(\underline{c})},$$

hence, $\underline{c}<\bar{c}$.

Consider the intermediate case (ii) with $\frac{\mathrm{d}\Pi}{\mathrm{d}s}\big|_{s=k\phi(1+c)^{-1}}<0$ and $\frac{\mathrm{d}\Pi}{\mathrm{d}s}\big|_{s=0}>0$ which happens whenever $\underline{c}<c<\bar{c}$ or, equivalently, when

$$k(1-\phi)<\frac{\gamma-cF(\underline{\theta}(s))}{c-\gamma}\frac{1}{H(\underline{\theta}(s))}<k(1-\phi(1+c)^{-1}). \tag{6}$$

By intermediate value theorem, there must exist at least one $s^* \in (0, k\phi(1+c)^{-1})$ such that $\frac{\mathrm{d}\Pi}{\mathrm{d}s} = 0$.

The FOC determining s^* can be expressed as

$$s^* = G(s^*)$$
$$G(s) = \frac{1}{c}\left[\frac{\gamma - cF(\underline{\theta}(s))}{c-\gamma}\frac{1}{H(\underline{\theta}(s))} - k(1-\phi)\right].$$

By (6), $0 < G(s) < k\phi(1+c)^{-1}$. Furthermore, because θ has non-decreasing hazard function, $\frac{\mathrm{d}G}{\mathrm{d}s} < 0$. To see this, note that

$$\frac{\mathrm{d}G}{\mathrm{d}s} = \frac{\mathrm{d}G}{\mathrm{d}\underline{\theta}}\frac{\mathrm{d}\underline{\theta}}{\mathrm{d}s}, \quad \frac{\mathrm{d}G}{\mathrm{d}\underline{\theta}} = -\frac{1}{cH(\underline{\theta})}\left[\frac{\gamma - cF(\underline{\theta})}{c-\gamma}\frac{1}{H(\underline{\theta})}\frac{\mathrm{d}H}{\mathrm{d}\underline{\theta}}(\underline{\theta}) + \frac{cf(\underline{\theta})}{c-\gamma}\right].$$

By (6), $cF(\underline{\theta}) < \gamma$. Then, a sufficient condition for $\frac{\mathrm{d}G}{\mathrm{d}\underline{\theta}} < 0$ is $\frac{\mathrm{d}H}{\mathrm{d}\theta} \geq 0$. Hence, we have $\frac{\mathrm{d}G}{\mathrm{d}\underline{\theta}} < 0$ and $\frac{\mathrm{d}G}{\mathrm{d}s} < 0$, which together with the condition $0 < G(s) < k\phi(1+c)^{-1}$ imply that there is unique $s^* \in (0, k\phi(1+c)^{-1})$ such that $s^* = G(s^*)$.

Proof of Corollary 1. Rewrite FOC (4) in terms of h:

$$\gamma - cF(\underline{\theta}^*) - [kh - c(k(1-h) - s^*)](c-\gamma)H(\underline{\theta}^*) = 0,$$

and differentiate it with respect to c holding h fixed:

$$\begin{aligned} 0 = &- F(\underline{\theta}^*) - cf(\underline{\theta}^*)\frac{\mathrm{d}\underline{\theta}^*}{\mathrm{d}c} + \left[k(1-h) - s^* - c\frac{\mathrm{d}s^*}{\mathrm{d}c}\right](c-\gamma)H(\underline{\theta}^*) \\ &- [kh - c(k(1-h) - s^*)]\left[H(\underline{\theta}^*) + (c-\gamma)\frac{\mathrm{d}H}{\mathrm{d}\theta}\frac{\mathrm{d}\underline{\theta}^*}{\mathrm{d}c}\right]. \end{aligned} \tag{7}$$

Next, the break-even codnition in terms of h is

$$(1-s)(1+\gamma) = (1+c)[k(1-h) - s] + \underline{\theta}(1 - F(\underline{\theta})) + \int_0^{\underline{\theta}} \theta \, \mathrm{d}F,$$

so that

$$\begin{aligned} \frac{\mathrm{d}\underline{\theta}}{\mathrm{d}c} &= \frac{\partial\underline{\theta}}{\partial c} + \frac{\partial\underline{\theta}}{\partial s}\frac{\mathrm{d}s}{\mathrm{d}c} \\ &= \frac{k(1-h) - s}{1 - F(\underline{\theta})} + \frac{c-\gamma}{1-F(\underline{\theta})}\frac{\mathrm{d}s}{\mathrm{d}c} \\ &= \frac{H(\underline{\theta})}{f(\underline{\theta})}\left[\Delta + (c-\gamma)\frac{\mathrm{d}s}{\mathrm{d}c}\right], \end{aligned}$$

where $\Delta \equiv \Delta(s) = k(1-h) - s > 0$. Accordingly, one can further rewrite (7) as

$$0 = -F(\underline{\theta}^*) - cH(\underline{\theta}^*)\left[\Delta^* + (c-\gamma)\frac{\mathrm{d}s^*}{\mathrm{d}c}\right] + \left[\Delta^* - c\frac{\mathrm{d}s^*}{\mathrm{d}c}\right](c-\gamma)H(\underline{\theta}^*)$$
$$-[kh - c\Delta^*]\left[H(\underline{\theta}^*) + (c-\gamma)\frac{\mathrm{d}H}{\mathrm{d}\theta}\frac{H(\underline{\theta})}{f(\underline{\theta})}\left[\Delta^* + (c-\gamma)\frac{\mathrm{d}s^*}{\mathrm{d}c}\right]\right].$$

Rearranging, one gets

$$\begin{aligned} &F(\underline{\theta}^*) + \gamma\Delta^* H(\underline{\theta}^*) + [kh - c\Delta^*]H(\underline{\theta}^*)\left[1 + \Delta^*\frac{\mathrm{d}H}{\mathrm{d}\theta}\frac{c-\gamma}{f(\underline{\theta})}\right] = \\ &-(c-\gamma)H(\underline{\theta}^*)\left[2c + [kh - c\Delta^*]\frac{\mathrm{d}H}{\mathrm{d}\theta}\frac{c-\gamma}{f(\underline{\theta})}\right]\frac{\mathrm{d}s^*}{\mathrm{d}c}. \end{aligned} \tag{8}$$

Finally, since

$$kh - c\Delta^* = k - \frac{k\phi}{1+c} - c\frac{k\phi}{1+c} + cs^* = k(1-\phi) + cs^* > 0,$$

all terms in all square brackets in (8) are positive. Hence,

$$\frac{\mathrm{d}s^*}{\mathrm{d}c} < 0.$$

Proof of Corollary 2. $\underline{c}$ is defined as the fixed point of J, where, as before, $J(x)$ is

$$J(x) \equiv \gamma\frac{1+Z(x)}{F(\underline{\theta}^+) + Z(x)}, \quad \text{with} \quad Z(x) \equiv k[1 - \phi(1+x)^{-1}]H(\underline{\theta}^+),$$

and $\underline{\theta}^+ \equiv \underline{\theta}^+(x)$ is implicitly defined by

$$\left[1 - \frac{k\phi}{1+x}\right](1+\gamma) = \underline{\theta}^+(1 - F(\underline{\theta}^+)) + \int_0^{\underline{\theta}^+}\theta\,\mathrm{d}F.$$

From $\underline{c}(\phi) = J(\underline{c}(\phi), \phi)$ one gets

$$\frac{\mathrm{d}\underline{c}}{\mathrm{d}\phi} = \frac{\partial J}{\partial x}(\underline{c})\frac{\mathrm{d}\underline{c}}{\mathrm{d}\phi} + \frac{\partial J}{\partial \phi} = \frac{\partial J}{\partial \phi}\left[1 - \frac{\partial J}{\partial x}(\underline{c})\right]^{-1}.$$

From the Proof of Corollary 3 we know that $\frac{\partial J}{\partial x} < 0$, hence it suffices to show that $\frac{\partial J}{\partial \phi} > 0$. To see this, note first that

$$\frac{\partial \underline{\theta}^+}{\partial \phi} = -\frac{k(1+\gamma)}{(1+x)(1 - F(\underline{\theta}^+))} < 0,$$

and

$$\frac{\partial Z}{\partial \phi} = \frac{\partial Z}{\partial \underline{\theta}}\frac{\partial \underline{\theta}^{+}}{\partial \phi} + \frac{\partial Z}{\partial \phi} = k[1-\phi(1+x)^{-1}]\frac{\partial H}{\partial \theta}\frac{\partial \underline{\theta}^{+}}{\partial \phi} - k(1+x)^{-1}H(\underline{\theta}^{+}) < 0.$$

Then,

$$\begin{aligned}\frac{\partial J}{\partial \phi} &= \gamma\left[\frac{\partial Z}{\partial \phi}(F(\underline{\theta}^{+})+Z) - (1+Z)\left(f(\underline{\theta}^{+})\frac{\partial \underline{\theta}+}{\partial \phi} + \frac{\partial Z}{\partial \phi}\right)\right][F(\underline{\theta}^{+})+Z]^{-2} \\ &= \gamma\left[-\frac{\partial Z}{\partial \phi}(1-F(\underline{\theta}^{+})) - f(\underline{\theta}^{+})\frac{\partial \underline{\theta}+}{\partial \phi}(1+Z)\right][F(\underline{\theta}^{+})+Z]^{-2} \\ &> 0.\end{aligned}$$

It follows that $\frac{\mathrm{d}\underline{c}}{\mathrm{d}\phi} > 0$.

B Appendix: Definitions and Sources of Asset Encumbrance

In this section we review the definitions of asset encumbrance and describe how assets become encumbered. We also review the most common sources of asset encumbrance (i.e., the liabilities or obligations that give rise to encumbered assets).

B.1 Defining asset encumbrance

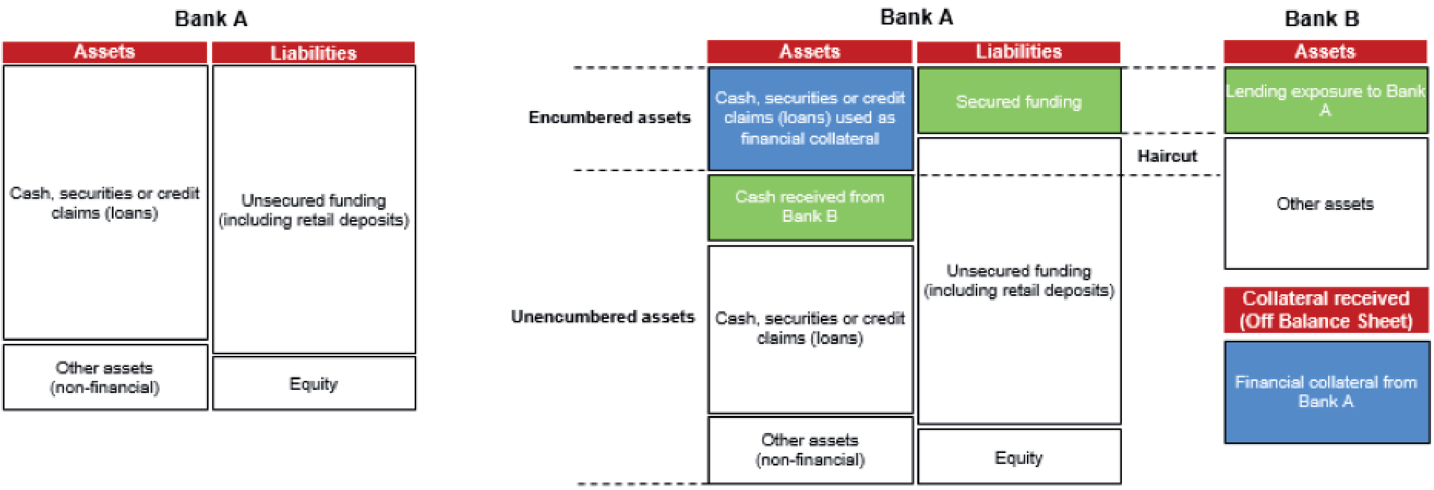
European regulations define encumbered assets as "*assets pledged or subject to any form of arrangement to secure, collateralize or credit enhance any transaction from which it cannot be freely withdrawn*".[24] The Basel Committee on Banking Supervision (BCBS) defines unencumbered assets as those assets which are "*free of legal, regulatory, contractual or other restrictions on the ability of the bank to liquidate, sell, transfer, or assign the asset*".[25]

To clarify the definition of encumbrance, let us consider a bank (Bank A) whose assets include loans and a portfolio of securities (government or corporate bonds, equities, etc.), financed via equity capital, retail deposits and unsecured wholesale funding, as shown in the left hand side of figure 3. Bank A could obtain additional funding from a counterparty, let us say Bank B, by entering into a secured financing transaction, as shown in the right hand side of figure 3. Under such arrangement Bank A provides collateral to Bank B in order to mitigate the risk of failing to keep interest repayments or repaying the borrowings. In exchange, Bank A benefits from cheaper funding when compared to an equivalent unsecured transaction.[26] The arrangement imposes restrictions to Bank A on its ability to sell, transfer or dispose of the collateral provided during the term of the transaction. Bank A would consider such assets encumbered.

Figure 3 represents the securities provided as collateral as recorded or recognised in Bank A's balance sheet rather than being transferred to Bank B's balance sheet. Collateral obtained by Bank B is therefore represented in an off-balance sheet (OBS) rather than an on-balance sheet, and is known as "OBS collateral" or simply "collateral received". The assumption that the collateral remains recognised from Bank A's balance sheet is a necessary condition for being considered an encumbered asset of Bank A. If the assets used as collateral were derecognised by Bank A then they would be recognised by Bank B and they would not be encumbered for Bank A.

[24] See European Commission (2015).
[25] See BCBS (2013)
[26] In addition, the arrangement may provide for savings in regulatory capital requirements to Bank B as well as lower regulatory liquidity requirements to Bank A and Bank B.

Figure 3. Encumbrance of assets when obtaining secured funding



In practice, the recognition or derecognition of collateral provided depends on the contractual terms of the transaction as well as its accounting treatment. Derecognition cannot occur unless the securities are transferred to the counterparty. This can be achieved by using "title transfer" arrangements, whereby full ownership of the collateral is passed on to the counterparty during the term of the transaction.[27] Collateral can also be provided under "security interest" arrangements, which do not transfer ownership but concede rights to the counterparty to obtain full ownership of the collateral under some pre-determined event, such as failure to repay.[28] The use of one technique over the other depends on market practice. Collateral provided in secured financing transactions such as repurchase agreements (i.e. repo) is typically provided by way of title transfer whereas collateral used as a margin for OTC derivatives can be provided using both methods.[29]

The transfer of title over collateral, however, is not a sufficient condition for derecognition to occur, with the actual outcome depending on the applicable accounting treatment. Under International Financial Reporting Standards (IFRS), IAS 39 applies a set of tests to assess whether (i) the risks and rewards and (ii) control over the asset have been transferred.[30] If the risks and rewards have not been transferred, or in other words, if the collateral provider continues to be exposed to the risks of ownership of the assets such as loss in market value and/or the

[27] Under title transfer, Bank B would have to return the collateral (or equivalent securities) to Bank A when the original transaction matures.

[28] Security interest arrangements are also known as collateral pledges.

[29] Under English Law the collateral for OTC derivatives is typically provided by way of title transfer, whereas under New York Law collateral is typically provided under security interest.

[30] The treatment under US GAAP (ASC 860) differs from IFRS since the focus is on whether the transferor has surrendered control over a financial asset.

benefits that they generate such as dividends, then the collateral would remain recognised on its balance even if a transfer of assets has occurred. But even if the risks and rewards had been transferred, further control tests are undertaken to understand which entity controls the asset. If the collateral provider could direct how the benefits of that asset are realised, then the collateral would not be derecognised either.

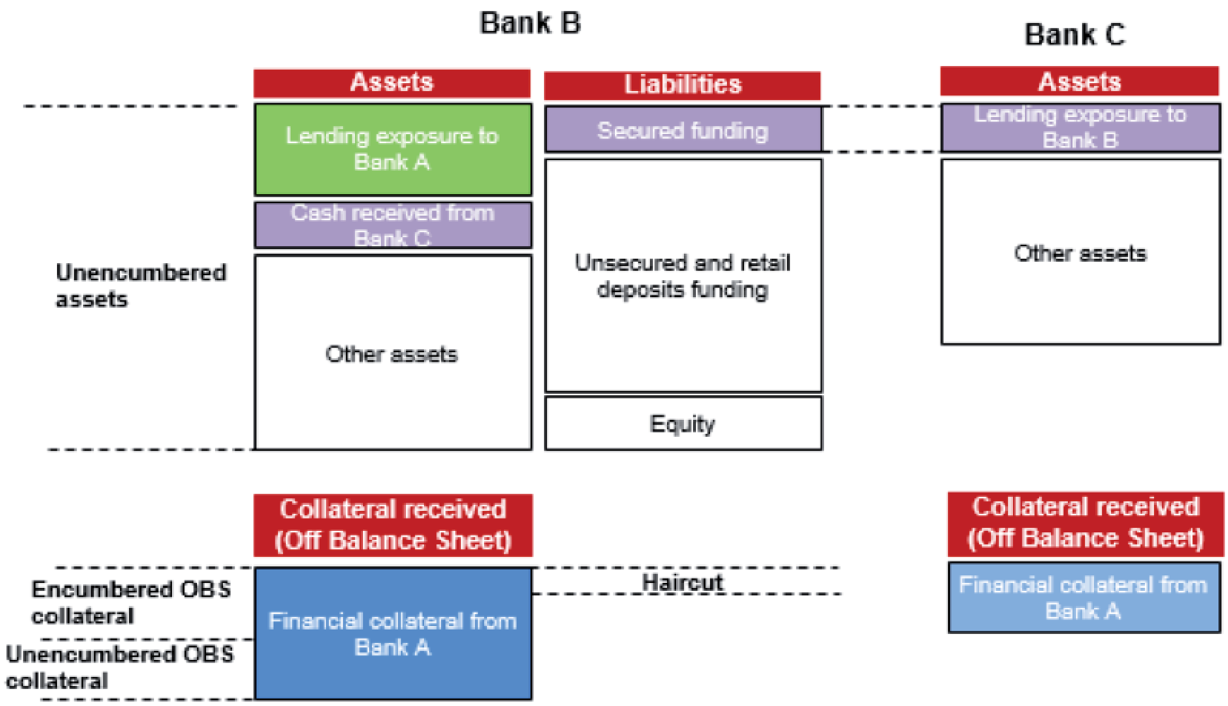
As illustrated in figure 3, the value of securities that Bank A posted as collateral is higher than the value of the borrowings. This practice is known as overcollateralisation and is intended to mitigate the risk of the collateral falling in value during the term of the transaction. It is usually undertaken by means of a "haircut" or "margin ratio".[31] Collateral agreements often require a frequent (sometimes daily) marked-to-market valuation of the collateral and requests to top up the value of collateral, known as collateral calls, may be triggered if its market value falls below certain pre-determined threshold amounts.

Even in the case in which the collateral received is not reflected in its balance sheet, Bank B could reuse some or all of the collateral received from Bank A to obtain financing from a third party (let us say, Bank C). As illustrated in figure 4, this re-use of collateral by Bank B would result in the encumbrance of OBS collateral. As such, encumbrance can affect both on-balance sheet assets as well as OBS collateral. The practice of providing collateral that has been previously received is known as collateral re-use or re-hypothecation. It is common practice and may result in long "collateral chains".[32]

[31] The agreed haircut or margin ratio determines the percentage by which the market value of a security is reduced for the purpose of calculating the amount of collateral being provided.

[32] The terms re-hypothecation and re-use are often used interchangeably and we will do so here. In practice there are legal distinctions between them that may be relevant in a different context. Recent studies have analysed the concept of re-hypothecation and "collateral velocity". Analytical work includes Adrian and Shin (2010) and Singh (2010) More recent work has focussed on liquidity mismatches and the role of collateral in intermediation chains. Brunnermeier and Krishnamurthy (2014) introduced the Liquidity Mismatch Index (LMI) which compares the market liquidity of assets and the funding liquidity of liabilities, thus capturing the length of collateral intermediation chains.

Figure 4. Collateral received and re-used



B.2 Sources of asset encumbrance

The liabilities or obligations that give rise to encumbered assets are known as "sources of asset encumbrance" or "matching liabilities". The typical bank will have encumbered assets from several sources but the simplest institutions may rely only on a single source or may present no encumbered assets at all. We now discuss some of the most common sources of asset encumbrance.[33]

B.2.1 Secured financing transactions

Secured financing transactions encompass myriad transactions involving the temporary provision of securities to borrow cash or other securities. Common types include repurchase agreements (repos), buy/sell backs or securities borrowing and lending. Collateral in repo is provided under a title transfer but it remains recognised in the balance sheet of the collateral provider's (i.e. the repo seller) since the risks and rewards of the collateral are retained.[34] Thus, repo col-

[33] In addition to the sources covered in this section, transactions that may result in encumbered assets include collateral swaps, also known as collateral upgrade transactions, where collateral of a different quality is exchanged. Collateralised guarantees rely on securities to secure an existing or future liability. Other arrangements, such as factoring which include the transfer of trade receivables to an institution may result in similar encumbrance to securitisations.

[34] If this was not the case, banks could artificially reduce its overall leverage by derecognising collateral in repurchase agreements. This treatment was exploited by Lehman Brothers under the well-known "Repo 105" scheme, characterised by the New York Attorney General Andrew Cuomo as a "massive accounting fraud" and leading to a review by the accounting standard settlers of the accounting treatment of repo transactions.

lateral is encumbered for the collateral provider. Encumbered assets in repo are predominantly government bonds, followed by corporate bonds and covered bonds. Asset-backed securities and equities are also used as collateral. Most of the funding provided by central banks is transacted through repo. Like Dexia, many European banks were, and some still are, heavily reliant on repo financing from the ECB.

B.2.2 Asset-backed securities (ABS) and mortgage-backed securities (MBS)

Another potential source of asset encumbrance is securitisations. These entail ABS and MBS bonds or notes being issued and receivables, which may include retail or commercial mortgages in MBS, or credit card debt or other loans in ABS, being used as collateral.

A traditional two-step securitisation involves the initial transfer of the receivables of the originating bank to a Special Purpose Vehicle (SPV) and the sale of the ABS or MBS to investors. The overall securitisation structure is intended to make sure that there is a true sale of receivables to the SPV and that the SPS is "bankruptcy remote". Accounting standards however, may require that the SPV is consolidated into the "sponsoring" bank balance sheet, including all of its assets and liabilities, even the receivables.[35] If the underlying receivables were consolidated, this would result in the recognition of such receivables on the sponsor's balance sheet. However, tests to assess whether the assets meet the criteria for accounting derecognition, as discussed earlier, shall still be undertaken. If derecognition criteria are not met the receivables would be encumbered. This is often the case since it is common for the sponsoring bank to keep an active role in the securitisation, for example, by servicing the assets or providing support by retaining certain tranches to absorb first losses and potential risks in relation to timings in the collection of the receivables.

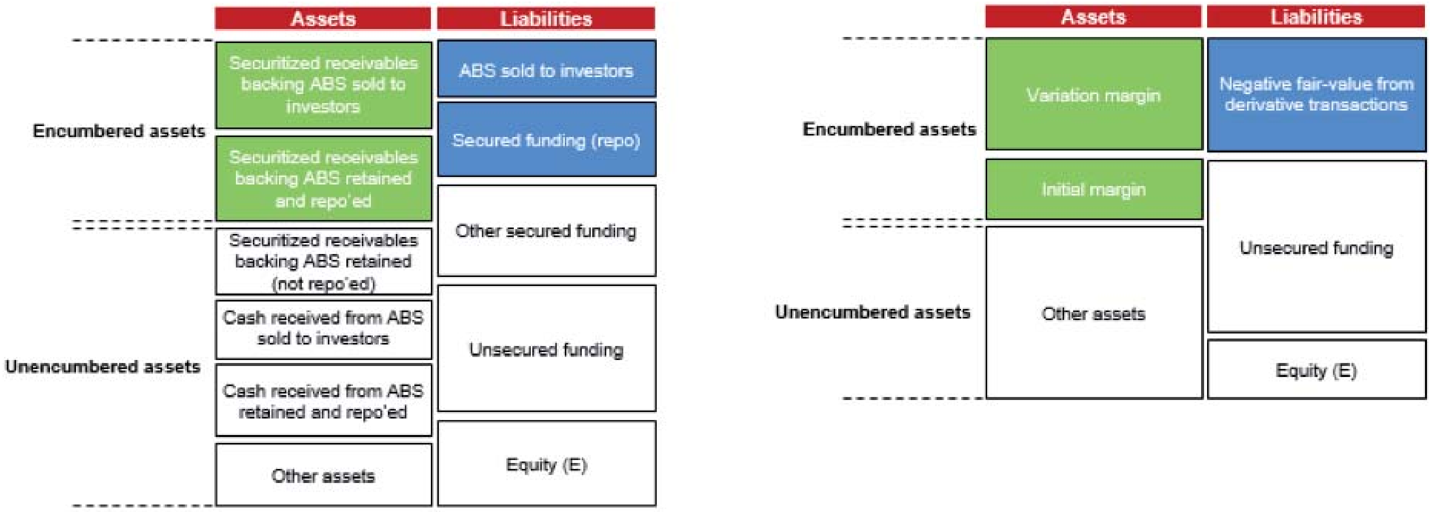
ABS or MBS can be used as collateral to raise funding with counterparties and central banks. Thus, a common practice across some banks, especially during the Eurozone crisis, is the retention of their self-issued ABS or MBS rather than its sale to investors.[36] If notes are retained, they would not be encumbered. But if the notes are used to raise fresh funding, for example, from the central bank via repo, the receivables would become encumbered as it occurs in securities' financing transactions.

[35] The consolidation models under IFRS and GAAP are relatively similar and are based on the criteria of entity control over the SPV.

[36] The acceptance of securitised notes as collateral in the ECB facilities led to an important increase in retention levels during the Eurozone crisis, with overall retention as a proportion of total gross issuance increasing from 26% in the first half of 2007 to 42% in the first half of 2012 (IMF (2013)).

Figure 5 (left-hand side) illustrates how securitised receivables can be encumbered (highlighted in green) by collateralising ABSs that are either (i) sold to investors or (ii) used as repo collateral to obtain funding from another counterparty.

Figure 5. Encumbered and unencumbered assets from securitization and derivative transactions



B.2.3 Covered bonds

Covered bonds are similar to MBS but the mortgages used as collateral always remain recognised on the consolidated balance sheet of the issuing entity and thus always generate encumbrance. The issuer and the investors have dual recourse to the collateral. This feature, together with the existence of overcollateralisation requirements and the dynamic replenishment of non-performing loans in the collateral pool imply that these instruments are perceived as being very safe. There is indeed no known default on covered bonds since their inception.

The use of covered bonds as collateral has significantly increased in recent times. For many banks in peripheral European countries (GIIPS) funding collateralised by retained covered bonds became the main source of long-term funding during the Eurozone sovereign crisis, as their access to unsecured markets was partially or fully closed (Van Rixtel and Gasperini (2013)).

B.2.4 Derivatives

Derivatives also generate encumbrance, as collateralisation has become a key method of mitigating counterparty credit risk in derivative markets, both on over-the-counter (OTC) and exchange-traded (ETD) derivatives. Collateralisation occurs because of the provisioning of the margin, in two different forms. A variation margin is posted during the course of the transaction to cover adverse changes in value (i.e. a negative mark-to-market value). Initial margin (also known as an independent amount) is posted at the beginning of a transaction to cover potential future adverse changes in the value of the contract, and is recalculated on a regular basis.

The margin provided is subject to restrictions and therefore constitutes encumbered assets. This is illustrated in figure 5 (right-hand side).[37] The margin can be provided in the form of cash or securities and it is common to provide re-hypothecation rights to the counterparty. According to the latest ISDA Margin Survey, for non-cleared OTC derivatives cash represents 76.6% of the collateral provided, followed by government bonds (13.4%) and other securities (10.1%), including US municipal bonds, government agency/government-sponsored enterprises (GSEs), and equities (ISDA (2015)).

[37]The figure assumes that the variation margin is not offset against the derivative liability (i.e. the negative fair value from the derivative) therefore becoming encumbered. Some contracts allow for such an offsetting of the variation margin. The outstanding exposure between the counterparties is settled and the terms of the derivative contracts are reset so that the fair value is zero, leading to no encumbered assets due to an exchange of the variation margin.

References

Adrian, T., and H. S. Shin (2010). “Liquidity and leverage”, *Journal of Financial Intermediation,* 19(3), pp. 418-437.

Ahnert, T., K. Anand, P. Gai and J. Chapman (2019). “Asset encumbrance, bank funding, and fragility”, *The Review of Financial Studies,* 32(6), pp. 2422-2455.

Akerlof, G. A., P. M. Romer, R. E. Hall and N. G. Mankiw (1993). “Looting: the economic underworld of bankruptcy for profit”, *Brookings Papers on Economic Activity,* 1993(2), pp. 1-73.

BCBS (2013). “Basel III: The liquidity coverage ratio and liquidity risk monitoring tools”, Basel Committee on Banking Supervision, BIS.

Beck, T., A. Demirgüç-Kunt and R. Levine (2003). “Law, endowments, and finance”, *Journal of Financial Economics,* 70(2), pp. 137-181.

Beck, T., and R. Levine (2008). “Legal Institutions and Financial Development”, in C. Ménard and M. M. Shirley (eds.), *Handbook of New Institutional Economics*, Springer Books, Chap. 11, pp. 251-278.

Benmelech, E., N. Kumar and R. Rajan (2020). *The decline of secured debt*, NBER Working Papers, No. 26637.

Berger, A. N., and G. F. Udell (1990). “Collateral, loan quality and bank risk”, *Journal of Monetary Economics,* 25(1), pp. 21-42.

Boyd, J. H., and H. Hakenes (2014). “Looting and risk shifting in banking crises”, *Journal of Economic Theory,* No. 149, pp. 43-64.

Brunnermeier, M. K., G. N. Dong and D. Palia (2020). “Banks’ Noninterest Income and Systemic Risk”, *The Review of Corporate Finance Studies,* 9(2), pp. 229-255.

Brunnermeier, M. K., and A. Krishnamurthy (2014). “Liquidity Mismatch”, *Risk Topography: Systemic Risk and Macro Modeling*, University of Chicago Press.

Brunnermeier, M. K., and L. H. Pedersen (2009). “Market liquidity and funding liquidity”, *The Review of Financial Studies,* 22(6), pp. 2201-2238.

Buckingham, S., S. Atanasova, S. Frazzani and N. Véron (2019). *Study on the differences between bank insolvency laws and on their potential harmonization*, report by Directorate-General for Financial Stability, Financial Services and Capital Markets Union, European Commission.

Caballero, R. J., and E. Farhi (2013). *A model of the safe asset mechanism (SAM): Safety traps and economic policy*, NBER Working Papers, No. 18737.

Calomiris, C. W., and C. M. Kahn (1991). "The role of demandable debt in structuring optimal banking arrangements", *The American Economic Review*, pp. 497-513.

Carbó-Valverde, S., D. Marques-Ibanez and F. Rodríguez-Fernández (2012). "Securitization, risk-transferring and financial instability: The case of Spain", *Journal of International Money and Finance,* 31(1), pp. 80-101.

CGFS (2013). "Asset encumbrance, financial reform and the demand for collateral assets", Committee on the Global Financial System, BIS.

Chan, Y.-S., and A. V. Thakor (1987). "Collateral and competitive equilibria with moral hazard and private information", *The Journal of Finance*, 42(2), pp. 345-363.

Dang, T. V., G. B. Gorton and B. Holmström (2013). *Haircuts and repo chain,* Working Paper.

De Nederlandsche Bank (2016). "Keeping encumbrance to a minimum", *Bank Newsletter,* April.

De Nederlandsche Bank (2020). "DNB measures in reaction to coronavirus", DNB press release, March 20.

Demirgüç-Kunt, A., E. Kane and L. Laeven (2014). *Deposit insurance database*, The World Bank.

Di Filippo, M., A. Ranaldo and J. Wrampelmeyer (2016). *Unsecured and secured funding,* Tinbergen Institute Discussion Papers, 18-038/IV, Tinbergen Institute.

Diamond, D. W., and R. G. Rajan (2001). "Liquidity Risk, Liquidity Creation, and Financial Fragility: A Theory of Banking", *Journal of Political Economy,* 109(2), pp. 287-327.

Diamond, W. (2020). "Safety transformation and the structure of the financial system", *The Journal of Finance,* 75(6), pp. 2973-3012.

Donaldson, J. R., D. Gromb and G. Piacentino (2020). “The paradox of pledgeability”, *Journal of Financial Economics,* 137(3), pp. 591-605.

Duffie, D., and D. A. Skeel (2012). “A Dialogue on the Costs and Benefits of Automatic Stays for Derivatives and Repurchase Agreements”, in K. E. Scott and J. B. Taylor (eds.), *Bankruptcy Not Bailout,* Hoover Institution, Stanford University, Chap. 5.

EBA (2014). *Guidelines on disclosure of encumbered and unencumbered assets*, European Banking Authority GL/2014/03.

EBA (2021). *EBA report on asset encumbrance (July*), European Banking Authority reports.

Eisenbach, T. M., T. Keister, J. McAndrews and T. Yorulmazer (2014). “Stability of funding models: an analytical framework”, *Economic Policy Review,* 20(1).

European Commission (2015). *Commission implementing regulation (EU) 2015/79 of 18 December 2014,* Commission Implementing Regulation.

Freixas, X., and J.-C. Rochet (2008). *Microeconomics of banking*, MIT Press.

FT (2011). “Bank collateral drying up in rush for security”, *Financial Times,* October 19.

Gai, P., A. G. Haldane, S. Kapadia and B. Nelson (2013). “Bank Funding and Financial Stability”, *Liquidity and Funding Markets: Proceedings of the Reserve Bank of Australia Annual Conference.*

Garcia-Appendini, E., S. Gatti and G. Nocera (2017). “Covered Bonds, Asset Encumbrance and Bank Risk: Evidence from the European Banking Industry”, FMA Annual Meeting, Boston.

Goldstein, I., and A. Pauzner (2005). “Demand–deposit contracts and the probability of bank runs”, *The Journal of Finance,* 60(3), pp. 1293-1327.

Gorton, G. B., S. Lewellen and A. Metrick (2012). “The safe-asset share”, *The American Economic Review,* 102(3), pp. 101-106.

Gorton, G. B., and A. Metrick (2009). *Haircuts*, NBER Working Papers, No. 15273.

Hardy, D. (2013). *Bank resolution costs, depositor preference, and asset encumbrance*, IMF Working Paper No. 13/172.

Helberg, S., and S. Lindset (2014). "How do asset encumbrance and debt regulations affect bank capital and bond risk?", *Journal of Banking & Finance,* No. 44, pp. 39-54.

IMF (2013). *Changes in bank funding patterns and financial stability risks,* IMF Global Financial Stability Report.

ISDA (2015). *ISDA margin survey 2015,* International Swaps and Derivatives Association.

Jackson, T. H., and A. T. Kronman (1979). "Secured financing and priorities among creditors", *The Yale Law Journal,* 88(6), pp. 1143-1182.

Juks, R. (2012). "Asset encumbrance and its relevance for financial stability", *Sveriges Riksbank Economic Review*, p. 3.

Krishnamurthy, A., and A. Vissing-Jorgensen (2012). "The aggregate demand for treasury debt", *Journal of Political Economy,* 120(2), pp. 233-267.

Lian, C., and Y. Ma (2021). "Anatomy of corporate borrowing constraints", *The Quarterly Journal of Economics,* 136(1), pp. 229-291.

Luck, S., and J. A. C. Santos (2019). *The Valuation of Collateral in Bank Lending*, Working Paper.

Magill, M., M. Quinzii and J.-C. Rochet (2020). "The safe asset, banking equilibrium, and optimal central bank monetary, prudential and balance-sheet policies", *Journal of Monetary Economics,* No. 112, pp. 113-128.

Mann, R. J. (1997). "Explaining the pattern of secured credit", *Harvard Law Review*, 110(3), pp. 625-683.

Nagel, J. (2013). "How Market Segments Changed over the Crisis — Challenges for Future Banking", ESE Conference 2013: "The Future of European Financial Supervision".

Panetta, F., and A. F. Pozzolo (2018). *Why do banks securitise their assets? Bank-level evidence from over one hundred countries in the pre-crisis period*, Bank of Italy Working Papers, No. 1183.

Rampini, A. A., and S. Viswanathan (2020). *Collateral and secured debt*, Working Paper.

Rauh, J. D., and A. Sufi (2010). "Capital structure and debt structure", *The Review of Financial Studies,* 23(12), pp. 4242-4280.

Rixtel, A. van, and G. Gasperini (2013). *Financial crises and bank funding: recent experience in the euro area,* BIS Working Papers, No. 406.

Rochet, J.-C., and X. Vives (2004). "Coordination failures and the lender of last resort: was Bagehot right after all?", *Journal of the European Economic Association,* 2(6), pp. 1116-1147.

Scott, R. E. (1996). "Truth about secured financing", *Cornell Law Review,* No. 82, p. 1436.

Singh, M. (2010). *Collateral, netting and systemic risk in the OTC derivatives market,* IMF Working Paper WP/10/99.

Smith, C. W., and J. B. Warner (1979). "On financial contracting: An analysis of bond covenants", *Journal of Financial Economics,* 7(2), pp. 117-161.

Stein, J. C. (2012). "Monetary policy as financial stability regulation", *The Quarterly Journal of Economics,* 127(1), pp. 57-95.

Stulz, R., and H. Johnson (1985). "An analysis of secured debt", *Journal of Financial Economics,* 14(4), pp. 501-521.

Thakor, A. V., and G. F. Udell (1991). "Secured lending and default risk: equilibrium analysis, policy implications and empirical results", *The Economic Journal,* 101(406), pp. 458-472.

Tirole, J. (2006). *The theory of corporate finance*, Princeton University Press.

BANCO DE ESPAÑA PUBLICATIONS

WORKING PAPERS

2020 VICTORIA IVASHINA, LUC LAEVEN and ENRIQUE MORAL-BENITO: Loan types and the bank lending channel.
2021 SERGIO MAYORDOMO, NICOLA PAVANINI and EMANUELE TARANTINO: The impact of alternative forms of bank consolidation on credit supply and financial stability.
2022 ALEX ARMAND, PEDRO CARNEIRO, FEDERICO TAGLIATI and YIMING XIA: Can subsidized employment tackle long-term unemployment? Experimental evidence from North Macedonia.
2023 JACOPO TIMINI and FRANCESCA VIANI: A highway across the Atlantic? Trade and welfare effects of the EU-Mercosur agreement.
2024 CORINNA GHIRELLI, JAVIER J. PÉREZ and ALBERTO URTASUN: Economic policy uncertainty in Latin America: measurement using Spanish newspapers and economic spillovers.
2025 MAR DELGADO-TÉLLEZ, ESTHER GORDO, IVÁN KATARYNIUK and JAVIER J. PÉREZ: The decline in public investment: "social dominance" or too-rigid fiscal rules?
2026 ELVIRA PRADES-ILLANES and PATROCINIO TELLO-CASAS: Spanish regions in Global Value Chains: How important? How different?
2027 PABLO AGUILAR, CORINNA GHIRELLI, MATÍAS PACCE and ALBERTO URTASUN: Can news help measure economic sentiment? An application in COVID-19 times.
2028 EDUARDO GUTIÉRREZ, ENRIQUE MORAL-BENITO, DANIEL OTO-PERALÍAS and ROBERTO RAMOS: The spatial distribution of population in Spain: an anomaly in European perspective.
2029 PABLO BURRIEL, CRISTINA CHECHERITA-WESTPHAL, PASCAL JACQUINOT, MATTHIAS SCHÖN and NIKOLAI STÄHLER: Economic consequences of high public debt: evidence from three large scale DSGE models.
2030 BEATRIZ GONZÁLEZ: Macroeconomics, Firm Dynamics and IPOs.
2031 BRINDUSA ANGHEL, NÚRIA RODRÍGUEZ-PLANAS and ANNA SANZ-DE-GALDEANO: Gender Equality and the Math Gender Gap.
2032 ANDRÉS ALONSO and JOSÉ MANUEL CARBÓ: Machine learning in credit risk: measuring the dilemma between prediction and supervisory cost.
2033 PILAR GARCÍA-PEREA, AITOR LACUESTA and PAU ROLDAN-BLANCO: Raising Markups to Survive: Small Spanish Firms during the Great Recession.
2034 MÁXIMO CAMACHO, MATÍAS PACCE and GABRIEL PÉREZ-QUIRÓS: Spillover Effects in International Business Cycles.
2035 ÁNGEL IVÁN MORENO and TERESA CAMINERO: Application of text mining to the analysis of climate-related disclosures.
2036 EFFROSYNI ADAMOPOULOU and ERNESTO VILLANUEVA: Wage determination and the bite of collective contracts in Italy and Spain: evidence from the metal working industry.
2037 MIKEL BEDAYO, GABRIEL JIMÉNEZ, JOSÉ-LUIS PEYDRÓ and RAQUEL VEGAS: Screening and Loan Origination Time: Lending Standards, Loan Defaults and Bank Failures.
2038 BRINDUSA ANGHEL, PILAR CUADRADO and FEDERICO TAGLIATI: Why cognitive test scores of Spanish adults are so low? The role of schooling and socioeconomic background
2039 CHRISTOPH ALBERT, ANDREA CAGGESE and BEATRIZ GONZÁLEZ: The Short- and Long-run Employment Impact of COVID-19 through the Effects of Real and Financial Shocks on New Firms.
2040 GABRIEL JIMÉNEZ, DAVID MARTÍNEZ-MIERA and JOSÉ-LUIS PEYDRÓ: Who Truly Bears (Bank) Taxes? Evidence from Only Shifting Statutory Incidence.
2041 FELIX HOLUB, LAURA HOSPIDO and ULRICH J. WAGNER: Urban air pollution and sick leaves: evidence from social security data.
2042 NÉLIDA DÍAZ SOBRINO, CORINNA GHIRELLI, SAMUEL HURTADO, JAVIER J. PÉREZ and ALBERTO URTASUN: The narrative about the economy as a shadow forecast: an analysis using Banco de España quarterly reports.
2043 NEZIH GUNER, JAVIER LÓPEZ-SEGOVIA and ROBERTO RAMOS: Reforming the individual income tax in Spain.
2101 DARÍO SERRANO-PUENTE: Optimal progressivity of personal income tax: a general equilibrium evaluation for Spain.
2102 SANDRA GARCÍA-URIBE, HANNES MUELLER and CARLOS SANZ: Economic uncertainty and divisive politics: evidence from the *Dos Españas*.
2103 IVÁN KATARYNIUK, VÍCTOR MORA-BAJÉN and JAVIER J. PÉREZ: EMU deepening and sovereign debt spreads: using political space to achieve policy space.
2104 DARÍO SERRANO-PUENTE: Are we moving towards an energy-efficient low-carbon economy? An input-output LMDI decomposition of CO_2 emissions for Spain and the EU28.

2105 ANDRÉS ALONSO and JOSÉ MANUEL CARBÓ: Understanding the performance of machine learning models to predict credit default: a novel approach for supervisory evaluation.

2106 JAVIER ANDRÉS, ÓSCAR ARCE and PABLO BURRIEL: Market polarization and the Phillips curve.

2107 JUAN de LUCIO and JUAN S. MORA-SANGUINETTI: New dimensions of regulatory complexity and their economic cost. An analysis using text mining.

2108 DANILO LEIVA-LEON and LUIS UZEDA: Endogenous time variation in vector autoregressions.

2109 CORINNA GHIRELLI, ANDREA GONZÁLEZ, JOSÉ LUIS HERRERA and SAMUEL HURTADO: Weather, mobility and the evolution of the Covid-19 pandemic.

2110 KLODIANA ISTREFI, FLORENS ODENDAHL and GIULIA SESTIERI: Fed communication on financial stability concerns and monetary policy decisions: revelations from speeches.

2111 YUNUS AKSOY, HENRIQUE S. BASSO and CAROLYN ST AUBYN: Time Variation in Lifecycle Consumption and Income.

2112 JENNIFER PEÑA and ELVIRA PRADES: Price setting in Chile: micro evidence from consumer on-line prices during the social outbreak and Covid-19.

2113 NEZIH GUNER, YULIYA A. KULIKOVA and ARNAU VALLADARES-ESTEBAN: Does the added worker effect matter?

2114 RODOLFO G. CAMPOS and JACOPO TIMINI: Unequal trade, unequal gains: the heterogeneous impact of MERCOSUR.

2115 JAVIER QUINTANA: Import competition, regional divergence, and the rise of the skilled city.

2116 PATRICK MACNAMARA, MYROSLAV PIDKUYKO and RAFFAELE ROSSI: Marginal Tax Changes with Risky Investment.

2117 RODOLFO G. CAMPOS, JACOPO TIMINI and ELENA VIDAL: Structural gravity and trade agreements: does the measurement of domestic trade matter?

2118 ALESSANDRO MELCARNE, JUAN S. MORA-SANGUINETTI and ROK SPRUK: Democracy, technocracy and economic growth: evidence from 20 century Spain.

2119 ÁNGEL ESTRADA and DANIEL SANTABÁRBARA: Recycling carbon tax revenues in Spain. Environmental and economic assessment of selected green reforms.

2120 ALEJANDRO FERNÁNDEZ-CEREZO, BEATRIZ GONZÁLEZ, MARIO IZQUIERDO and ENRIQUE MORAL-BENITO: Firm-level heterogeneity in the impact of the COVID-19 pandemic.

2121 EDUARDO GUTIÉRREZ and CÉSAR MARTÍN MACHUCA: The effect of tariffs on Spanish goods exports.

2122 JACOPO TIMINI: Revisiting the 'Cobden-Chevalier network' trade and welfare effects.

2123 ALEJANDRO BUESA, JAVIER J. PÉREZ and DANIEL SANTABÁRBARA: Awareness of pandemics and the impact of COVID-19.

2124 ALICIA AGUILAR and DIEGO TORRES: The impact of COVID-19 on analysts' sentiment about the banking sector.

2125 SILVIA ALBRIZIO, IVÁN KATARYNIUK, LUIS MOLINA and JAN SCHÄFER: ECB euro liquidity lines.

2126 ANTHONY BALD, ERIC CHYN, JUSTINE HASTINGS and MARGARITA MACHELETT: The causal impact of removing children from abusive and neglectful homes.

2127 IRMA ALONSO, PEDRO SERRANO and ANTONI VAELLO-SEBASTIÀ: The impact of heterogeneous unconventional monetary policies on the expectations of market crashes.

2128 MARÍA T. GONZÁLEZ-PÉREZ: Lessons from estimating the average option-implied volatility term structure for the Spanish banking sector.

2129 SIMÓN A. RELLA, YULIYA A. KULIKOVA, EMMANOUIL T. DERMITZAKIS and FYODOR A. KONDRASHOV: Rates of SARS-COV-2 transmission and vaccination impact the fate of vaccine-resistant strains.

2130 MATÍAS LAMAS and DAVID MARTÍNEZ-MIERA: Sectorial holdings and stock prices: the household-bank nexus.

2131 ALBERT BANAL-ESTAÑOL, ENRIQUE BENITO, DMITRY KHAMETSHIN and JIANXING WEI: Asset encumbrance and bank risk: theory and first evidence from public disclosures in Europe.