Correlation, Price Discovery and Co-movement of ABS and Equity

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by

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Abstract

Asset-backed securitization (ABS) has become a viable and increasingly attractive risk management and refinancing method either as a standalone form of structured finance or as securitized debt in *Collateralized Debt Obligations* (CDO). However, the absence of industry standardization has prevented rising investment demand from translating into market liquidity comparable to traditional fixed income instruments, in all but a few selected market segments. Particularly low financial transparency and complex security designs inhibit profound analysis of secondary market pricing and how it relates to established forms of external finance. This paper represents the first attempt to measure the intertemporal, bivariate causal relationship between matched price series of equity and ABS issued by the same entity. In a two-dimensional linear system of simultaneous equations we investigate the short-term dynamics and long-term consistency of daily secondary market data from the U.K. Sterling ABS/MBS market and exchange traded shares between 1998 and 2004 with and without the presence of cointegration. Our causality framework delivers compelling empirical support for a strong co-movement between matched price series of ABS-equity pairs, where ABS markets seem to contribute more to price discovery over the long run. Controlling for cointegration, risk-free interest and average market risk of corporate debt hardly alters our results. However, once we qualify the magnitude and direction of price discovery on various security characteristics, such as the ABS asset class, we find that ABS-equity pairs with large-scale CMBS/RMBS and credit card/student loan ABS reveal stronger lead-lag relationships and joint price dynamics than whole business ABS.

Keywords: co-movement, causality test, vector autoregression (VAR), vector error correction mechanism (VECM), short-term price dynamics, price discovery, asset-backed securities (ABS), securitization, mortgage-backed securities (MBS), collateralized debt obligation (CDO), captive finance, Pfandbrief, cointegration

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CFR research programs: risk measurement

1 INTRODUCTION

1.1 Research question

In integrated and efficient capital markets financial assets with similar risk characteristics should yield similar expected returns, so investors expect to earn similar risk-adjusted returns on comparable exposures. Likewise, we also observe a consistent and close pairwise association between market prices of different state-contingent claims when their value depends on the same underlying asset generating process, such as the empirical relationship between bonds and stocks. The emergence of alternative off-balance sheet (structured) finance begs the question whether *asset-backed securities* (ABS) also share a similar pattern of intertemporal association with the market value of the issuing firm. This paper examines whether price co-movement does exist between publicly traded equity and default sensitive asset-backed securities (ABS) issued by the same entity – and if so, whether lower agency cost of asymmetric information of securitized debt improves price discovery. Past research on the empirical relationship of issued claims and securities on similar exposures has been limited to traditional on-balance sheet asset classes.

The investigation of the empirical relationship between ABS and equity of the same issuer has topical appeal. The substitution of market-based external finance for credit finance through asset securitization has developed into an increasingly attractive risk management and refinancing method. The emergence of new forms of external finance has only recently urged a more thorough investigation into the asset correlation and possible causal interaction between different asset claims on similar exposure, e.g. cash markets (e.g. corporate bonds) and structured finance (e.g. credit default swaps (CDS)). In a three-dimensional autoregressive specification of bond, equity and CDS prices of the same issuer Norden and Weber (2004b) corroborate previous studies by Blanco et al. (2004) and Zhu (2004), who find that CDS and equity prices are cointegrated over the long run and share a stationary difference series under the assumption of no arbitrage.[1] In earlier studies, Houwelling and Vorst (2001) and Hull et al. (2003) specifically explore the credit risk pricing between the bond and CDS markets and find

[1] Chan-Lau and Kim (2004) apply a similar set-up for their analysis of equity prices, CDS prices and bond spreads in emerging markets based on a limited dataset on several sovereigns.

little price discrepancy if swap rates are chosen as benchmark risk-free rates. Empirical evidence on the lead-lag relationship in capital markets suggests primary price discovery in the CDS market[2] (especially in capital market-based financial systems and liquid CDS markets on large firms) and price adjustment in bond and equity markets. So far, however, no research study has attempted to account for price dynamics of ABS and equity markets for loss of available and suitable market data.

ABS tranches provide opportunities of active arbitrage through both put-call-parity replication of equity and can be structured to match the asset correlation of other conventional investments and indices. Nonetheless, the primary and secondary markets of ABS still exhibit certain shortcomings: (i) the notoriously complex security design of multi-layered synthetic transactions and the lack of rigorous standardization (Rutledge, 2005) impairs fair asset pricing and restricts informed investment; (ii) the dominance of a few players (mainly banks, institutional investors and other money managers) is a deterrent to the lending width in the market; (iii) investors prevent market deepening by holding ABS deals until maturity ("buy and hold"); (iv) the absence of comprehensive trading platforms inhibits efficient information dissemination across different segments of capital markets; and (v) low retail participation impedes greater diversification of ABS demand across the financial system. The upshot of all of these features *dulls the efficiency of price discovery* in ABS markets and largely *compromises the adequate specification of price dynamics*.[3]

In this paper we investigate the intertemporal, bivariate causal relationship between matched equity and ABS prices of the same issuer. In efficient financial markets, we would expect state

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[2] Note that Norden and Weber (2004a) as well as Hull et al. (2003) also find strong evidence that the CDS market anticipates credit rating announcements (particularly negative rating events) of up to three months and more, whereas equity and bond markets register a much short reaction time to changes in credit quality.

[3] Although the Dow Jones *iTraxx®* index of CDS obligations and the *iBoxx®* index of collateralized debt obligations have inaugurated the first round of emerging standardization, large parts of the ABS market have shed little of their frequently deplored opacity. Market observers point to the changing hedging patterns for customized ABS claims in advent of liquid pricing benchmarks (Tsui, 2005). For instance, *Collateralized Debt Obligations* (CDOs) are generally structured to meet specific investor needs. In the past, issuers would hedge unbalanced positions through complex subordinated, multi-tranche structures ("transaction-based"), whose complexity inhibited transparent asset pricing. Now, standardized claims on liquid indices (e.g. Dow Jones *iTraxx®*)[3] offer a base correlation measure ("CDO delta") for the "market-based" hedging of bespoke and mostly privately transacted single-tranche transactions (arranged for single investors) or multi-tranche transactions with mezzanine tranches indexed to equity prices.

contingent financial claims with different risk exposure but identical (or very similar) underlying fundamental assets to share a cointegration relationship with a difference stationary (base) series. In keeping with technically related work on price co-movement in CDS and bond markets, we adopt *vector autoregression* methods with and without cointegration restriction (VAR and VECM) to support a comprehensive (non-structural) causality test framework of random disturbances on a linear, two-dimensional system of simultaneous autoregressive equations of time-varying means. We also employ traditional (linear) Granger causality testing to investigate the presence of linear predictive power of past price movements in pairwise issuer-matched price series in both markets. We define the *short-term dynamics* and *long-term consistency* of co-movement between matched ABS and equity prices as jointly determined by the lagged polynomials of past observations and individual price adjustments of each asset class after controlling for risk-free interest and the market price of risk. In particular, we study the efficiency of price discovery in response to changes in the quality of issuers and their securitized debt. Our approach improves short-term univariate forecasts of price movements in each market and reveals whether the asset correlation and the joint dynamics associated with the causal interaction of cointegrated price movements significantly inform the price formation in each market over time. We apply our methodology to a dataset of actual market prices covering a pool of 68 matched pairs of U.K. ABS and equity price series over a time period of more than five years. Although we qualify the degree and direction of price discovery on various security characteristics of selected ABS, such as issue (credit) quality, maturity and securitized asset class (whole business ABS vs. CMBS/RMBS/other ABS), the lack of fundamental information about the credit-linkage of securitized assets to the operational performance of the issuer does not permit fully efficient pricing of ABS and equity under equivalence conditions within integrated capital markets. Nonetheless, our methodology yields stylized facts about price discovery in both markets over time, which might guide future theoretical and empirical research into potential divergence in price discovery between different capital market sectors.

Several new issues emerge from our research. We find only weak empirical support for the argument that the joint dynamics of ABS and equity prices improve univariate, short-run predictions of future price movements. Notwithstanding this result, the lead-lag relationship of ABS and equity prices over the long run is statistically and economically meaningful, with

ABS markets dominating price discovery. If we test for cross-sectional sensitivity of error correction, we find that that the strength of long-term intertemporal causality and the relative importance of ABS markets seem to vary substantially by rating, maturity and asset type of ABS issue.[4] The VAR-based specification of co-movement between ABS and equity pairs indicates that the contribution of ABS markets to price discovery is substantially stronger for CMBS/RMBS/other ABS than whole business ABS. Despite the robustness of our findings to the order of cointegration, cross-sectional variation in the intertemporal relationship between ABS and equity prices warrants more empirical and theoretical research.

This paper is structured as follows. The next section reviews our proposed methodology and links the time series properties of our sample to previous findings in the literature. The subsequent sections present the properties of our data set and the technical specifications of various causality tests. After a thorough discussion of our results, the paper concludes with a summary of significant findings and recommendations for possible extensions, improvements and further research.

1.2 Research motivation

On the heels of Standard & Poor's recent downgrading of General Motors Corp. and Ford Motor Co. to non-investment grade status, a drumbeat of warnings about the soundness of the economic reasoning and risk measurement standards of *Collateralized Debt Obligations* (CDOs). Subsequent haircut unwinding of CDO positions exposed to these corporate downgrades has investors and regulators worrying about the resilience of these leveraged structured claims to potentially risky corporate debt as reference assets in times of stress. This recent unfolding of events has been anticipated by incipient theoretical and empirical research on the valuation of CDOs (Gibson, 2004; Egami and Esteghamat, 2003; Jobst, 2002 and 2005a; Duffie and Gârleanu, 2001 and 1999), which looks for potential trouble spots in this segment of fixed income markets. Over the last few years the CDO market has been the fastest growing area of structured finance. Generally, a CDO represents a form of asset-backed securitization (ABS), which converts large pools of mostly illiquid exposures into commoditized structured claims issued as tradable capital market debt instruments. The conventional security design of

[4] The type of ABS could also serve as proxy of degree of insulation of securitized exposures from issuer

CDOs with tranche subordination as risk sharing mechanism induces a leverage effect on constituent tranches, whose distinct risk-return profiles can be tailored to specific investment preferences.[5] *Synthetic CDOs* are classified as "hybrid" risk transfer instruments and credit derivatives in a wider sense (see Fig. 1). In contrast to *cash CDOs*, they enlist wads of credit derivatives to create partially funded and highly leverage investment from synthetic claims on the performance of designated credit exposures (Jobst, 2003). Whereas the classification "pure credit derivatives" only applies to credit default swaps (CDSs), total return swaps and credit spread options, unfunded/partially funded structured finance transactions, synthetic CDOs straddle the indistinct boundary between securitization and credit derivatives. The synthetic assembly of credit exposures and the composition of derivative elements in complex, subordinated CDO transactions pose interesting questions about the valuation and price formation of leveraged credit risk transfer mechanisms in structured finance.

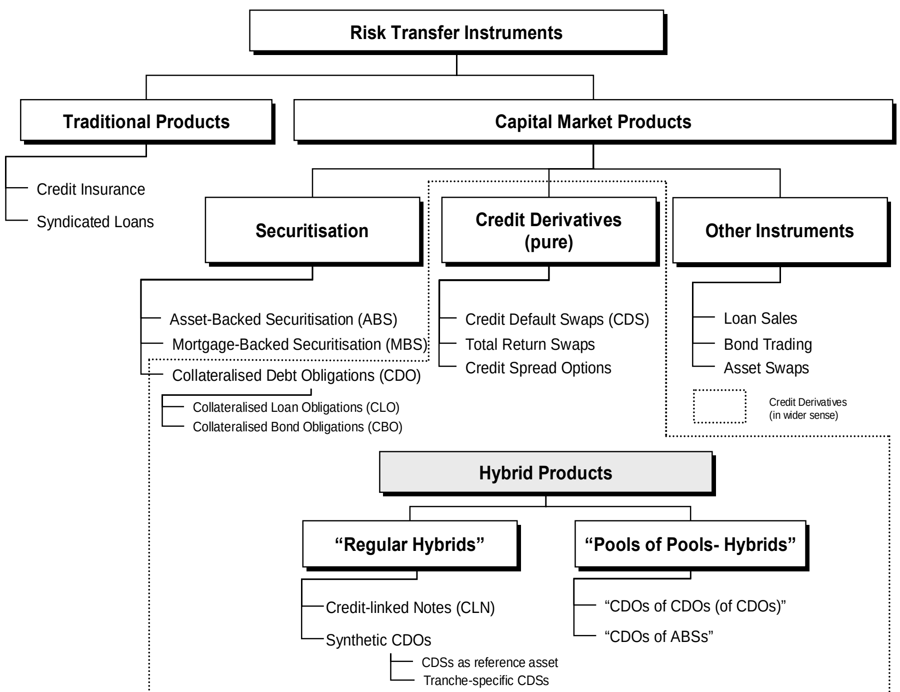

Fig. 1. *Overview of risk transfer instruments (adapted from Effenberger (2003)).*

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and the ABS investor's participation in the issuer's future operational performance in many instances.

5 Although investors should expect the same returns for CDOs as for similar credit risk exposure in plain vanilla debt, the risk profile of CDO tranches varies dramatically in response to changes in the valuation of the underlying (reference) asset (Jobst, 2005b).

The flexible structure of synthetic CDOs allows issuers to devise almost an infinite number of ways to combine various asset classes in order to both transfer asset risk by shortening the notional amount of designated asset exposures and to arbitrage "spreads between different debt markets, between debt of different issuers, between different classes of debt on a single company's balance sheet" (Shepherd, 2005) or between comparable securities on similar fundamental asset values. Actually, the unfunded combination of distinct contingent claims is essential to turning asset correlation of selected securities into a tradable asset class, which can be leveraged depending on the seniority of investment. This property of CDOs had led to the emergence of growing interest in asset correlation and price dynamics between different investment products in the bid to detect and exploit pricing anomalies of credit risk. Besides CDSs, many CDO structures also include seasoned ABS deals in "pools of pools" reference portfolios ("CDOs of ABSs" or "CDO^2").[6] Hence, the asset correlation and the joint price dynamics of ABS prices and other traded security prices are fundamental to the development of robust forecasting models for dynamic portfolio adjustment and the risk management of synthetically composed credit exposures and their dynamic adjustment over time.

Since ABS can be issued as a standalone asset class or included in a more evolved combination of structured claims, the price dynamics of ABS as senior debt claims on the securitized exposures also involve important aspects of corporate finance and capital structure choice. Reference assets underlying ABS transactions are typically "fenced out" from the total asset value of the issuer. Depending on the transaction structure of various types of ABS (true sale vs. synthetic), securitized claims can preserve a very close economic and legal association with the issuer's asset value changes. Moreover, many issuers of ABS retain an equity claim as a highly leveraged call option on the residual value of securitized exposures, which constitutes a reservation utility upon maturity if realized losses fall short of expected losses. The linkage of ABS reference assets to the asset performance of the issuer, determines the strength of the empirical relationship between ABS and equity claims. It also indicates whether the option-pricing theory (OPT)-based correlation of debt and equity valuation (Merton, 1974) applies to the market prices of ABS tranches and equity issued by one and the same entity.

[6] "In many instances, investors in CDOs that also include well-diversified ABS deals (alongside individual asset exposures) in their underlying portfolios might unwittingly compromise their diversification at the margin. This is because the pooling of diversified securitized exposures might

1.2.1 Relationship between bond prices, ABS prices and equity

In synthetic CDO and ABS transactions with on-balance sheet reference assets, the intuition behind the empirical relation of securitized debt and equity claims can be assessed within the theoretical valuation of balance sheet identities in the context of the capital structure-based *option pricing theory* (OPT) by Merton (1974).[7] According to Merton' structural model, owners of corporate equity in leveraged firms have the option to default if their firm's asset value (reference asset) declines below the cumulative face value of outstanding debt (strike price). So, corporate bond investors effectively write European put options to equity owners, who hold a residual claim on the firm's asset value (see Appendix I). The factors that determine the riskiness of debt are the duration, the leverage of the firm and asset value volatility. Hence, equity and debt are always positively correlated. Their correlation increases in higher default risk and leverage, which imply a higher probability that the asset value of the firm will drop below the default threshold. Bond and equity prices should also be cointegrated and share an equilibrium price relationship.

Fig. 2 illustrates the stylized profile of equity and bond prices of a leveraged firm with a notional amount of outstanding debt ("default threshold") *D*. The firm is in default if its asset value falls below the notional amount of outstanding debt. The correlation between bonds and equity declines asymptotically to zero. By keeping the debt level constant, if the firm is low-rated and operates at a high risk of default, the chances of both equity holders and creditors being affected by bankruptcy are high, so we would expect a high correlation between bonds and equity (see Fig. 2) as we traverse levels of asset value that warrant a low credit rating. At a sufficiently high firm asset value, the distance to default reaches a level, at which the chances of bankruptcy become remote and the correlation between bonds and equity tapers off.

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actually increase the conditional probability of default for systemic risk events and backfire on investors when default correlation increases even slightly (Jobst, 2005b)."

[7] Although the same intuition applies, we acknowledge different economic significance depending on the structural characteristics of ABS.

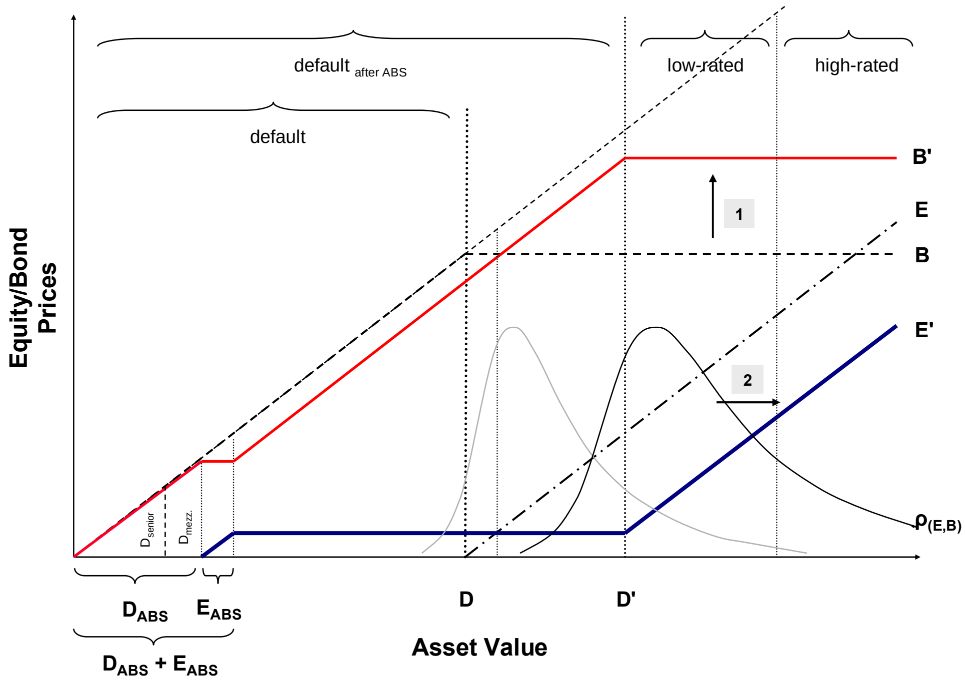

Fig. 2. *Payoff profile of equity and bond prices before and after securitization according to OPT.*

The different state-contingent payoff functions of equity and debt claims on firm value in the traditional capital structure choice of on-balance sheet funding cause agency costs of asymmetric information. Debt represents a disciplinary device to prevent non-value maximizing managers from implicitly transferring wealth from creditors to equity holders ("asset substitution") if they engaged in sub-optimal risky investments at a too low a level of debt (Jensen and Meckling, 1976). However, an excessive debt burden induces the opportunity cost of abandoning profitable future investment opportunities ("underinvestment problem" (Myers, 1977 and 1984)). Asset securitization might redress these conflicts of interest between creditors and shareholders (Stulz and Johnson, 1985), because it allows issuers to appropriate partial debt holder wealth by carving out a defined pool of reference assets to satisfy securitized debt claims, which capture *ex ante* gains from the firm's future asset value. Thereby, issuers subordinate existing creditors and render existing debt less inhibitive on the realization of new investment opportunities.[8] The bankruptcy level increases to *D'* (even if the reference assets are sold off-balance, which would shrink the total asset base of the issuing firm). Our illustration also shows that the issuance of ABS discounts future asset value of

[8] This effect ultimately depends on the way the investment policy guides the riskiness of the use of securitization proceeds relative to the riskiness of the issuer before the securitization issue (Jobst, 2005c).

securitized exposures, whose pay-offs would have otherwise accrued to equity holders if the firm does not default at maturity. The correlation between bond and equity prices should still persist and be consistent over time, though at different statistical significance and higher asset values of the firm, if the issuing firm retains appreciable default risk after the ABS transaction.

Also note that positive correlation due to the issuer's proximity to bankruptcy coincides with the notion of securitization as a preferred form of external finance if issuers face high capital costs of internal funds according to the *pecking-order* (Myers and Majluf, 1984) and *debt trade-off* theories of capital structure choice under asymmetric information.[9] In keeping with the pecking-order theory,[10] lower agency cost from valuation uncertainty renders securitized debt safer than straight debt, as the value of the insulated reference portfolio can be assessed more precisely than the issuer's firm value. Since capital market investors in securitization transactions receive their payment directly from a diversified pool of asset exposures insulated from the issuer, securitized debt carries lower agency cost. Hence, debt holders of ABS would require less information about the issuing firm than debt holders of (unsecured) corporate bonds or equity holders to make an equally informed assessment about the fundamental asset value. So, the analysis of the intertemporal relation between ABS and equity prices is tantamount to gauging the joint price dynamics of asset classes with different degrees of informed investment for a certain capital structure decision.

1.2.2 Sensitivity of securitized debt to the issuer's asset value

ABSs do not reflect the present value of any gains from the firm's future investment income outside the reference portfolio. However, the credit risk associated with their estimated future repayment is indicative of the issuer's asset quality. Almost all securitization transactions maintain a significant degree of economic and/or legal association with the original issuer. In

[9] The pecking order theory states that firms prefer internal to external finance due to adverse selection arising from information asymmetry in financial relationships between insiders and outsiders. Without asset securitization firms with high internal refinancing cost and low bankruptcy cost generally prefer debt to equity because of lower information costs from valuation uncertainty. In contrast, the trade-off theory postulates that managers choose a leverage level, where the marginal benefit of debt, such as the interest tax shield, just outweighs the costs of debt, including agency and financial distress cost ("optimal trade-off").

[10] Additionally, securitized debt does not carry restrictive bond covenants and might be easier to negotiate.

contrast, equity claims derive their value as a call option on current and future operational gains from overall issuer performance above some bankruptcy threshold. Given these characteristics, the strength of the price relationship between equity and ABS issues is expected to depend on the security design of ABS. In the case of *synthetic* structures, for instance, the issuer retains so-called *credit-linkage* to securitized exposures, and the ABS will be exposed to the counterparty risk emanating from the volatility of the issuing firm's value over time.[11] In the alternative case of a *true sale* transaction with a complete legal transfer of selected asset exposures, it is commonplace to observe *first loss coverage* by issuers as a structural support mechanism to mitigate agency costs of asymmetric information. Here, the market price of ABS is contingent on whether the asset value of the issuing firm implies adequate financial capacity to support first loss coverage.[12] The upshot is that we expect the strength of the intertemporal relationship of ABS to the distribution of the issuing firm's value to depend on the linkage of securitized debt to issuer performance.

1.3 Hypotheses

The capital structure-based correlation of debt and equity as well as the sensitivity of securitized exposures to the asset value of the issuing entity establish a sound theoretical foundation to the joint price dynamics of securitized debt and equity. We ascribe great importance to both the *economic linkage of securitized exposures* to the future performance of the issuer and *asset correlation of ABS and equity claims* as possible constituent elements of synthetic CDOs. We apply these insights to a comprehensive analysis of the joint price dynamics of name-matched ABS and equity pairs to gain a better understanding of information processing in ABS markets vis-à-vis equity markets in response to changes in fundamental asset value of issuers. Our research motivation delivers three complementary hypotheses, which substantiate the economic plausibility of an intertemporal causal relation between equity and ABS prices.

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[11] Depending on the funding level of this type of ABS structure, *credit default swaps* (CDS) form an integral part of the security design and contribute largely to a very close association between securitized debt and the issuer valuation, if the issuer retains the role of default protection provider with or without provisions of legal recourse in credit events.

[12] The market value of ABS is derived from a pre-defined stream of present or future proceeds ("cash flow ABS", e.g. "whole business ABS") or a diversified reference portfolio of existing or future asset exposures, which have either been randomly drawn from a population of own assets ("balance sheet ABS") or acquired for the sole purpose of securitization ("arbitrage ABS").

Hypothesis 1: *If we rule out any ABS transaction that would increase the issuer's liabilities beyond its asset value, securitized debt is positively correlated with equity of the same issuer and both share a long-term equilibrium price relationship. Since structural models ascribe higher call option value to equity the higher the duration of outstanding debt, the firm leverage and the volatility of firm assets, low-rated issuers and/or issuers that operate close to bankruptcy exhibit a stronger degree of correlation than highly-rated issuers.*

Hypothesis 2: *The type of ABS defines the proximity of ABS debt to the asset value process of the issuer. The closer the economic and/or legal association between securitized exposures and the issuer (e.g. project finance, whole business securitization), the more sensitive securitized debt will be to changes in the fundamental asset value of the issuer. In this case we find economically strong and statistically meaningful long-term consistency between price movements of equity and securitized debt.*

Hypothesis 3: *We expect ABS markets to lead equity markets in price discovery of the fair market value of firm performance. Outside investors can assess the fair value of ABS more easily than the value of other forms of external finance, mainly because securitized debt is specifically issued on the back of designated exposures.*

Hypothesis 4: *Given Hypotheses 2 and 3, ABS transactions with a close economic and/or legal association to the asset value of the issuer better inform the price formation of corresponding equity than other types of ABS, such as CMBS and RMBS issues.*

2 DATASET

Although asset-backed securitization has established itself as an increasingly attractive structured finance mechanism for investors looking for greater diversification and lower risk exposure than with traditional corporate bonds, rising investment demand has yet failed to translate into a level of market liquidity comparable to conventional fixed income markets. Hence, reliable trading data of securitized debt as a truthful reflection of market price volatility is hard to come by. For this analysis, we were granted access to a proprietary database of market prices collected by a major European commercial bank as a syndicated member of the *iBoxx®* bond index. We obtained more than five years worth of daily[13] secondary market (indicative) bid quotes of fixed-interest tranches of U.K. Sterling-denominated ABS ("Sterling ABS/MBS"), one of the most actively traded ABS asset class in Europe (see Fig. 1).[14] We reconciled these ABS price series with the price information of exchange-traded equity issued by the same exchange-listed entities (see Fig. 2). We also collected the U.K. bond benchmark with a 15-year weighted average maturity from *Bloomberg* and the 3-month LIBOR[15] on U.K. Sterling deposits from *Thomson Financial Datastream*. Our initial ABS panel data set covered the daily quoted security (bid) prices (250 working days p.a.) of a maximum of 1,405 observations from 1 September 1998 to 24 January 2004 of 149 individual tranches of 104 U.K. Sterling denominated ABS and MBS transactions. We were able to obtain specific ABS security information, such as issuer name, tranche specification (class of note), issue date, original rating, principal value, coupon rate (fixed), maturity date, domicile of securitized assets, type of ABS transactions [whole business ABS, captive finance ABS, CMBS, RMBS (prime), multi-borrower ABS, equipment leasing ABS, credit card ABS, student loan ABS], denomination of securitized assets, and ISIN[16]). The time series of observed price quotes was complete in all but a few instances. We substitute for missing observations of daily price information by linear interpolation (Hull et al., 2003). We eliminated four defaulted or matured tranches from the database, leaving us with a total number of 145 ABS tranches of 78 transactions.

Subsequently, we verified the availability of shares prices of as many issuers of ABS transactions as possible to create matched ABS-equity pairs. A combined query of various

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[13] Similar to Blanco et al. (2004) and Zhu (2004) in their studies on the leading role of CDS prices in price formation of default risk we contest the appropriateness of measuring the short-term dynamic interactions on weekly price observations in Longstaff et al. (2003).

[14] The data used in our study is not explicitly supported by actual trades and should be viewed as indicative "matrix" quotes offered by the data provider as bid prices. Hence, our price information might partly reflect an information advantage enjoyed by the data provider as major broker in the Sterling ABS/MBS market.

[15] We choose the 3-month LIBOR, mainly because it is used as base index/reference rate for adjustable rate ABS tranches in the Sterling ABS/MBS market.

[16] The *International Securities Identifying Number* (ISIN) uniquely identifies a fungible security, whose structure is defined in ISO 6166. Securities with ISIN coding can be debt securities, equities, options, derivatives and futures. ISINs consist of two alphabetic characters, which are the ISO 3166-1 code for the issuing country, nine numeric digits (the *National Securities Identifying Number* (NSIN), which identifies the security), and one numeric checksum digit.

sources, including *Reuters*, *Bloomberg*, *Thomson Financial Datastream*, *Yahoo Finance* and *The Financial Times Online* generated only 36 issuers (or parent companies of issuers in case of consolidated subsidiaries and/or lines of business) of our ABS data set, which were publicly listed at the *London Stock Exchange* (LSE) or at other exchanges (in the case of foreign parent companies of U.K.-domiciled issuers).[17] We were able to assign equity price series (end-of-day mid-quotes) to a corresponding set of 81 ABS tranches of 42 ABS transactions.[18] 55 out of all 81 ABS tranches issued by exchange-traded entities (or their parent company) were classified as whole business ABS, project finance (captive finance) ABS or other ABS (e.g. credit cards and student loans), whereas the remaining 26 tranches were either CMBS or RMBS. We finally excluded another set of 11 ABS series (from five individual transactions), which shared only a small time window of price observations with the matched equity series, rendering it useless for co-movement analysis. After elimination of two further ABS-equity pairs due to level persistence in order to avoid biased estimation results, our final data sample consisted of 68 matched ABS-equity pairs (with 31 different issuers of 38 ABS transactions).

We distinguish between ABS transactions in matched ABS-equity pairs by ABS properties (type of ABS asset class, rating category and maturity) to analyze the cross-sectional sensitivity of our estimation results. ABS-equity pairs with different ABS asset classes might exhibit different price co-movement due to a higher degree of association of equity and ABS prices in the case of whole business and captive finance ABS ("whole business ABS") as opposed to RMBS, CMBS and other ABS (student loans, credit cards, equipment leasing, multi-borrower) transactions ("CMBS/RMBS/other ABS"),[19] which are mostly issued by financial institutions or large parent/holding companies. We conjecture that the market pricing of the latter type of ABS might be less sensitive to equity price changes; yet, higher market liquidity and greater transparency of CMBS/RMBS could also engender stronger joint price dynamics.

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[17] Equity price series of seven non-U.K. issuers *(Eurohypo AG, Württembergische Hypothekenbank AG, MBNA America Bank, N.A., SLM (Student Loan Marketing Association) Corp., Allmerica Financial Corporation (AFC), MBNA Bank Corp., Capital One Bank Corp.)* were obtained from the *New York Stock Exchange* (NYSE) and the Frankfurt-based *Deutsche Börse* (German Stock Exchange). We subsequently converted the local currency-denominated stock prices into Pound Sterling at the applicable exchange rate.

[18] Note that we retained several ABS transactions in our data set that were issued by the same entity and/or included two or more constituent fixed-rate tranches.

We record the rating classification of each ABS tranche and form a composite rating a consensus view of an initial issue rating in cases when two or even three rating agencies have assigned tranche ratings (see Tab. 1) to identify the overall rating. Most tranches are rated by all three rating agencies (30), with 41, 44 and 64 tranches being rated by Moody's, S&P and Fitch respectively. Only 11 tranches are rated by just one rating agency. If tranches are rated by at least two rating agencies, they are more likely to have been rated by Fitch and either S&P or Moody's. A lower incidence of joint ratings by Moody's and S&P conforms to the notion that many issuers of ABS elect either of the two divergent rating approaches by Moody's or S&P as primary rating agency to obtain the most favorable rating. The Fitch rating could be thought of as a third-party "seal of approval". The mean and median composite ratings of all ABS tranches in the total sample are 4.16 (AA-, Aa3) and 3.00 (AA, Aa2) on our numeric rating scale, with the highest rating classification 1.00 (AAA/Aaa) being most common.[20]

3 METHODOLOGY

In order to test for the existence of a price equilibrium our methodology follows a sequence of analytical procedures commensurate to the incidence of possible cointegration relations in the joint dynamics of K number of price series. If $k = K$, the time series of all variables in our sample are level stationary, and the use of unrestricted VAR specification of price dynamics without a cointegration vector is warranted. If $1 \leq k - 1 < K$, one series is first order differentiable so that at least one cointegration vector (i.e. difference stationarity) exists. This case requires a cointegration restriction of VAR in the form of a VECM specification or a Granger causality test procedure if the individual series are also level stationarity.[21] Finally, if

[19] We adopt this broad distinction of ABS asset classes in the further analysis of cross-sectional variation of estimation results.

[20] The total sample of ABS-equity pairs only includes ABS tranches without past rating events (rating change or rating watch). Failure to do so might otherwise bias our discriminatory analysis of cross-sectional sensitivity of intertemporal error correction in cointegrated series.

[21] The linear representation of an equilibrium price relation has proven to be inadequate for non-stationarity time series (Granger and Newbold, 1974). The alternative hypothesis of significant explanatory power in conventional inference procedures (e.g. ordinary least squares (OLS)) might actually flag an non-existing empirical relation between two variables, which drift away from the initial value with an individually time-varying trend. In this case, also the linear Granger causality testing procedure is biased. Hence, if we observe variables with a unit root, the existence of cointegration is needed to establish incontrovertible evidence of long-term price consistency between time series.

$k = 0$ all series are at least first order integrated. In this case, we would calculate VAR estimates on first difference of price series data.

Since inference procedures of standard parametric models assume non-integration and level stationarity of both dependent and explanatory variables, we analyze each time series for individual stationarity at level and first differences by means of unit root tests. Based on a linear price relationship of stationary series, we complete the traditional Granger test of any linear predictive power in the (short-term) price dynamics of pairwise matched equity and ABS prices for each issuer. We relax the stationarity requirement in favor of long-term economic causality through cointegration. We examine the presence of cointegration in the long-term relationship between equity and ABS price series in order to control for possible biased inference procedures in a linear specification of higher order integrated pairwise time series.

The concept of cointegration is defined as the stationary linear combination of two time series (Johansen and Juselius, 1990; Engle and Granger, 1987), whose long-run equilibrium relationship converges to a difference stationary series, i.e. the values of the linear combination of as coefficients of the cointegration vector are centered around a mean and have a constant variance.[22] So if the constituent price series are first-order integrated and share a cointegration relationship, the equivalence relationship between both markets on an equilibrium price, holds and their difference series describes a stationary process. In other words, as we drop the stationarity condition of individual series, the existence of cointegration allows us to test for a long-term empirical price relationship and empirical causality of short-term price adjustments. We adopt a vector-based simultaneous equation model of autoregressive specification to study the intertemporal causal interaction of both markets with and without the presence of long-term cointegration. We use VAR and VECM as appropriate econometric tools for measuring the speed and the degree of price discovery in these markets.

[22] So if two series follow a random walk I(1) process and their difference series is stationary, they are considered cointegrated. The order d of integration I(d) indicates the number of unit roots contained in a series and the number of differencing operations required to yield a stationary series. In the context of this paper, the co-integration of two financial series on the same underlying asset process eliminates a long-term arbitrage opportunity by shorting the overvalued asset to finance a long position in the undervalued asset.

4 STATIONARITY AND COINTEGRATION

Prior to the examination of the lead-lag relationship between equity and ABS prices in a causality framework of several simultaneous equation models, we need to examine the univariate stochastic properties of the price series in our sample. The price series could either exhibit mean reversion or conform to a random walk with a constant forecast value, conditional on time, and time-varying autocovariance, whose first order integration yields a stationary difference series. We choose classical unit root testing by Dickey and Fuller (1979 and 1981) and Phillips and Perron (1987), the *Augmented Dickey-Fuller* (ADF) and the *Phillips-Perron* (PP) test statistics (Greene, 1993), to investigate the presence of mean reversion. These tests are based on a linear AR(p) model with p number of lags, which considers all combinations of price sensitivity γ to past mean prices and the significance of some resilient price level as drift. We run the ADF test with a linear trend on level and first differences of spreads of up to five lags in order to control for serial correlation. We also complete the PP test diagnostic corrected by the Newey-West autocorrelation consistent variance estimator, which accounts for the number of periods of serial correlation through six truncation lags. For both test we employ MacKinnon (1996) critical values for (one-sided) rejection of the unit root null hypothesis. We complement our analysis by testing for statistically significant residual autoregressive effects on the basis of the *Llung-Box* Q-statistic. As opposed to the most recent study on secondary market pricing in ABS/MBS markets (Koutmos, 2002), we find that the asset generating processes of both ABS and equity series are generally difference stationary. The sample mean and median values of the ADF and PP test statistics as well as high degrees of autocorrelation suggest that ABS price series especially defy level stationarity. Similar to earlier research on the price dynamics of U.S. ABS/MBS spreads, both ADF and PP test diagnostics strongly reject the null hypothesis of a unit root in all cases for ABS and equity prices at first difference. This implies stationary residual series with autocorrelation effects of up to five lags at most according to the *Llung-Box Q-statistic*. Since first order integration of individual equity and ABS price series yields stationary I(0) processes, our unit root test estimates suggest that equity and ABS prices share at least one unique co-integration vector, where a mean-reverting difference series with time-independent autocovariance suggests an intertemporal relationship of mutual price discovery.

We identify market liquidity and data frequency as possible causes of slightly divergent stochastic properties across equity and ABS prices at level and first differences. Although our sample period stretches more than five years (from September 1998 to January 2004), varying lengths of price quote series for the various ABS transactions result in median (mean) of 698 (683) observations over the sample period – about half the 1,404 (1,539) observations we obtained for the equity price of the corresponding issuers in question. Moreover, we find only weak and scarce statistical evidence of mean-reverting ABS prices. Whereas Koutmos (2002) used weekly time series data of more than 30 years to substantiate his findings on the level stationary of U.S. MBS spreads (grouped by rating classification and maturity), our shorter time horizon certainly inhibits the same degree of measurability of long range cycles of mean-reversion, even though we are almost able to always match the absolute number of observations in his study. We also recognize that persistent stochastic processes over long spans of time with a small autoregressive component (due to low liquidity and infrequent trading activity) could bias the ADF and PP tests into rejecting the unit root in absence of strong statistical power against the alternative of level stationarity (Papell and Prodan, 2003).[23] Although we do not observe "stale" price movements with autoregressive residuals, this might well be the case for our comparatively short time horizon of five years. We find that first order integration yields strong mean reversion, which in turn renders standard hypothesis testing appropriate for either ABS or equity prices at first differences with and without cointegration.

In the effort to explain the long-term consistency of joint movements of equity and ABS prices we also test the pairwise time series data for the degree of correlation (see Tab. 2) and the existence of one or more cointegration vectors (see Tab. 3). We find that positive correlation is most prevalent in the sub-sample of ABS-equity pairs with either non-investment grade rated ABS or whole business ABS. This observation concurs our structural model-based hypotheses of higher correlation between debt and equity of low-rated issuers and issuers of ABS transactions that display a higher degree of proximity to the fundamental asset value process of the issuer, such as whole business ABS. However, the joint incidence of both characteristics yields a negative correlation value. We attribute this result to the uneven sample composition

[23] The danger of type II error misspecification, which also operates in the presence of a nonlinear data generating process, has critical implications on the interpretation of ADF results for inference testing in the presence of a nonlinear data generating process. The linear specification of ADF biases the unit root test into rejecting the unit root hypothesis (Taylor, 2001; Taylor and Peel, 2000).

buy cross-sectional characteristics of ABS-equity pairs. Since both ABS and equity price series reflect the market value of different security claims on the same asset generating process (albeit at different degrees of exposure and state contingency), we would expect their difference series to be first order integrated with a time-invariant mean and autocovariance. The existence of a cointegrating relationship is defined as $B_{i,t} = \alpha_i + \beta_i S_{i,t}$ with $\alpha_i = 0$ and $\beta_i = 1$ for each *i*-pair of ABS and equity series with prices B_t and S_t. If we remove the cointegration restriction from the difference stationary series, long-term consistency of price co-movement toward an equilibrium price would yield the one-dimensional cointegration vector *kx1*, with vector $[1 \quad -1]$ representing the simplest form of first order cointegration. We follow Johansen (1988, 1991 and 1995) as well as Hansen and Joselius (1995) to examine the existence of statistically significant cointegration on the basis of the trace statistic, whose critical values are reported by Osterwald and Lenum (1992).[24] We find supporting evidence for at least one statistically significant cointegration vector at a 95% confidence level in 51 out of 68 cases of the total sample of matched ABS-equity pairs. Moreover, long-run price consistency between matched equity and ABS series appears to vary by ABS asset class, with the long-term price dynamics of whole business ABS diluting the economic and statistical significance of cointegration. While almost 80% of all ABS series of CMBS/RMBS are cointegrated with the corresponding equity price of their issuer at a statistical significance of 5% or lower, we observe a similar degree of cointegration only in 70% of all ABS series of whole business ABS.

[24] The cointegration rank test by Johansen (1991) investigates the existence of a stationary linear combination of first order integrated time series on the basis of a VAR of $\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \mathrm{E}_t$ (with difference operator Δ) as the first difference specification of $Y_t = \sum_{t=1}^{p} \mathrm{A}_t Y_{t-1} + e_t$ at an autoregressive lag order *p* without gaps, with A_t and Γ_i as (2x2) parameter coefficient matrices for the $k \times 1$ price vectors $Y_t = (S_t, B_t)'$ and $\Delta Y_t = (\Delta S_t, \Delta B_t)'$ of past ABS and equity prices, as well as e_t and E_t as (2x1) vectors $\left(\varepsilon_t^{(S_t)}, \varepsilon_t^{(B_t)}\right)'$ and $\left(\varepsilon_t^{(\Delta S_t)}, \varepsilon_t^{(\Delta B_t)}\right)'$ of serially uncorrelated, zero mean i.i.d. residuals with covariance structures Ω and Σ. The Johansen cointegration test evaluates the null hypothesis of no cointegration relation between the selected time series. We reject the null hypothesis if the coefficient matrix $\Pi = \alpha\beta'$ of $k \times 1$ vectors has reduced rank equal to 1 (H_0: full rank equal to 2), with β being the cointegration vector. The existence of cointegrated time series gives rise to an equilibrium price relationship beyond possible linear bias in standard inference models.

5 SHORT-TERM DYNAMIC LINKAGES AND LONG-TERM CONSISTENCY

We break down our investigation of a possible empirical relationship between ABS and equity prices into short-term dynamic linkages and long-term consistency of intertemporal co-movement. We first examine the short-term dynamics between equity and ABS prices without the requirement of cointegration in two different linear specifications of stationary series. Before we apply a two-dimensional *vector autoregressive* (VAR) model in a linear system of simultaneous equations to study price discovery in response to changes in the quality of issuers and their securitized debt, we resort to the traditional linear approach of *Granger causality* testing to better explain current and future price movements in ABS and equity markets on the basis of short-term joint (multivariate) price dynamics.

5.1 Granger causality

The Granger causality test is a non-vector forecasting alternative to VAR (see section 5.2 below) and yields insights about the direction of the empirical relationship between equity and ABS prices, without imposing limitations on the long-run consistency of price dynamics. Granger (1969) defines the causality between two scalar-valued, stationary and ergodic time series $\{X_t\}$ and $\{Y_t\}$ on the grounds of significant reciprocal (autoregressive) influence of past information on the conditional probability distribution of X_t. Given the bivariate information set I_{t-1} defined as *Lx*-length lagged vector $X_{t-Lx}^{Lx} \equiv (X_{t-Lx}, X_{t-Lx+1}, ..., X_{t-1})$ of X_t (or in short a lag polynomial $I_{t-1}(L_x)$ of X_t) and an *Ly*-length lagged vector $Y_{t-Ly}^{Ly} \equiv (Y_{t-Lx}, Y_{t-Lx+1}, ..., Y_{t-1})$ of Y_t, the time series $\{Y_t\}$ strictly Granger causes $\{X_t\}$ if one can reject $F(X_t | I_{t-1}) = F(X_t | I_{t-1} - Y_{t-Ly}^{Ly})$ for time period t. So past knowledge about past values of $\{Y_t\}$ helps predict current and future values in $\{X_t\}$. Our bivariate autoregressive specification of Granger causality with intercept reads as

$$\Delta S_t = c_1 + \sum_{j=1}^{q} \alpha_{1,j} \Delta B_{t-j} + \sum_{j=1}^{q} \beta_{1,j} \Delta S_{t-j} + \xi_{1,1} L_t + \xi_{1,2} M_t + \upsilon_{1,t} \qquad (1)$$

$$\Delta B_t = c_2 + \sum_{j=1}^{q} \alpha_{2,j} \Delta B_{t-j} + \sum_{j=1}^{q} \beta_{2,j} \Delta S_{t-j} + \xi_{2,1} L_t + \xi_{2,2} M_t + \upsilon_{2,t}, \quad (2)$$

where the non-autoregressive disturbance terms $\upsilon_{1,t}$ and $\upsilon_{2,t}$ are i.i.d. and follow a zero mean process with constant variance $N(0,\sigma^2)$. This specification of intertemporal causality of non-cointegrated, difference stationary series tests whether the coefficients of the lagged polynomials of first-order equity and ABS prices, $\Delta S_t = S_t - S_{t-1}$ and $\Delta B_t = B_t - B_{t-1}$, are jointly zero on the basis of standard F-tests. We also include the 3-month LIBOR rate L_t and a 15-year U.K. bond market benchmark rate M_t as weakly level stationary, explanatory variables. The lag length q is chosen using the *Akaike information criterion* (AIC), the *Bayesian information criterion* (BIC) and the *Schwarz information criterion* (SIC). We selected a maximum lag of six days. The joint rejection of $H_0 : \beta_{1,t-1} = \beta_{1,t-j} = ... = \beta_{1,t-q} = 0$ implies that ΔS_t strictly Granger causes ΔB_t. Similar statistical significance of $\alpha_{2,t-j}$ across all lagged endogenous variables indicates a similar feedback effect of ΔB_t on ΔS_t. Bi-directional feedback as two-way Granger causality exists if both lagged polynomials of the opposite asset class are sufficiently significantly different from zero so that the exclusion restriction is rejected.

The Granger causality specification of short-term joint price dynamics indicates statistical significance of lagged polynomials of either ABS or equity prices (as past information sets) in roughly 40% of all selected ABS-equity pairs of the total sample and sub-samples (see Tabs. 3-4). The richness of our dataset allows us to estimate Granger causality at different levels of statistical significance and across cross-sectional variations of ABS characteristics of both ABS categories, CMBS/RMBS and whole business ABS, within the total sample of ABS-equity pairs. In the total sample, we reject the null hypothesis of no Granger causality of ABS prices (at first difference) on equity prices (25.0% of all ABS-equity pairs) more frequently than Granger causality of equity prices (14.7% of all ABS-equity pairs). Past ABS prices are generally at least twice as likely as past equity prices to Granger cause price movements of equity once we narrow the selection of eligible price series data to cointegrated ABS-equity pairs and further ABS properties, such as U.K. domiciled issuers, investment grade rating and long-term maturity. Upon breaking down the total sample into sub-samples of ABS-equity pairs with either CMBS/RMBS or whole business ABS, we detect an intriguing variation in the explanatory power of lagged polynomials of equity and ABS series. In the subset of ABS-equity pairs with whole business ABS, price changes of equity series tilt the general pattern of joint short-term price dynamics of ABS and equity series against pervasive ABS-based Granger causality. Now, past equity prices (at first difference) chip away considerably at the dominant ABS discovery and claim higher explanatory power in price discovery almost (or even more than) three times as often as past ABS prices. In contrast, the sub-sample of ABS-equity pairs with CMBS/RMBS mirrors the general pattern of Granger causality estimates observed for the price series data of all ABS-equity pairs (i.e. the total sample of cointegrated series). Here, ABS series outscore equity price series in price discovery at a rate of four to one. Despite the weak stochastic reliability of Granger causality compared to subsequent estimations based on two-dimensional vector-based estimations, we can make a coherent case for strong price discovery by ABS (equity) prices in ABS-equity pairs with CMBS/RMBS (whole business ABS) at first difference invariant of the presence of cointegration concerning short-term co-movements with ABS and equity prices. Our findings suggest that the joint price dynamics of both asset classes are superior to univariate forecasts of future price changes of either asset class (at least over the short-run). The low importance of past information of whole business ABS prices in the price formation of equity seems to suggest that whole business ABS series might display lower autoregressive effects at higher levels of persistence than corresponding equity series of the same issuer compared to CMBS/RMBS series. However, we need to be mindful of the change in sample composition as we derive two ABS asset-class specific sub-samples (whole business ABS vs. CMBS/RMBS) of different sizes (31 cases vs. 38 cases). Although our (linear) Granger causality framework testifies to a consistent pattern of a lead-lag relationship between equity and ABS price series, it does not provide conclusive evidence about actual economic causality, even if we control for non-linearity bias. Hence, we advance our investigation to a vector-based system of simultaneous equations.

5.2 (Unrestricted) Vector Autoregression (VAR)

As a vector-based alternative to Granger causality testing of short-term dynamics, we present a two-dimensional vector autoregression (VAR) to analyze the dynamic impact of random disturbances on interrelated time series. The linear equation system of VAR assumes stationarity of exogenous and endogenous variables without restricting the interrelated time series to a cointegrating relationship. Since most ABS and equity prices in our sample series are not I(0) level stationary, we specify the (unrestricted) VAR of vector $X_t = (\Delta S_t, \Delta B_t)'$ of equity and ABS prices at first differences at time *t* as[25]

$$\begin{bmatrix} \Delta S_t \\ \Delta B_t \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + \begin{bmatrix} \sum_{j=1}^{p} \varphi_{1,j} \Delta B_{t-j} \\ \sum_{j=1}^{p} \varphi_{2,j} \Delta B_{t-j} \end{bmatrix} + \begin{bmatrix} \sum_{j=1}^{p} \gamma_{1,j} \Delta S_{t-j} \\ \sum_{j=1}^{p} \gamma_{2,j} \Delta S_{t-j} \end{bmatrix} + \begin{bmatrix} \xi_{1,1} L_t \\ \xi_{2,1} L_t \end{bmatrix} + \begin{bmatrix} \xi_{1,2} M_t \\ \xi_{2,2} M_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix}$$

$$\Leftrightarrow X_t = C + \sum_{j=1}^{p} \phi_t X_{t-j} + \Xi_t Z_t + \mathrm{E}_t, \qquad (3)$$

with C as a (2x1) vector of constants c_1 and c_2, ϕ_t as (2x2) parameter coefficient matrix for past X_t values up to *p* number of lags,[26] Ξ_t as (2x2) parameter coefficient matrix of vector $Z_t = (L_t, M_t)'$ of the contemporaneous level controls L_t (3-month LIBOR rate) and M_t (bond market benchmark rate) for the risk-free interest rate and average U.K. corporate bond returns, and E_t as (2x1) vector $\left(\varepsilon_t^{(\Delta S_t)}, \varepsilon_t^{(\Delta B_t)}\right)'$ of non-autoregressive i.i.d. residuals $\varepsilon_t \sim N(0, \Sigma)$.[27] We consider a lag structure without gaps at a maximal autoregressive lag of order six to capture the weekly variation of the underlying economic relationship for daily observations. The parameter coefficients are estimated as matrix vectors of lagged and contemporaneous values of the designated endogenous variables for each ABS-equity pair across the sample selection.

5.3 Vector autoregressive error correction model (VECM)

[25] See also Lutkepohl (1991) for consistent lag order selection in VAR models.

[26] The choice of lag structure and the maximum lag order *p* reflect a conscious trade-off between over-parameterization (and the corresponding loss of degrees of freedom) and over-simplification. Since the maximum lag order should capture the overall information processing and aggregation time in each market, we mainly rely on individual partial autocorrelation of ABS and equity series in our sample (Taylor and Peel, 2000) in addition to the *Akaike* information criterion and the stepwise maximum likelihood ratio test.

[27] Errors are uncorrelated with their own lagged values and all endogenous variables, but may be contemporaneously correlated with each other. The assumption of not serially correlated residuals is not restrictive, since any residual serial correlation could be easily absorbed by an increase of polynomial lag *p*.

Since most ABS-equity pairs exhibit intertemporal (linear) causality with at least one cointegration vector, we control for intertemporal price adjustment of cointegrated ABS-equity pairs to improve our analysis of joint dynamics of past price movements in both equity and ABS markets. The intertemporal lead-lag relationship of price discovery indicates which market is more efficient in reflecting changes in the quality of the issuer (and the value of associated securitized debt). We augment our (unrestricted) VAR specification above by introducing a so-called *error correction term* to account for price adjustment of I(1) cointegrated levels of lagged difference series of equity and ABS prices for $B_{i,t} = \alpha_i + \beta_i S_{i,t}$, where α_i and β_i are endogenously determined. We apply a two-dimensional (bivariate) *vector error correction model* (VECM) as a restricted VAR (Hamilton, 1994; Davidson and MacKinnon, 1993) to time series data of ABS-equity pairs that are known to be cointegrated. This specification allows us to extend our perspective to the *long-term consistency* of price dynamics and lays the foundation for a more advanced investigation into the economic causality of prices in both markets. VECM restricts the long-run behavior of endogenous variables to converge to their cointegrating relationships (through price adjustments) while allowing a wide range of short-run dynamics of past price movements as random disturbances on joint price dynamics within a linear system of simultaneous equations. The degree of cointegration is reflected in the specification of the error correction term, which gradually corrects past deviations from long-run equilibrium through a series of partial short-run price adjustments. Although the cointegration restriction of long-term consistency in VECM does not necessarily require level stationarity of the constituent time series, it implies a level stationary I(0) difference series of each time series regardless of the individual degree of integration.

We consider VECM with constant drift and no trend for difference stationary series of ABS and equity prices at time *t* with at least one cointegrating vector as

$$X_t = C + \Lambda\left(B_{t-1} - \alpha_0 - \beta_1 S_{t-1}\right) + \sum_{j=1}^{p} \phi_t X_{t-j} + \Xi_t Z_t + E_t, \tag{4}$$

where C, ϕ_t, X_t, Ξ_t and Z_t are identical to the parameter specification of VAR above. The lagged difference between both level series denotes the "error correction term" (or "cointegration equation") as an additional endogenous variable of possible long-term consistency (with complete cointegration at $\alpha_0 = 0$ and $\beta_1 = 1$). Λ is a (2x1) vector of adjustment coefficients λ_1 ("equity λ") and λ_2 ("ABS λ") of the (contemporaneous) error correction term. The adjustment coefficients indicate the degree of short term price adjustment by movements of equity prices vis-à-vis ABS prices and vice-versa so as to correct pricing discrepancies against a long-term trend of difference (covariance) stationarity. If λ_1 is sufficiently positive in the above specification of error correction, ABS prices anticipate price changes (e.g. due to changes in the quality of securitized assets) and the mean-reverting parameter of equity prices in adjusts to remove pricing errors in response to changes of issuer valuation (e.g. due to changes in credit conditions). The converse argument holds and equity prices contribute most to price discovery relative to ABS prices λ_2 is sufficiently negative. The (relative) degree of adjustment to price discrepancies is reflected in the economic significance of coefficient β_1. So the statistical and economic significance of the error correction term indicates which of the two markets lags price changes and how fast price adjustment takes place. If (significant) positive values for λ_1 and negative values for λ_2 coincide in the λ-vector of the error correction term, the relative magnitude of both λ_1 and λ_2 coefficients reflects the role of each market in price discovery (see Tab. 6).

Besides analyzing the incidence of statistical and economic significance of error correction in the ABS and equity equation of VECM individually, we also examine the pattern of joint price adjustment of cointegration for each matched ABS-equity pair in our sample. Hence, as a succinct representation of the lead-lag relationship between both series, we compute different ratios of the respective error correction coefficients to gauge how much each market contributes to price discovery. We entertain two indicative measures of relative error correction: the (original) GG-test measure $\lambda_1/(\lambda_1 - \lambda_2)$ by Gonzalo and Granger (1995) and a modified version $(\lambda_1 - \lambda_2)/(|\lambda_1| + |\lambda_2|)$ ("modified GG-test") thereof, where λ_1 and λ_2 denote the error correction term coefficients for equity and ABS prices respectively. Both ratio tests complement each other to provide instant information about the dominant contribution to price discovery and the corresponding adjustment for pricing errors in either market. The GG-test measure emphasizes the relative magnitude of error correction terms in both the ABS and equity equation of VECM, but it does not explicitly check for the signs of the λ coefficient values. In contrast, the modified GG-test measure resembles a sign test of the "right" combination of error correction coefficients for dominant price discovery of a lead-lag relationship. If the GG-test approaches unity, the "equity λ" dominates, implying that the price series of the first term in the error correction term $\left(B_{t-1} - \alpha_0 - \beta_1 S_{t-1}\right)$ of VECM plays a leading role in price discovery and the second term adjusts. If the ratio is close to 0, the roles of these two markets reverse. For a measure close to 0.5, both markets equally contribute to price discovery and there is no definite evidence of consistent price adjustment in either series over time. Positive values of the modified GG-test attribute greater economic significance to price adjustment of the second term of the error correction equation, whereas the reverse holds true for negative values of the modified GG-test (see Tabs. 7-8). If ABS prices adjust with certainty, we find $GG_{\text{mod}} = -1 : \lambda_1 <> \lambda_2 \forall \lambda_1 < 0, \lambda_2 > 0$, and in the opposite case of "pure" price discovery by equity prices we find $GG_{\text{mod}} = 1 : \lambda_1 <> \lambda_2 \forall \lambda_1 > 0, \lambda_2 < 0$ (see Fig. 3).

6 ESTIMATION RESULTS

Both the unrestricted and restricted two-dimensional vector-based estimation of intertemporal autoregressive effects between equity and ABS prices within a linear system of simultaneous equations in VAR and VECM show that lagged prices of each asset class have similar statistically significant explanatory power to improve forecasts on the short-term joint price dynamics with and without cointegration. In a nutshell, our findings generally conform to Hypothesis 1 of a positive long-term consistency of intertemporal causal interaction (co-movement) between cointegrated equity and ABS prices, where the ABS market contributes more to price discovery of issuer valuation (Hypothesis 3), albeit with some variations across different sub-samples of ABS security characteristics. Although whole business ABS display an economically stronger empirical association with corresponding equity prices (Hypothesis 2), the incidence and statistical significance of price discovery is stronger for CMBS/RMBS/other ABS (with lower sensitivity to changes in equity value). Hence, we reject Hypothesis 4.

6.1 Lagged polynomials in VAR and VECM

The utility of this exercise lies in the comparative investigation of the statistical and economic significance of short-term joint dynamics of pairwise matched equity and ABS price series based on the coefficient estimates of lagged polynomials in VAR and VECM specifications. We investigate the degree to which past information in both markets improves univariate estimates of autoregressive effects.

A detailed analysis of the incidence of VAR and VECM estimated coefficients of the lagged polynomials at a common level of at least 10% statistical significance testifies to a largely positive and statistically significant influence of past joint price dynamics of ABS-equity pairs on short-run forecasts of current and future price movements (Hypothesis 1), with greater overall economic significance attributable to price information of ABS-equity pairs with whole business ABS (Hypothesis 2) and ABS with long maturities. While the lagged polynomials of ABS exhibit consistently negative autoregressive effects in both VAR and VECM, we detect mostly negative (positive) autoregressive effects in equity prices series up to six lags of past price information in VAR (VECM) specifications. We find that controlling for cointegration can affect how past knowledge helps improve forecasted price movements (results not reported). We detect strong and statistically significant autoregressive effects in equity prices series up to six lags of past price information in both VAR and VECM specifications.[28] Autoregressive effects of ABS series tend to be similar to equity only with cointegration restriction in VECM. The lagged polynomial of ABS prices (level and first differences) explains changes in equity prices only in the subsets of ABS-equity pairs with (i) CMBS/RMBS in both VAR and VECM (based on a sufficiently high incidence of significant cases), (ii) whole business ABS in VAR (based on a significant FM t-statistic), and (iii) ABS with long maturity or investment grade rating (based on a sufficiently high incidence of significant cases). Autoregressive effects of equity on ABS prices are limited to ABS-equity pairs with investment grade rated ABS in both VAR and VECM (based on a significant FM t-statistic). The coincidence of significant FM t-statistics and a high score of significance cases implies little skewness in the distribution of coefficient values across all series in the sample (which might otherwise bias the statistical significance of parametric testing procedures). However, our evidence *generally negates the statistical significance of short-term joint dynamics* between both equity and ABS price series for level data and first differences.

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[28] We might explain greater explanatory power of past equity prices especially for ABS-equity pairs with CMBS/RMBS on the grounds of market liquidity. Issuers of CMBS/RMBS tend to be larger and tender more actively traded equity than issuers of whole business ABS, whose lack of operational scale make them issue securitized debt only as a complementary source of external finance. Univariate descriptive statistics (not reported) of equity prices of issuers of whole business ABS also exhibit higher persistence

Our exogenous control factors, the daily level data of the 15-year U.K. bond benchmark and the three-month U.K. Sterling LIBOR rate (both obtained from *Bloomberg*), play a economically strong but statistically weak role in both equity and ABS equations of VECM. We recognize that the count of significant cases is occasionally inconsistent with the FM t-statistic owing to a skewed distribution of sample coefficient estimates for these control variables. The FM-statistic attributes statistical power to control variables at common levels of significance across various sub-samples only without cointegration restriction (VAR).

6.2 Error correction in VECM

We analyze the statistical and economic significance of error correction in the long-run price dynamics of equity-ABS pairs based on the individual incidence of positive or negative coefficients of error correction and the paired coincidence of price adjustment of pooled sample estimates. We summaries the mean and median values of error correction and their individual incidence of the error correction coefficients as well as two composite GG-test measures for both the entire sample and pre-defined sub-samples of ABS-equity pairs, where the ABS price series is either a whole business ABS or a RMBS/CMBS transaction. We also control for the degree of statistical significance of price adjustment by four designated "significance categories": (i) both coefficients λ_1 and λ_2 are statistically significant (at least at the 10% level), (ii) only λ_1 (i.e. equity price adjustment) is statistically significant (at least at the 10% level), (iii) only λ_2 (i.e. ABS price adjustment) is statistically significant (at least at the 10% level), and (iv) neither λ_1 nor λ_2 is statistically significant (at least at the 10% level). Moreover, we qualify our results of intertemporal causality on the following cross-sectional properties: (i) presence of one or more cointegration vectors between the price series of matched ABS-equity pairs, (ii) issuer domicile of U.K. Sterling denominated ABS/MBS (U.K.-based issuer vs. U.S. and German issuers), (iii) seniority of the ABS transaction (investment grade vs. non-investment grade), and (iv) maturity of the ABS transaction (at least 25 years vs. shorter maturities).

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of the sample period with longer autoregressive cycles than equity series of ABS-equity pairs associated with CMBS/RMBS issuers.

6.2.1 *Analysis of individual error correction coefficients of VECM*

We analyze individual error correction of long-term price consistency in the VECM specification of cointegrated ABS-equity pairs by means of both sample mean and median of estimated error correction term coefficients λ_1 and λ_2 and numerical incidence of positive and negative values of error correction (see Tab. 6). We examine cross-sectional variation of mutual price adjustment across different cases of statistical coincidence of estimated error correction coefficients ("significance categories") and different types of ABS series. We find that at least one λ-coefficient in VECM of cointegrated ABS-equity pairs is always statistically significant at the 10% level or better (based on one-sided p-values). Although the numerical count of error correction terms reveals sizeable price adjustment in both markets, we find appreciable differences in how much equity and ABS prices contribute to price formation. For all cointegrated ABS-equity pairs (Panel A), ABS prices respond to price discrepancies in 94.1% of all cases, whereas only 60.8% of all equity issues adjust. Equity prices are almost seven times more likely to move ahead in price discovery than the corresponding ABS prices, which lead only in 5.9% of all cases. The degree of error correction and price discovery between equity and ABS prices seems to depend strongly on the type of ABS, but also on the maturity and the rating of ABS. Panels B-C imply a preponderance of positive λ_1 values (i.e. equity prices adjust) with the highest proportional incidence of 64.4% of all cointegrated equity series in the total sample of ABS-equity pairs with U.K.-based issuers and 66.7% of cointegrated ABS-equity pairs with CMBS/RMBS as ABS asset class. We also record a lower chance of equity-based price discovery in ABS-equity pairs with whole business ABS as ABS asset class. Also, λ_2 values are highly negative (i.e. ABS prices adjust) in almost every ABS-equity pair throughout the sample invariant of cointegration and ABS asset properties. We mark the highest incidence of 96.7% for negative λ_2 values for all cointegrated ABS-equity pairs with CMBS/RMBS/other ABS as ABS asset class.

In light of significant individual intertemporal error correction of both ABS and equity prices, higher economic significance determines the dominant direction of price discovery between these cointegrated series. We find that equity prices tend to adjust twice as strongly as ABS prices over the same set of matched series (Hypothesis 3) in almost all sample selections. The median sample values of $\lambda_1(\lambda_2)$ in the total sample of ABS-equity pairs all carry positive (negative) signs, irrespective of the “significance category” of the matched λ-coefficients.

We find that the absolute median (mean) values of error correction are consistently higher for equity prices than for ABS prices at a multiple of up to 3 (44), which implies economic dominance of ABS tranches in price discovery in almost all cases of ABS-equity pairs. Only matched series with equity error correction as the lone statistically significant price adjustment (at 10% level or less) and cointegrated series of ABS-equity pairs with whole business ABS as ABS asset type diverge from the general pattern of absolute dominance of ABS series in price discovery. However, negative median sample values of λ_1 indicate declining error correction of equity series in response to ABS price movements. At the same time, corresponding ABS series retain a strong inclination of price adjustment based on highly negative λ_2 values (though statistically insignificant). Once we restrict our observations to price series of ABS-equity pairs with RMBS/CMBS/other ABS, U.K.-based issuers or ABS tranches with investment grade ratings or long maturity, our results provide strong support for price discovery by the ABS market. We find the most coherent median error adjustment in equity markets whenever we disregard whole business ABS prices. In fact, the total sample of ABS-equity pairs clouds weak ABS price leadership for ABS-equity pairs with whole business ABS tranches, especially if we take into consideration our findings from the Granger causality test.

Despite allegedly closer proximity of whole business ABS transactions to the operational performance of issuers, stronger price discovery by CMBS/RMBS transactions cannot be attributed to longitudinal differences between CMBS/RMBS and whole business transactions (in light of positive (negative) correlation of ABS-equity pairs with whole business ABS (CMBS/RMBS transactions)). Several conjectures might plausibly explain much weaker price discovery of whole business ABS (in rejection of Hypothesis 4) on the grounds of liquidity-based market risk and information transparency. Higher liquidity from more frequent trading activity and higher incidence of synthetic transactions structures in CMBS/RMBS deals (with a stronger associated economic linkage to the issuer in the form of payment and insolvency guarantees) could facilitate a closer empirical relationship between ABS and equity price series.[29] Different market liquidity might also be attributable to concentrated "buy and hold" ownership by large institutional investors.

The cointegrated relationship between ABS and equity series of the same issuer is marked by more economically profound contribution of ABS markets to price discovery in accordance with Hypothesis 3. Nonetheless, in cases of equity price adjustment as the only significant error correction, our results are inconsistent with the general properties of intertemporal causality. In some instances when disparate autoregressive effects and/or time trends of matched series impede error correction of equity prices, we also attribute dominant price discovery to equity markets. Although this qualification on general price adjustment of equity series seems limited in scale and scope, our findings on the basis of simple non-matched counts of equity error correction do not betray conclusive evidence of pervasive price leadership by ABS markets.

6.2.2 Analysis of paired error correction coefficients of VECM

Unfortunately, the incidence of statistically significance and the economic significance of individual price adjustment of both ABS and equity series fails to reflect how λ_1 and λ_2 values square up against each other in matched λ-pairs in our VECM specification of matched ABS-equity pairs. For this purpose, we derive the original and a modified GG-test diagnostic from the coefficient values of the error correction terms of matched ABS and equity series to measure the relative contribution of each market to price discovery (see Tabs. 6-7). We find that the values for both GG-tests of matched error correcting λ-pairs remain largely positive and stable throughout the entire sample and the designated sub-samples of whole business ABS and RMBS/CMBS as well as over most significance categories. The numerical count of significance categories of all error correcting λ-pairs reveals only one significant λ value of each λ-pair to be most common (in two thirds of all cases), once we limit our analysis to I(1) cointegrated equity-ABS pairs. Most median values of both GG-tests are close to unity every time paired adjustment coefficients share the same statistical significance (and to a lesser extent when either λ-value represents the only statistically significant error correction). The GG-test

[29] Also note that equity of issuers of whole business ABS might be less liquid than the equity of CMBS issuers, which tend to be large banks, non-bank financial institutions and real estate agencies.

results imply a preponderance of positive λ_1 and negative λ_2, with $|\lambda_1| > |\lambda_2|$, which suggest that ABS investment informs price formation and equity markets almost perfectly adjust to price discovery in the ABS market (Hypothesis 3).

We also represent graphically the numerical analysis of paired error correction coefficients at different significance categories in Fig. 3. For "perfect" price leadership of ABS (equity) we would expect the corresponding λ-pairs to exhibit statistically significant, positive (negative) λ_1 and λ_2 values, where $\lambda_2 < \lambda_1$ $(|\lambda_1| < |\lambda_2|)$. We represent the preference order of price adjustment behavior of ABS and equity price series in segments from 1 (strong evidence of ABS lead in price discovery) to 8 (strong evidence of equity lead in price discovery). We find most observations (which incidentally also show the most complete statistical significance of λ-pairs) in segments 3 and 4.

Our results of price leadership of ABS are weakest for ABS-equity pairs with whole business ABS, irrespective of further cross-sectional variation of ABS characteristics, or if statistically significant error correction is limited to ABS prices. If we only consider ABS-equity pairs with CMBS/RMBS as ABS series, the GG-tests usually retain positive values across all significance categories (except in the case of ABS with long-maturity and/or positive correlation when only the equity series exhibits statistically significant error correction).[30] For ABS-equity series with whole business ABS, however, matched λ-pairs yield consistently negative GG-test values whenever the ABS error correction is the only statistically significant price adjustment. Interestingly, the cross-sectional restriction of investment grade and/or long-maturity ABS of eligible ABS-equity pairs marginally improve both the general statistical significance of λ-pairs and the economic significance of ABS-based price discovery.

7 CONCLUSION

In extension to the past literature on the empirical relationship between different asset classes, this paper represents the first attempt to measure the intertemporal causal relationship between matched price series of equity and ABS issued by the same entity. Over a time period

[30] Note that the cross-sectional qualification of co-movement based on issuer domicile, ABS rating and maturity as selection criteria does not imply significant selective bias.

of more than five years, we investigated the short-term dynamic linkages and long-term consistency of price co-movement of selected price series in these markets, within an autoregressive time series framework of a two-dimensional linear system of simultaneous equations – with and without the presence of cointegration. We applied bivariate vector autoregression (VAR) and Granger causality testing to paired ABS and equity price series to better explain how their joint dynamics over the short run as well as their intertemporal lead-lag relationship inform current and future prices. We also qualified the degree and direction of price discovery on various security characteristics of selected ABS, such as issue (credit) quality, maturity and the type of ABS transaction (whole business ABS vs. CMBS/RMBS/other ABS).

Our methodology generated stylized facts about price co-movement, which might guide future research on correlation trading, information dissemination and price formation across different capital market sectors. We found that knowledge about the joint dynamics of pairwise matched past equity and ABS prices only slightly improved short-term univariate forecasts of price movements of both markets based on a VAR specification. Nonetheless, Granger causality testing and autoregressive specifications of cointegrated price dynamics with correction for intertemporal price adjustment to past innovations revealed that much can be learned about the price formation in each market by analyzing the long-term consistency of price movements. Generally, our findings delivered compelling empirical evidence of strong price co-movement (Hypothesis 1) and endorsed pervasive ABS dominance in price discovery between ABS and equity series over time (Hypothesis 3). Our results of long-term consistency of price dynamics is economically stronger for cointegrated ABS-equity pairs with whole business ABS (Hypothesis 2). However, the magnitude and direction of price discovery by ABS markets varies by security characteristics. ABS-equity pairs with large-scale (and investment grade rated) CMBS/RMBS transactions exhibited stronger and statistically more significant lead-lag relationships than ABS-equity pairs with whole business ABS. In this case, ABS prices seemed to contribute little to price discovery over time and were more inclined to adjust to price discrepancies vis-à-vis the matched equity price series (in rejection of Hypothesis 4). We attributed this intriguing result to higher market liquidity and higher incidence of stronger credit-linkage to the issuer in the (mostly) synthetic transaction structures of CMBS/RMBS.[31]

This instructive exercise sets the stage for a comprehensive econometric analysis of secondary market price dynamics in ABS markets and the changes of correlation risk in synthetic structured finance transactions – a largely unexplored area of asset pricing. As financial institutions and large corporations administer asset securitization primarily as a premier asset funding and hedging mechanism, joint price dynamics inform both sound risk management and regulatory policy as regards price discovery and systemic risk between different capital market sectors. We are able to ascribe some information benefits to ABS investment based on our findings about the joint dynamics of ABS and equity markets within the empirical scope of our analysis.

Many extensions to his paper are feasible, such as nonlinear Granger causality testing by means of a detailed examination of VAR residuals and the cross-validation of squared errors. Additionally, depending on the availability of credit ratings for all equity names in our samples, the examination of the impact of issuer credit ratings on the empirical relationship of debt and equity prices could help testing Hypothesis 1 more comprehensively. As an econometric improvement, we might need to relax our assumption of non-correlated, zero-mean residuals with unit variance in favor of a transmission mechanism of time-varying innovation through ARCH effects. Lastly, the most challenging proposition of a subsequent study would be an extension of empirical scope by including highly-frequent secondary market data on other ABS markets and/or the inclusion of corresponding bond price information in keeping with the analysis of the three-way interaction of CDS, equity and bond prices.

8 REFERENCES

[31] Although we cannot claim an equivalence relationship between ABS and equity under arbitrage-free conditions due to missing fundamental information about the proximity of ABS to the change of issuer valuation, we note that varying price responses between equity and ABS would allow traders in these markets to appropriate arbitrage gains from price differentials in the short run.

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9 APPENDIX I: RELATIONSHIP BETWEEN BOND, ABS AND EQUITY PRICES

In synthetic CDO and ABS transactions with on-balance sheet reference assets, the intuition behind the empirical relation of securitized debt and equity claims can be assessed based on the valuation of balance sheet identities in the context of the capital structure-based *option pricing theory* (OPT) by Merton (1974).[32] According to Merton' structural model, a firm's outstanding liabilities constitute a bankruptcy level as a "distance to default" threshold. Owners of corporate equity in leveraged firms have the option to default if their firm's asset value (reference asset) declines below the cumulative face value of outstanding debt (strike price) owed to bondholders at maturity. Hence, equity and debt are always positively correlated. Their correlation increases in higher default risk and leverage, which imply a higher probability that the asset value of the firm will drop below the default threshold. Bond and equity prices should also be cointegrated and share an equilibrium price relationship.

Merton's balance sheet approach assumes that the firm's debt consists of a zero-coupon bond with a notional value F and maturity of T periods. The firm's outstanding liabilities constitute a bankruptcy level as a "distance to default", whose threshold value is density of the standard normal for a given probability of default if the firm's asset process is lognormal. This capital structure-based evaluation of contingent claims on firm performance implies that the firm defaults if its asset value is insufficient to meet the amount of debt owed to bondholders at maturity. By definition, the firm's bond price B and equity price E are always positively correlated and can be represented as $B/E = \left(\Phi(d_1) - d\Phi(d_2)\right)^{-1} - 1$, where the firm leverage $d = Fe^{-rT}/V$ is the ratio of the face value of outstanding debt F, discounted by the risk-free rate r, and the asset value of the firm V, with $d_1 = \left(-\log(d) + 1/2\sigma^2 T\right)/\sigma\sqrt{T}$ and $d_2 = d_1 - \sigma\sqrt{T}$ and Φ as the standard normal c.d.f. So prices of equity and bonds move in same direction. The correlation of bond and equity prices increases in the firm's leverage and approaches 0 whenever $B/E \to 0$. Moreover, the proximity of the firm's asset value to the default threshold, which is reflected in the default risk, contributes to a closer association of the valuation of debt and equity on the asset value of firms. Since low-rated firms have an asset value just enough to cover debt obligations, a small deterioration of asset value causes default, with negative price (co-)movement of debt holders and equity holders as residual claimant. Highly-rated firms, in contrast, shed correlation between issued equity and debt claims as even larger deteriorations in asset value would not compromise their ability to repay existing debt. The positive relation between equity and debt also increases in the leverage ratio,

[32] Although the same intuition applies, we acknowledge different economic significance depending on the structural characteristics of ABS.

which induces a higher probability that the asset value of the firm will drop below the default threshold of outstanding debt at the time of maturity.

10 APPENDIX II: TABLES & FIGURES

10.1 Univariate descriptive statistics: sample composition, stationarity, autocorrelation and cointegration

10.1.1 Sample composition

ABS/Equity Sample Composition (cross-sectional)	
total number of equity series (i.e. issuers)	35
org. total number of ABS tranches (ABS transactions)	81 (48)
selected number of ABS tranches (ABS transactions)	68 (42)
rated by one/two/three rating agencies	11/26/30
rated by Moody's/S&P/Fitch	41/44/64
jointly rated by	
Moody's & Fitch	40
S&P & Fitch	42
Moody's & S&P	30
composite rating of ABS tranches	
mean	4.16 (AA-,Aa3)
median	3.00 (AA,Aa2)
mode	1.00 (AAA,Aaa)
ABS tranche size	
mean	≈ Brit. £283,058,168
median	≈ Brit. £240,000,000
remaining maturity of tranches (at sample start date)	
mean/median/mode	26.73/29.16/35.10 yrs.
remaining maturity of tranches (at sample end date)	
mean/median/mode	21.33/23.76/29.70 yrs.
seasoning of tranches (at sample end date)	
mean/median/mode	3.07/2.90/0.20 yrs.

Tab. 1. *Cross-sectional sample descriptives of ABS and equity price series.*

10.1.2 Test of correlation and cointegration

Sample correlation measures								
	mean	*median*	*std. dev.*	*#*	*mean*	*median*	*std. dev.*	*#*
	Panel A: *by rating category*							
	Investment Grade Rating				Non-investment grade rating			
level	-0.1503	**-0.3216**	0.5861	55	0.1367	**0.2976**	0.6069	13
1st diff.	-0.0073	-0.0158	0.1587	55	-0.0376	-0.0085	0.0702	13
	Panel B: *by ABS type*							
	Whole Business				CMBS/RMBS/Other			
level	0.1603	**0.3608**	0.6171	30	-0.3180	**-0.4480**	0.4829	38
1st diff.	0.0086	-0.0088	0.1936	30	-0.0303	-0.0199	0.0925	38
	Panel C: *whole business ABS*							
	Investment Grade Rating				Non-investment grade rating			
level	0.1863	**0.4196**	0.6023	23	0.0750	**-0.2836**	0.7067	7
1st diff.	0.0239	-0.0050	0.2155	23	-0.0416	-0.0476	0.0837	7
	Panel D: *CMBS/RMBS/other ABS*							
	Investment Grade Rating				Non-investment grade rating			
level	-0.0298	**-0.0255**	0.0983	32	0.0778	**0.3175**	0.5336	6
1st diff.	-0.0298	-0.0255	0.0983	32	-0.0329	-0.0024	0.0580	6

Tab. 2. *Pooled correlation measures of matched ABS and equity pairs by cross-sectional variation for two sub-samples of whole business ABS and CMBS/RMBS as ABS price series.*

		No. of cases			**Eigenvalue**		**Trace stat.**	
	#	*not sign.*	*≤ 5%*	*≤ 1%*	*median*	*mean*	*median*	*mean*
		proportional. share (%)					crit. value (5%/1%)	
No. of CE(s)		**Panel A:** *total sample (all ABS-equity pairs)*						
H_0: *None*	68	17	11	40	0.042	0.110	21.980***	27.001***
		25.0%	16.2%	58.8%			(15.41/3.76)	
H_0: *At most 1*	68	44	12	12	0.004	0.012	2.367	3.543
		64.7%	17.7%	17.7%			(20.04/6.65)	
No. of CE(s)		**Panel B:** *whole business ABS*						
H_0: *None*	30	9	8	13	0.042	0.108	18.913***	22.885***
		30.0%	26.7%	43.3%			(15.41/3.76)	
H_0: *At most 1*	30	23	2	5	0.003	0.014	1.204	2.839
		76.7%	6.7%	16.7%			(20.04/6.65)	
No. of CE(s)		**Panel C:** *CMBS/RMBS/other ABS*						
H_0: *None*	38	8	3	27	0.040	0.111	28.116***	30.251***
		21.1%	7.9%	71.1%			(15.41/3.76)	
H_0: *At most 1*	38	21	10	7	0.005	0.011	3.429	4.099
		52.6%	29.0%	18.4%			(20.04/6.65)	

Tab. 3. *Cointegration test of ABS and equity level data: The Johansen test identifies the cointegration relationship (i.e. the existence of cointegration vectors ("CE")) of all matched (68) ABS-equity pairs on a level basis. We also test the cross-sectional variation of cointegration relationships for two sub-samples of whole business ABS and CMBS/RMBS/other ABS as ABS price series. For each panel we count the cases when the null hypothesis of no cointegrating vector cannot ("N.S.") or can be rejected at the 5%(1%) significance level across the entire sample. In the subsequent columns we present median and mean eigenvalues as well as the trace statistic (with critical value at the 5%(**) and the 1%(***) significance level) of all matched ABS-equity pairs.*

10.2 Estimation results of short-term dynamics: Granger causality test (linear)

	Panel A: *all series without cointegration restriction*					**Panel B:** *only cointegrated series*				
	Total Sample									
	sign. level			*no.*	*% expl.*	*sign. level*			*no.*	*% expl.*
Direction of causality	*≤ 10%*	*≤ 5%*	*≤ 1%*			*≤ 10%*	*≤ 5%*	*≤ 1%*		
[ΔB_t] H_1: Equity expl. ABS	10	9	2	68	14.71	8	7	2	51	15.69
[ΔS_t] H_1: ABS expl. equity	17	15	9	68	25.00	14	12	8	51	27.45
Total	*27*	*24*	*11*	*68*	*39.71*	*22*	*19*	*10*	*51*	*43.14*
	Whole Business ABS									
	sign. level			*no.*	*% expl.*	*sign. level*			*no.*	*% expl.*
Direction of causality	*≤ 10%*	*≤ 5%*	*≤ 1%*			*≤ 10%*	*≤ 5%*	*≤ 1%*		
[ΔB_t] H_1: Equity expl. ABS	7	6	2	30	23.33	6	5	2	21	28.57
[ΔS_t] H_1: ABS expl. equity	2	1	-	30	6.67	2	1	-	21	9.52
Total	*9*	*7*	*2*	*30*	*30.00*	*8*	*6*	*2*	*21*	*38.09*
	CMBS/RMBS/other ABS									
	sign. level			*no.*	*% expl.*	*sign. level*			*no.*	*% expl.*
Direction of causality	*≤ 10%*	*≤ 5%*	*≤ 1%*			*≤ 10%*	*≤ 5%*	*≤ 1%*		
[ΔB_t] H_1: Equity expl. ABS	3	3	-	38	7.89	2	2	-	30	6.67
[ΔS_t] H_1: ABS expl. equity	15	14	9	38	39.47	12	11	8	30	40.00
Total	*18*	*17*	*9*	*38*	*47.36*	*14*	*13*	*8*	*30*	*46.67*

Tab. 4. *Granger causality test of ABS-equity pairs and sub-samples at first differences without cointegration restriction (Panel A) and with cointegration restriction (Panel B).*

	Panel C: *only cointegrated series with U.K. issuer of ABS*					Panel D: *only cointegrated series with investment grade ABS (S&P ≥A-)*					Panel E: *only cointegrated series with ABS tranche maturity > 25 yrs.*				
	Total Sample														
	sign. level			*no.*	*% expl.*	*sign. level*			*no.*	*% expl.*	*sign. level*			*no.*	*% expl.*
Direction of causality	*≤ 10%*	*≤ 5%*	*≤ 1%*			*≤ 10%*	*≤ 5%*	*≤ 1 %*			*≤ 10%*	*≤ 5%*	*≤ 1%*		
$[\Delta B_t]$ H_1: Equity expl. ABS	8	7	2	45	15.25	5	5	-	39	12.82	4	4	-	37	8.11
$[\Delta S_t]$ H_1: ABS expl. equity	13	11	7	45	27.12	11	10	7	39	28.21	14	13	7	37	29.73
Total	*21*	*28*	*9*	*45*	*42.37*	*16*	*15*	*7*	*39*	*41.03*	*18*	*17*	*7*	*37*	*37.84*
	Whole Business ABS														
	sign. level			*no.*	*% expl.*	*sign. level*			*no.*	*% expl.*	*sign. level*			*no.*	*% expl.*
Direction of causality	*≤ 10%*	*≤ 5%*	*≤ 1%*			*≤ 10%*	*≤ 5%*	*≤ 1 %*			*≤ 10%*	*≤ 5%*	*≤ 1%*		
$[\Delta B_t]$ H_1: Equity expl. ABS	6	5	-	21	28.57	3	3	-	15	20.00	4	4	-	16	18.75
$[\Delta S_t]$ H_1: ABS expl. equity	2	1	-	21	9.52	2	1	-	15	13.00	2	1	-	16	12.50
Total	*8*	*6*	*-*	*21*	*38.09*	*6*	*5*	*-*	*15*	*33.33*	*6*	*5*	*-*	*16*	*31.25*
	CMBS/RMBS/other ABS														
	sign. level			*no.*	*% expl.*	*sign. level*			*no.*	*% expl.*	*sign. level*			*no.*	*% expl.*
Direction of causality	*≤ 10%*	*≤ 5%*	*≤ 1%*			*≤ 10%*	*≤ 5%*	*≤ 1 %*			*≤ 10%*	*≤ 5%*	*≤ 1%*		
$[\Delta B_t]$ H_1: Equity expl. ABS	2	2	-	24	8.33	2	2	-	24	8.33	-	-	-	21	-
$[\Delta S_t]$ H_1: ABS expl. equity	11	10	7	24	45.83	9	9	6	24	37.50	12	12	7	21	42.86

Total	*13*	*12*	*7*	*24*	*54.16*	*17*	*17*	*9*	*24*	*45.88*	*12*	*12*	*7*	*21*	*42.86*

Tab. 5. *Granger causality test of cointegrated ABS-equity pairs at first differences for the sub-samples of ABS-equity pairs of U.K.-based issuers (Panel C), investment grade rated ABS (Panel D) and ABS of long maturity (> 25 years) (Panel E).*

10.3 Estimation results of long-term consistency: individual error correction and GG-tests of VECM

10.3.1 Analysis of individual error correction coefficients (VECM)

	Panel A: *all cointegrated series*					**Panel B:** *all cointegrated series with whole business ABS*					**Panel C:** *only cointegrated series with CMBS/RMBS/other ABS*				
	Error correction term λ_1 (Equity)														
			no. (%)					no. (%)					no. (%)		
	mean	*median*	*pos.*	*neg.*	#	*mean*	*median*	*pos.*	*neg.*	#	*mean*	*median*	*pos.*	*neg.*	#
λ_1 and λ_2 sign. $\leq$10%	0.739	0.532	75.0%	25.0%	12	0.617	0.648	100.0%	-	5	0.826	0.233	57.1%	42.9%	7
Equity λ_1 sign. $\leq$10%	-6.985	0.001	53.3%	46.7%	15	-0.349	-0.604	50.0%	50.0%	6	-11.409	0.001	55.6%	44.4%	9
ABS λ_2 sign. $\leq$10%	0.096	0.047	58.3%	41.7%	24	-0.048	-0.022	30.0%	70.0%	10	0.199	0.139	78.6%	21.4%	14
λ_1 and λ_2 not sign.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*-1.835*	*0.083*	*60.8%*	*39.2%*	*51*	*0.024*	*0.033*	*52.4%*	*47.6%*	*21*	*-3.137*	*0.139*	*66.7%*	*33.3%*	*30*
	Error correction term λ_2 (ABS)														
			no. (%)					no. (%)					no. (%)		
	mean	*median*	*pos.*	*neg.*	#	*mean*	*median*	*pos.*	*neg.*	#	*mean*	*median*	*pos.*	*neg.*	#
λ_1 and λ_2 sign. $\leq$10%	-0.079	-0.056	-	100.0%	12	-0.092	-0.107	-	100.0%	5	-0.070	-0.055	-	100.0%	7
Equity λ_1 sign. $\leq$10%	-0.042	-0.017	20.0%	80.0%	15	0.022	-0.013	33.3%	66.7%	6	-0.084	-0.017	11.1%	88.9%	9
ABS λ_2 sign. $\leq$10%	-0.090	-0.066	-	100.0%	24	-0.116	-0.056	-	100.0%	10	-0.071	-0.067	-	100.0%	14
λ_1 and λ_2 not sign.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*-0.073*	*-0.057*	*5.9%*	*94.1%*	*51*	*-0.071*	*-0.044*	*9.5%*	*90.5%*	*21*	*-0.075*	*-0.058*	*3.3%*	*96.7%*	*30*

Tab. 6. *Analysis of individual error correction (VECM): The panels show the mean, median and the incidence of significant individual error correction for all ABS-equity pairs with cointegration restriction (Panel A), with whole business ABS (Panel B), and with CMBS/RMBS/Other ABS (Panel C).*

10.4 GG-Tests of error correction coefficients (VECM)

	Panel A: *all series without cointegration restriction*			**Panel B:** *only cointegrated series*			**Panel C:** *only U.K. issuers of ABS and cointegrated series*		
				Total sample					
mod. GG-test (orig. GG-test)	*mean*	*median*	*#*	*mean*	*median*	*#*	*mean*	*median*	*#*
Both λ_1 and λ_2 sign. $\leq$10%	0.597 (0.876)	1.000 (0.905)	14	0.548 (0.960)	1.000 (0.927)	12	0.686 (0.955)	1.000 (0.909)	11
Equity λ_1 sign. $\leq$10%	0.201 (0.997)	0.952 (1.000)	27	0.069 (0.955)	0.897 (1.000)	15	0.094 (0.938)	0.897 (0.965)	11
ABS λ_2 sign. $\leq$10%	0.691 (0.029)	1.000 (0.465)	26	0.713 (-0.145)	1.000 (0.439)	24	0.731 (-0.104)	1.000 (0.449)	23
Both λ_1 and λ_2 not sign.	1.000 (0.806)	1.000 (0.806)	1	-	-	-	-	-	-
Total	*0.482 (0.599)*	*1.000 (0.920)*	*68*	*0.485 (0.438)*	*1.000 (0.870)*	*51*	*0.564 (0.409)*	*1.000 (0.865)*	*45*
				Whole Business ABS					
mod. GG-test (orig. GG-test)	*mean*	*median*	*#*	*mean*	*median*	*#*	*mean*	*median*	*#*
Both λ_1 and λ_2 sign. $\leq$10%	1.000 (0.869)	1.000 (0.868)	6	1.000 (0.867)	1.000 (0.858)	5	1.000 (0.867)	1.000 (0.858)	5
Equity λ_1 sign. $\leq$10%	-0.041 (1.046)	-0.490 (1.003)	11	0.002 (0.995)	0.002 (0.984)	6	0.002 (0.995)	0.002 (0.984)	6
ABS λ_2 sign. $\leq$10%	0.469 (-0.277)	0.487 (-0.026)	12	0.478 (-0.757)	0.487 (-0.377)	10	0.478 (-0.757)	0.487 (-0.377)	10
Both λ_1 and λ_2 not sign.	1.000 (0.806)	1.000 (0.806)	1	-	-	-	-	-	-
Total	*0.406 (0.474)*	*0.925 (0.889)*	*30*	*0.466 (0.131)*	*0.897 (0.840)*	*21*	*0.466 (0.131)*	*0.897 (0.840)*	*21*
				CMBS/RMBS/other ABS					
mod. GG-test (orig. GG-test)	*mean*	*median*	*#*	*mean*	*median*	*#*			
Both λ_1 and λ_2 sign. $\leq$10%	0.295 (0.880)	0.894 (0.978)	8	0.225 (1.025)	1.000 (0.979)	7	0.424 (1.027)	1.000 (0.978)	6
Equity λ_1 sign. $\leq$10%	0.367 (0.964)	1.000 (1.000)	16	0.114 (0.928)	1.000 (1.000)	9	0.205 (0.870)	1.000 (0.948)	5
ABS λ_2 sign. $\leq$10%	0.882 (0.292)	1.000 (0.672)	14	0.882 (0.292)	1.000 (0.672)	14	0.925 (0.398)	1.000 (0.724)	13
Both λ_1 and λ_2 not sign.	-	-	-	-	-	-	-	-	-
Total	*0.542 (0.699)*	*1.000 (0.947)*	*38*	*0.549 (0.654)*	*1.000 (0.653)*	*30*	*0.650 (0.653)*	*1.000 (0.869)*	*24*

Tab. 7. *Aggregate analysis of paired error correction coefficient based on the modified GG-test, $(\lambda_1 - \lambda_2)/(|\lambda_1| + |\lambda_2|)$, and the original GG-test $\lambda_1/(\lambda_1 - \lambda_2)$, of all ABS-equity pairs without cointegration restriction (Panel A), with cointegration restriction (Panel B) and cointegrated ABS-equity pairs with U.K.-based issuers (Panel C).*

	Panel D: *only cointegrated ABS with investment grade rating (S&P ≥A-)*			**Panel E:** *only cointegrated ABS with maturity > 25 yrs.*			**Panel F:** *only cointegrated ABS-equity pairs with positive correlation*		
				Total sample					
mod. GG-test (orig. GG-test)	*mean*	*median*	*#*	*mean*	*median*	*#*	*mean*	*median*	*#*
Both λ_1 and λ_2 sign. ≤10%	0.397 (0.982)	1.000 (0.946)	9	0.397 (0.982)	1.000 (0.946)	9	0.783 (0.938)	1.000 (0.858)	7
Equity λ_1 sign. ≤10%	0.003 (0.986)	0.002 (1.000)	14	-0.074 (0.995)	-0.893 (1.000)	13	0.032 (0.996)	0.053 (0.988)	4
ABS λ_2 sign. ≤10%	0.761 (-0.361)	1.000 (0.465)	12	0.748 (-0.385)	1.000 (0.429)	15	0.745 (-0.473)	1.000 (0.429)	9
Both λ_1 and λ_2 not sign.	-	-	-	-	-	-	-	-	-
Total	*0.364 (0.524)*	*1.000 (0.939)*	*35*	*0.374 (0.433)*	*1.000 (0.909)*	*37*	*0.616 (0.314)*	*1.000 (0.795)*	*20*
				Whole Business ABS					
mod. GG-test (orig. GG-test)	*mean*	*median*	*#*	*mean*	*median*	*#*	*mean*	*median*	*#*
Both λ_1 and λ_2 sign. ≤10%	1.000 (0.880)	1.000 (0.902)	3	1.000 (0.880)	1.000 (0.902)	3	1.000 (0.867)	1.000 (0.858)	5
Equity λ_1 sign. ≤10%	0.002 (0.995)	0.002 (0.984)	6	0.002 (0.995)	0.002 (0.984)	6	0.369 (0.990)	1.000 (0.965)	3
ABS λ_2 sign. ≤10%	0.546 (-1.310)	0.528 (-0.473)	6	0.599 (-1.103)	1.532 (-0.440)	7	0.541 (-1.269)	0.442 (-0.632)	5
Both λ_1 and λ_2 not sign.	-	-	-	-	-	-	-	-	-
Total	*0.419 (0.050)*	*1.000 (0.948)*	*15*	*0.450 (0.055)*	*1.000 (0.948)*	*16*	*0.678 (0.074)*	*1.000 (0.840)*	*13*
				CMBS/RMBS/other ABS					
mod. GG-test (orig. GG-test)	*mean*	*median*	*#*	*mean*	*median*	*#*	*mean*	*median*	*#*
Both λ_1 and λ_2 sign. ≤10%	0.095 (1.034)	0.242 (0.997)	6	0.095 (1.034)	0.242 (0.997)	6	0.095 (0.191)	0.242 (0.484)	2
Equity λ_1 sign. ≤10%	0.004 (0.980)	0.011 (1.000)	8	-0.139 (0.995)	-0.978 (1.000)	7	-0.139 (-0.277)	-0.978 (-1.955)	1
ABS λ_2 sign. ≤10%	0.977 (0.589)	1.000 (0.672)	6	0.879 (0.244)	1.000 (0.672)	8	1.000 (0.522)	1.000 (0.561)	4
Both λ_1 and λ_2 not sign.	-	-	-	-	-	-	-	-	-

Total	*0.323 (0.879)*	*1.000 (0.964)*	*20*	*0.316 (0.879)*	*1.000 (0.964)*	*21*	*0.501 (0.761)*	*1.000 (0.724)*	*7*

Tab. 8. *Aggregate analysis of paired error correction coefficient based on the modified GG-test,* $(\lambda_1 - \lambda_2)/(|\lambda_1| + |\lambda_2|)$*, and the original GG-test* $\lambda_1/(\lambda_1 - \lambda_2)$*, of all cointegrated ABS-equity pairs with investment grade rated ABS (Panel D), long maturity (> 25 years) (Panel E) and positive pairwise correlation on levels (Panel F).*

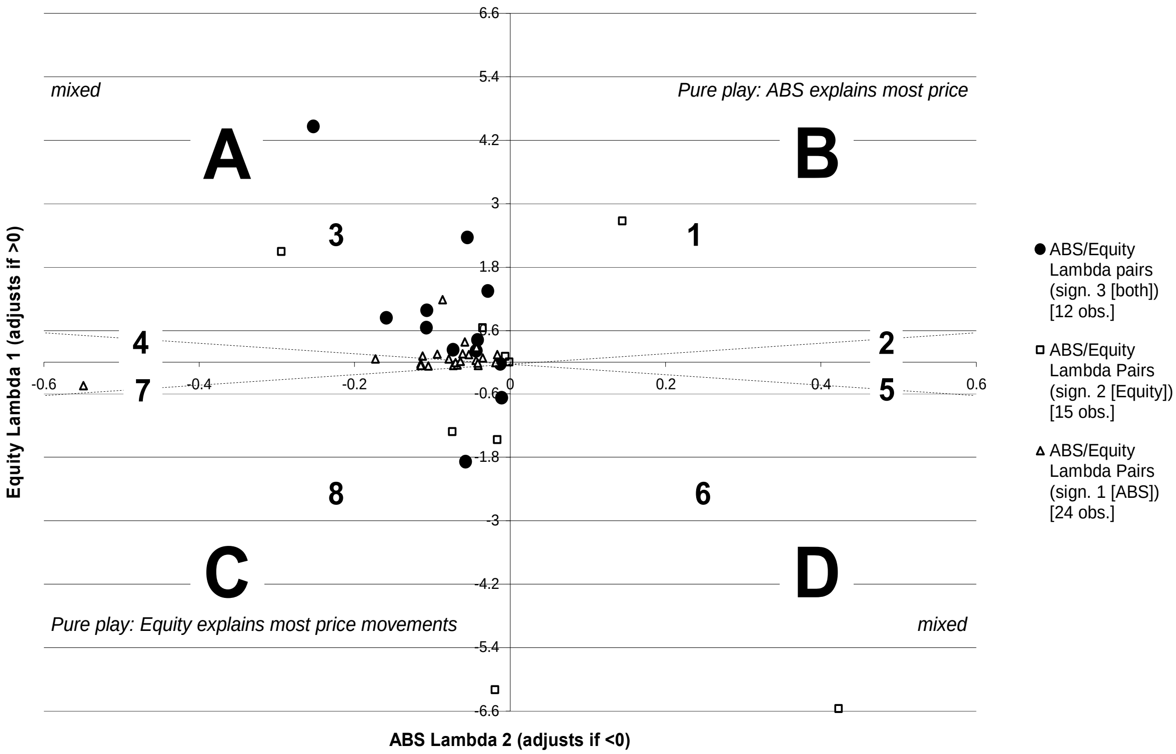

Fig. 3. *Long-term consistency of price dynamics: VECM-based estimation of the error correction term ("equity λ", λ_1, and "ABS λ", λ_2) of all cointegrated ABS and equity prices over the entire sample of matched ABS-equity pairs. The alpha-numerical sector preference (1-8) is geared towards statistically and economically significant price discovery by the ABS market. Observations of error correction coefficients in sectors B and C indicate "pure plays" of dominant price discovery by ABS and equity price information respectively. We also distinguish the statistical importance of error correction on the basis of "significance categories" 1-3, which indicate that both ABS and equity show statistically significant error correction (1), only the equity series shows statistically significant error correction (2) or only the ABS series shows statistically significant error correction (3).*