Safe Asset Carry Trade*

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Abstract

We provide an asset pricing analysis of one of the main categories of near-money or safe assets, the repurchase agreement (repo). Heterogeneity in repo rates allows for a remunerative carry trade. The return on this carry trade, our carry factor, together with a market factor explain the temporal and cross-sectional variation in repo rates within a no-arbitrage framework: While the market factor determines the level of short-term interest rates, the carry factor accounts for the cross-sectional dispersion. Consistent with the safe asset literature, the carry factor reflects heterogeneity in convenience premia and is explained by the safety premium, the liquidity premium, and the opportunity cost of holding money.

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Investors pay a "convenience premium" for the safety and liquidity benefits provided by near-money or safe assets. This convenience premium varies across securities and market conditions. For example, U.S. Treasury securities have a lower yield than otherwise equivalent safe assets, such as investment grade corporate bonds, due to their safety and liquidity attributes (Krishnamurthy and Vissing-Jorgensen, 2012). The convenience premium also varies based on market and economic factors, such as the opportunity cost of holding money (Nagel, 2016) and uncertainty (Moreira and Savov, 2017).

While the temporal and cross-sectional variation in the prices of safe assets is well documented in the literature, our understanding of their asset pricing implications is still very limited. We provide the first systematic asset pricing analysis of one important category of safe assets, the

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repurchase agreement (repo) (Gorton, 2017). We find that heterogeneity in repo rates allows for a remunerative safe asset carry trade. This carry trade involves a long position in "less expensive" (high repo rate) safe assets and a simultaneous short position in their "more expensive" (low repo rate) counterparts. The return on this investment strategy, our carry factor, exhibits time-variation, which points toward time-dependent cross-sectional differences among safe assets. A standard, no-arbitrage model with two risk factors, a *market* factor and a *carry* factor, is able to explain the price of safe assets: While the market factor determines the level of short-term interest rates, the carry factor accounts for their cross-sectional dispersion. From the perspective of the safe asset literature, our carry factor reflects the convenience premium of a portfolio "long" in assets with low safety and liquidity premia and "short" in assets with high safety and liquidity premia. Consistent with the literature, the carry factor is explained by three main factors: the safety premium, the liquidity premium, and the opportunity cost of holding money.

By applying an asset pricing approach to safe assets, our analysis delivers new insights to academics, investors, and policymakers. On the academic side, our work highlights asset pricing implications of the convenience premium variation of safe assets. We show that a no-arbitrage asset pricing model with two state variables, a market factor and a carry factor, matches the temporal and cross-sectional variation in the prices of near-money assets. For investors, the repo market is a source for obtaining funding liquidity or specific assets over short periods. Both practices provide utility to investors but also include risks, and both have become extremely important since the Global Financial Crisis of 2007/2008: The repo market has emerged as the predominant source of funding liquidity, and it has become increasingly relevant for sourcing High Quality Liquid Assets (HQLA), whose supply has been reduced due to unconventional monetary policies, such as Quantitative Easing (e.g., Bank for International Settlements, 2017). For policymakers, repo rates act as a benchmark in financial markets and as a reference rate for the implementation of monetary policy. The growing imbalance between the demand for and supply of safe assets has become increasingly important in recent policy debates about financial globalization and stability (e.g., International Monetary Fund, 2012).

We access a unique and comprehensive data set of European repo transactions to perform our analysis. The European market is particularly well suited for such an analysis for three main reasons. First, with its sheer size of more than EUR 7 trillion in outstanding contracts (ICMA, 2015), the European market is the largest repo market worldwide. Our data set includes all transactions traded on the three main trading platforms, thereby covering more than 70% of the total European repo market. Second, the European repo market represents the ideal laboratory to analyze how convenience premia determine asset prices. On the one hand, the market infrastructure is based on central clearing and anonymous centralized electronic order book platforms (Mancini, Ranaldo, and Wrampelmeyer, 2016), which guarantees homogeneous counterparty credit risk and a fairly efficient price formation. On the other hand, repos are mostly secured by government bonds, which are safe assets per se, carrying different convenience premia because they are issued by different countries and provide different liquidity benefits. Third, by focusing on repo transactions denominated in the same currency, we avoid any currency effects.

To identify the carry factor, we build daily portfolios sorted by the respective repo rates. The collateral can either be a particular asset ("special repo") or any asset from a predefined basket of assets ("general collateral repo"). We form eight portfolios: The first portfolio contains the repos with the lowest repo rate while the last portfolio contains the repos with the highest repo rate. By going long in the last portfolio (via a reverse repurchase agreement) while shorting the first portfolio (via a repurchase agreement), this trading strategy represents a self-financing (cash-neutral) collateral swap. Once the two positions are unwound on the next day, the carry return materializes as the difference between the two repo rates.

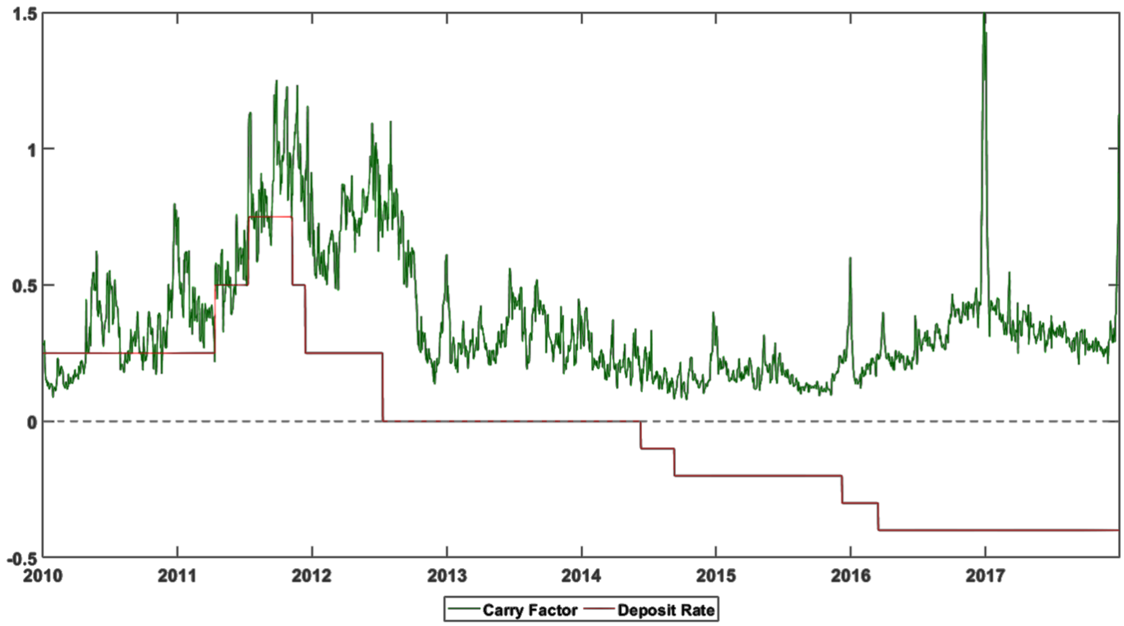


Figure 1: Development of the Safe Asset Carry Return

Figure 1 depicts the development of our carry return net of transaction cost across time. The average annualized carry return amounts to 0.37% with a standard deviation of 0.23%. In line with our safe asset interpretation, the Sharpe ratio is shaped by the denominator and translates into a yearly average of 1.6.[1] The carry return is almost always positive, with the spread to the riskless rate of the European Central Bank's (ECB) deposit facility markedly increasing in the negative interest rate environment. Time-dependent cross-sectional differences are particularly

[1]The Sharpe ratio is defined as the annualized average over the annualized standard deviation.

evident during the European sovereign debt crisis, providing prima facie evidence of heterogeneity in safety and liquidity premia during distressed periods.

To operate the repo leg, the collateral asset (or basket) must already be held in order to be sold, while on the reverse-repo leg, the collateral asset (or basket) is bought and can then be reused. Therefore, the carry return measures the forgone utility of one asset against the received utility of another asset for the time between the purchase and repurchase (i.e., one day), which captures the convenience premium differential between the two assets. Market makers and dealer banks which already hold a large portfolio of government bonds are best positioned to implement this safe asset carry trade. Alternatively, market participants could establish a portfolio of government bonds in order to exploit this carry trade opportunity. We show that the performance of our carry factor remains positive and increases once we account for the bond portfolio return.

The first two principal components of our portfolios explain most of the time-series variation in portfolio returns. The first principal component accounts for about 95% of the common variation and can be interpreted as the *level factor* since all portfolios load equally on it. The second principal component accounts for the remaining 5% of the common variation and can be interpreted as the *slope factor* since the portfolio loadings increase monotonically from negative to positive, from the portfolio containing the repos with the lowest rate to the one containing the repos with the highest rate. The principal component analysis supports the view that the portfolio returns can be matched by covariances with two risk factors. The first is a market factor determining the level of short-term interest rates that captures the opportunity cost of holding money or near-money assets. The second is a carry factor accounting for the cross-sectional dispersion in short-term interest rates as determined by differences in the safety and liquidity premia. We define the market factor to be the average repo rate across the repo market universe and the carry factor to be the high-minus-low carry return. The correlation of the first principal component with our market factor is 0.99, and the correlation of the second principal component with our carry factor is 0.93.

The asset pricing results show that our two risk-factor candidates, the market factor and the carry factor, are able to explain a large share of the price variation of near-money assets. For the empirical analysis, we assume a linear factor model and estimate factor betas and factor prices using two approaches: a two-stage ordinary least squares (OLS) estimation following Fama and MacBeth (1973) and a generalized method of moments (GMM) estimation following Hansen (1982). The time-series regressions confirm our intuition obtained from the principal component analysis. The factor betas for the market factor are essentially all equal to one, while the factor betas for the carry factor increase monotonically from -0.84 for the first portfolio to 0.40 for the last portfolio. As expected, the market factor explains the level of short-term interest rates, while the carry factor accounts for the cross-sectional dispersion in short-term interest rates. The cross-sectional regressions show that the market price of the carry factor is highly statistically significant at a level of 0.40% per annum. The second factor, the market factor, has a slightly negative price consistent with the negative level of short-term interest rates during our sample period. The standard errors on the market factor are large, as it is the carry factor that explains most of the cross-sectional dispersion in short-term interest rates. We perform a number of additional tests, which confirm that our results are robust across sub-sample periods and term types. The carry return is also present if we only consider general collateral repo transactions grouped by country or basket, which supports the idea that our results are not only driven by specialness in the sense of Duffie (1996).

In the remainder of the paper, we shed light on the economic determinants of our carry factor. Through the lens of the safe asset literature[2], the carry factor is a portfolio-based convenience premium determined by three main factors: the safety premium and the liquidity premium, which, in turn, are affected by the opportunity cost of holding money. Our first hypothesis is that the carry return increases in the safety premium. The primary source of asset risk is a loss of fundamental value exposing agents to adverse selection and inducing them to produce private information (e.g., Gorton and Pennacchi, 1990; Gorton and Ordonez, 2014; Dang, Gorton, and Holmström, 2015; Dang et al., 2017). In case of public safe assets, the asset risk relates to the sovereign and relative weaknesses of the fundamentals (Krishnamurthy, He, and Milbradt, 2019). In case of private safe assets, their supply depends on that of the government (Holmstrom and Tirole, 1998). However, financial institutions cannot issue completely default-free debt, as they can be excessively leveraged (Stein, 2012) and exposed to funding risk and worst-case losses in long-term and illiquid investments (Krishnamurthy and Vissing-Jorgensen, 2015). The second hypothesis is that the carry return increases in the liquidity premium. Krishnamurthy and Vissing-Jorgensen (2012) show that the liquidity premium of safe assets rises with their scarcity. Additionally, the financial sector responds to the demand for money-like claims based on monetary policy conditions (Sunderam, 2015). However, financial intermediaries undertake a "fragile liquidity transformation," as the liquidity provision by the private sector disappears when the environment becomes more uncertain (Moreira and Savov, 2017). The third hypothesis is that the carry return increases with the opportunity cost of holding money (Nagel, 2016). The convenience of near-money assets is more valuable when the opportunity cost of holding money is high.

Following the previous literature, we measure risk as the differential in the credit default swap (CDS) prices between the set of countries composing the high- and low-rate carry trade portfolios. Analogously, we measure asset supply as the differential in the debt to GDP ratio between the set of countries composing the high- and low-rate carry trade portfolios. The opportunity cost of holding money are measured via the main Euro-area short-term interest rate benchmark (Eonia). Our main results clearly show that the economic determinants of the convenience yield embedded in our carry factor are (i) the safety premium, (ii) the liquidity premium, and (iii) the opportunity cost of holding money. Taken together, these variables explain a large share of the variability in our carry factor, thereby supporting the safe asset predictions. We perform various tests, experiment

[2]See Gorton (2017) for an excellent literature survey.

with alternative measures, and control for market frictions and arbitrage constraints, for instance, by accounting for the covered interest parity (CIP) basis.

Our analysis contributes to three strands of the literature. First, our analysis contributes to the asset pricing literature by introducing a new focus on short-term interest rates. Prior research has extensively examined asset pricing theories within integrated capital markets. The first string of this literature emerged from the equity and bond markets. Fama and French (1993) document three common risk factors in equity markets (i.e., market, size, and value factor) and two common risk factors in bond markets (i.e., maturity and default factor). More recently, a second string of this literature emerged from the foreign exchange (FX) market. Inspiring our methodology to build the level and slope factors, Lustig, Roussanov, and Verdelhan (2011) identify a market-related dollar risk factor and a carry trade risk factor. Koijen et al. (2018) provide an overview of different carries in equity, fixed income, and option markets.

Second, we contribute to the literature on the dispersion in short-term interest rates. Nagel (2016) analyzes how the opportunity cost of holding money affects the yield spread between three-month general collateral repos and three-month U.S. T-bills. Greenwood, Hanson, and Stein (2015) highlight differences in sovereign yields resulting from the government's choice on debt maturity. They find that short-term U.S. Treasury securities trade at a yield that is lower than that predicted by the interpolated yield curve.[3] A growing body of literature focuses on repo markets and documents cross-sectional dispersion in repo rates in Europe (e.g., Mancini, Ranaldo, and Wrampelmeyer, 2016; Boissel et al., 2017) and the United States (e.g., Bartolini et al., 2011; Copeland, Martin, and Walker, 2014; Krishnamurthy, Nagel, and Orlov, 2014; Gorton and Metrick, 2012; Infante, 2019). We are the first highlighting that heterogeneity in repo rates allows for a remunerative carry trade and explaining it from a safe asset perspective.

Third, we add to the growing literature on safe asset shortages and their macroeconomic and financial stability implications (e.g., Caballero and Krishnamurthy, 2009; Caballero, Farhi, and Gourinchas, 2017; Caballero and Farhi, 2017). We provide empirical support for safe asset theories predicting cross-sectional dispersion in safe assets (e.g., Krishnamurthy and Vissing-Jorgensen, 2012; Stein, 2012; Sunderam, 2015; Caballero, Farhi, and Gourinchas, 2016; Nagel, 2016; Moreira and Savov, 2017; Krishnamurthy, He, and Milbradt, 2019). By taking an asset pricing approach to show that two factors explain the price variation of near-money assets, we also add to the empirical literature on safe assets (e.g., Gorton and Metrick, 2012; Krishnamurthy and Vissing-Jorgensen, 2012; Greenwood and Vayanos, 2014; Krishnamurthy and Vissing-Jorgensen, 2015; Kacperczyk, Perignon, and Vuillemey, 2019).

This paper is laid out as follows: Section 1 documents the carry return in safe assets, Section 2

[3] A vast literature documents dispersion across long-term interest rates; see, for instance, Krishnamurthy and Vissing-Jorgensen (2012) analyzing the spread between AAA-rated corporate bonds and U.S. Treasury securities, Krishnamurthy (2002) investigating the on-the-run / off-the-run phenomenon, and Fleckenstein, Longstaff, and Lustig (2014) comparing real to nominal yields.

shows that this carry factor, in combination with the market factor, is able to explain short-term interest rates, Section 3 relates the existence of the carry factor to the different drivers of safe asset determination, and Section 4 concludes the paper.

1 Carry Factor

To introduce our carry factor, we first explain the main characteristics of the repo contract by focusing on the European repo market, which essentially represents a safe asset investment environment.

1.1 Repo Market

In the repo market, two counterparts exchange cash for collateral (first leg) for a predefined time period with a fixed repurchase obligation (second leg). The asset being used as a collateral can be a particular asset ("special repo") or any asset from a predefined basket of assets ("general collateral repo"). Repurchase agreements are a form of short-term borrowing, as collateral is typically sold on an overnight basis.[4] In the European setting, the most common term types are Overnight (ON), Tomorrow-Next (TN), and Spot-Next (SN), with the purchase date being tonight, tomorrow, or the day after tomorrow, respectively, and the repurchase date one day thereafter. Haircuts are applied based on the asset being used as collateral, thus impacting the convenience and fungibility an asset carries. A repurchase agreement is in essence a very short-term loan (over-)collateralized by sovereign bonds. All transactions are conducted via a central counterparty (CCP), which provides for the homogenization of risk and a high degree of information insensitivity (in the sense of, e.g., Dang, Gorton, and Holmström, 2015 and Gorton, 2017). This short-term, secured, and anonymous trading nature characterizes the European repo market as the stereotype safe asset investment environment.

We analyze the European repo market, which is the largest repo market in the world, with more than EUR 7 trillion in outstanding contracts (ICMA, 2015). Its infrastructure is based on three main features: First, it mostly operates through central clearing houses, which apply homogeneous collateral and (credit) risk policies to CCP members and market participants. For instance, CCPs pre-establish common rules in terms of initial margins and margin variations. Second, it is an interbank market in which different types of banks trade anonymously via centralized electronic order book platforms, thereby clustering liquidity and providing pre- and post-trade transparency. Third, it features a large variety of eligible collateral assets. The vast majority is composed of government bonds, which are by themselves an important category of safe assets. Thus, the repo price variation comes directly from the repo market and indirectly from collateral assets.[5]

[4] In our data set, about 97% of the transactions are on an overnight basis.

[5] More detailed information about the European repo market infrastructure can be found in various publications

Our analysis features transaction-level data from the beginning of 2010 to the end of 2017 from the three major trading platforms: BrokerTec, MTS, and Eurex. These three trading venues account for more than 70% of the total European repo market. From the original data set, we exclude repos in currencies other than Euro to eliminate any currency-related risk. We also exclude repos with floating rates, repos of term-type "open," repos of type "PTF,"[6] and repos that are not cleared via a CCP. The end of quarter and end of ECB maintenance periods have also been removed.[7] In addition, we exclude less liquid repos, which are traded infrequently.[8] Our final data set features a cross-section of 1018 repos, all of which are one-day tenors to avoid term premia and maturity effects. Regarding the tenor, 75, 919, and 886 types of repos are included in the ON, TN, and SN market segments, respectively. For all transactions in our data, we compute the daily volume-weighted average repo rate per term type as well as an average across the three term types based on the trade date. The main part of our analysis focuses on the average rate, whereas Section 2 also details term-specific results. We compute transaction cost as the difference in repo rates between borrower-initiated and lender-initiated trades. Borrower-initiated trades refer to the counterparty borrowing cash in the repo market as the aggressor (i.e., "ask" rate), whereas lender-initiated trades refer to the counterparty lending cash in the repo market as the aggressor (i.e., "bid" rate). We compute transaction cost for each repo type (i.e., special and general collateral repo) separately.

Figure 2 shows the development of the General Collateral (GC) repo rate for the four largest countries in our data set (i.e., Germany, France, Italy, and Spain) in relation to the ECB's deposit and marginal lending facility rate, the difference of which is often referred to as the ECB corridor[9]: The repo rates for Germany and France are depicted in green shades, while those for Italy and Spain are depicted in blue shades; the dashed red lines represent the ECB corridor. The repo rates for Germany and France as well as the repo rates for Italy and Spain co-move across time, with cross-sectional differences between the two pairs of countries being time-dependent. Across time, repo rates for the safest countries (Germany and France) are lower than those for less safe countries (Italy and Spain). The spread between the two pairs of countries increased during the European sovereign debt crisis pointing to safety attributes. Since 2016, German and French repo rates have fallen below the ECB's rate on the deposit facility, while Italian and Spanish repo rates have stayed

of the ECB (e.g., European Central Bank, 2015; Mancini, Ranaldo, and Wrampelmeyer, 2016; Nyborg, 2016; Bank for International Settlements, 2017).

[6] Bilaterally pre-arranged transactions reported to the CCP.

[7] Repo rates vary much more at the end of the quarter and at the end of the maintenance period. To be conservative, we excluded these periods that boost the performance of the carry factor.

[8] To be included in our analysis, a repo type needs to be traded on at least 200 trading days (i.e., one-year of data) and needs to be traded at least once a week, on average.

[9] The deposit facility allows for overnight deposits with the ECB, while the marginal lending facility provides overnight central bank liquidity against the presentation of sufficient eligible assets. The rate on the deposit facility and the rate on the marginal lending facility define the corridor for the overnight interest rate at which banks lend to each other.

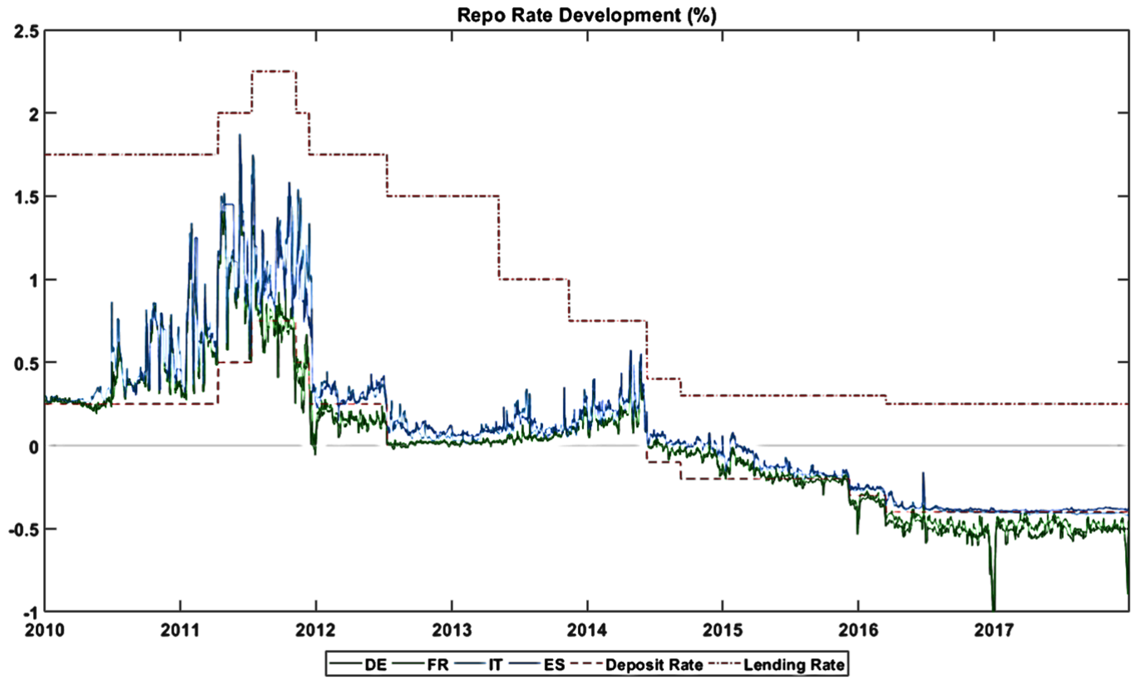


Figure 2: GC Repo Rate Development

at the level of the deposit facility. These developments are eye-catching, as they show (i) time-varying divergent patterns across repos and (ii) the banks' willingness to accept lower overnight interest to exchange cash for collateral in the repo market instead of depositing the money at the ECB. A possible explanation for the first pattern refers to differences in the safety premia, while a possible explanation for the second pattern involves some assets offering liquidity benefits larger than those provided by central bank reserves. All these developments call for an in-depth analysis of heterogeneity in the convenience premia, as we present in the remaining part of this paper.

1.2 Safe Asset Portfolios

To build portfolios of safe assets, we consider the entire repo market universe, including general collateral and special repos. At the end of each trading day t, we allocate repos in the sample into eight portfolios based on the repo rate observed during that day: The first portfolio contains the repos with the lowest repo rate during the preceding day, while the last portfolio contains the repos with the highest repo rate during the preceding day. Portfolios are re-balanced daily. For the purpose of computing portfolio returns net of transaction cost, we assume that investors short all the repos in the first portfolio while going long in all other repos. In practice, this trading strategy represents a self-financing (cash-neutral) collateral swap. Table 1 provides an overview of the properties of the eight repo portfolios.

Table 1: Portfolio Return (%)

Portfolio	**1** *short*	**2** *long*	**3** *long*	**4** *long*	**5** *long*	**6** *long*	**7** *long*	**8** *long*
Gross Return	0.35	-0.09	-0.04	-0.02	0.00	0.03	0.06	0.10
Net Return	0.29	-0.12	-0.06	-0.04	-0.02	0.01	0.05	0.08
Standard Deviation (net)	0.37	0.40	0.41	0.40	0.40	0.40	0.40	0.42
Sharpe Ratio (net)	0.78	-0.29	-0.15	-0.09	-0.04	0.03	0.12	0.20
High-minus-Low	-	0.17	0.23	0.25	0.27	0.30	0.34	0.37

Data refer to average rate across term types ON, TN, and SN.
The Sharpe ratio is defined as the annualized average over the annualized standard deviation.

For each portfolio n, we report the average returns gross and net of transaction cost, the standard deviation and Sharpe ratio of the net returns, as well as the return on the high-minus-low investment strategy, which shorts portfolio n=1 while going long in portfolios n=2, 3,...,8. To adjust for transaction cost, we assume a borrower-initiated trade for portfolio n=1 (i.e., "ask" rate to borrow money) and lender-initiated trades for portfolios n=2, 3,...,8 (i.e., "bid" rate to lend money).[10] The average annualized gross return increases monotonically from -0.35% for the repos in the first portfolio to 0.10% for the repos in the last portfolio. Similarly, the average annualized return on the high-minus-low investment strategy increases monotonically from 0.17%, considering the second portfolio, to 0.37%, considering the last portfolio. Investors benefit from the negative rates on the repos in the first portfolio as well as from the positive rates on the repos in the last portfolio. The standard deviation of the annualized returns is comparable across the eight portfolios at a level of about 0.40%. To assess the importance of specific asset characteristics (e.g., geographical origins), we analyze the composition of the long and short portfolios and conduct sub-sampling analyses by focusing only on general collateral repos. Table 2 shows the average fraction that each country's collateral contributes to each portfolio n=1, 2,...,8. As expected, the first portfolio predominantly consists of countries associated with a strong and resilient economy as well as political stability (e.g., Germany), whereas the last portfolio predominantly consists of countries associated with

[10] Since we compute a volume-weighted repo rate across borrower- and lender-initiated trades, we add half the borrower-lender spread to the average rate for portfolio 1 while we subtract half the borrower-lender spread from the average rate for portfolios n=2, 3,...,8.

weaker, more vulnerable economies and political uncertainty (e.g., Italy). Notably, countries like Spain or Portugal have nearly even fractions of their collateral contributing to portfolios 1 and 8, respectively. A detailed inspection of the country composition by portfolio and year indicates some persistence but also some changes over time (see Appendix A.1).

Table 2: Portfolio Constituents

Portfolio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Austria	3.5%	5.3%	7.5%	11.9%	12.3%	5.9%	1.8%	0.9%
Belgium	11.3%	11.7%	11.8%	14.4%	21.5%	10.6%	2.8%	1.2%
Germany	31.6%	36.5%	37.6%	33.4%	20.7%	8.3%	2.8%	2.5%
Spain	15.4%	10.6%	6.9%	5.8%	9.0%	18.6%	13.8%	15.2%
EU	1.3%	0.7%	0.3%	0.2%	0.4%	2.4%	2.4%	4.2%
Finland	3.5%	4.9%	6.3%	7.4%	6.7%	3.2%	1.1%	0.7%
France	0.0%	0.1%	0.1%	0.3%	1.1%	1.8%	1.0%	1.1%
Ireland	7.3%	3.0%	1.8%	1.5%	2.1%	3.2%	2.5%	6.6%
Italy	10.7%	12.6%	11.0%	9.9%	14.9%	38.0%	67.3%	59.0%
Netherlands	5.4%	10.6%	14.3%	13.4%	8.7%	4.1%	1.3%	0.6%
Portugal	10.2%	4.0%	2.3%	1.8%	2.6%	4.0%	3.1%	7.9%

The number of portfolio constituents changes across time.

1.3 High-minus-Low

The portfolio results provide the motivation for our carry trade investment strategy. The schematic view of the carry trade approach is illustrated in Figure 3. By going long in the last portfolio (via a reverse repurchase agreement) while shorting the first (via a repurchase agreement), we create a seemingly riskless investment with zero net exposure. Our carry trade position represents a cash-neutral collateral swap. Once the two positions are unwound on the next day, the carry return materializes as the difference between the two repo rates. The carry return therefore captures the initial cost and the forgone utility (opportunity cost) of one asset (or basket) against the utility of receiving and reusing another asset (or basket) for the time between the purchase and repurchase (i.e., one day). Within the context of the safe asset literature, the carry return captures the convenience premium differential between the assets in the two portfolios.

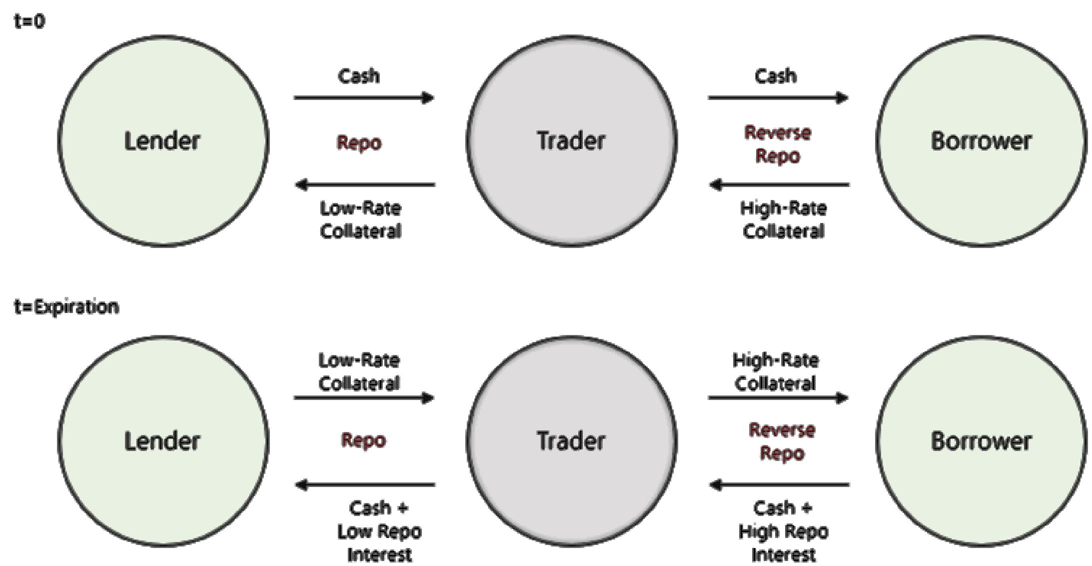


Figure 3: Carry Trade

The development of the carry return across time is depicted in Figure 1. The average annualized carry return is 0.37%, with an annualized standard deviation of 0.23%. Cross-sectional differences between safe assets are time-dependent. We observe the highest annualized returns during the European sovereign debt crisis in 2011 and 2012 (0.69% and 0.63%, respectively). We also observe an increase in the carry return to about 0.35% in 2017 during the period of unconventional monetary policy. The standard deviation of the carry return is lower than the individual standard deviations of each portfolio due to a positive correlation among portfolio returns. In line with our safe asset interpretation, the Sharpe ratio is characterized by two main systematic patterns: a relatively small but constantly positive return and very low risk. Jointly, these translate into a yearly average of 1.6. At the end of each year (in particular at the end of 2016 and 2017), we observe window dressing effects, which are reflected in the year-end spikes of our carry return. Detailed summary statistics can be found in Table 3.

Table 3: Summary Statistics (%)

Mean	0.37	Percentile	
Median	0.30	1%	0.11
Min	0.08	5%	0.13
Max	1.90	25%	0.21
St.Dev.	0.23		
Skewenes	1.54	75%	0.44
Kurtosis	5.53	95%	0.87
AC 1	0.97	99%	1.11

The Dickey and Fuller (1979) and Phillips and Perron (1988) test provide evidence that the null hypothesis of a unit root can be rejected. From an economic perspective, stationarity is the natural result of the tight connection of repo rates with the monetary policy target rate.[11] The existence of the carry factor remains unaffected by an increase in the number of portfolio constituents in the short and long leg to 25% or 50% of the entire repo market universe, with the carry return decreasing in the number of portfolio constituents. A summary of the annual carry returns for different portfolio sizes is depicted in Table A2.1 in Appendix A.2. Our results are robust across all three repo market segments (i.e., ON, TN, and SN; see Appendix A.2). The carry factor is also present if we consider special or general collateral repo transactions separately (see Appendices A.3 and A.4).

The repo leg requires that the collateral asset is held before entering the borrowing position.

[11]The carry trade could be implemented relative to the ECB's deposit facility rate, and since private repo market rates are co-integrated with the ECB's target rate, this would provide stationarity to our carry factor.

The reverse-repo leg implies that the collateral asset is bought and can then be reused by the lender. In case of a special repo, it can be costly and difficult to obtain a specific security subject to exceptional demand. The security might be valued more than the cash position, and the borrower (lender) might demand (supply) cash in exchange for the collateral at relatively "cheap" rates. The likelihood to hold or easily obtain a given security depends on the bank's business model, size, and characteristics. For instance, dealer banks hold large portfolios including government securities by acting as a market maker and by participating in government auctions. Similarly, the CCP itself holds large portfolios of government securities due to its role as a central counterparty. These institutions are naturally best positioned to implement this carry trade.

Alternatively, market participants could establish a portfolio of government bonds, for which we consider a dynamic buy-and-hold and a net buy-and-sell approach. In the dynamic buy-and-hold approach, the hypothetical carry trader adds to his portfolio the securities needed as collateral to establish the respective low repo-rate positions. After purchase, the bonds remain in his portfolio until expiration, i.e., they can be re-used as collateral if part of the low repo-rate portfolio at any future point in time.[12] This dynamic buy-and-hold strategy implies low transaction costs on the bond side and eliminates daily exposure to bond price movements. In the net buy-and-sell approach, the carry trader is exposed to price changes of the securities used as collateral. His position is positively exposed to price changes of the securities pledged on the repo side and negatively exposed to price changes of the securities obtained on the reverse repo side for the term of the repo. The net buy-and-sell strategy relates the carry return to the net value changes of the pledgable assets. In both approaches, we account for coupon returns[13] and funding cost. Since the bond market is characterized by buy-and-hold investors, we only consider transaction cost in the dynamic buy-and-hold approach. Table A5.1 provides an overview of the return properties of the two approaches using actual, intra-day high-frequency quotes from the MTS Cash Market, the largest inter-dealer trading platform in the European area. While the dynamic buy-and-hold approach provides for stable income, the net buy-and-sell approach features higher bond returns that show a development consistent with our safe asset carry factor. Overall, the bond portfolio analysis highlights that the performance of our carry factor remains positive and even increases after accounting for the bond portfolio return.

[12]Part of the portfolio consists of securities which have not yet matured at the end of our sample period.

[13]Since the owner of a government bond remains the ultimate beneficiary even if the security is pledged as collateral on the repo side, we add the coupon return on the low repo-rate position.

2 Common Factors

This section shows that the sizable returns described in the previous section can be matched by covariances with two risk factors: a market factor, which determines the level of short-term interest rates, and a carry factor, which determines the cross-sectional dispersion in short-term interest rates.

2.1 Principal Component Analysis

Factor pricing models predict that average returns of assets can be explained by their exposure to risk factors for which an investor demands a factor premium as compensation. We motivate our asset pricing analysis by a principal component analysis of our portfolio returns to demonstrate that the development of short-term interest rates can be attributed to the exposure to two factors. Table 4 reports the portfolio loadings on the eight principal components as well as the share of the total variance explained by each principal component.[14]

Table 4: Principal Component Analysis

	PCA 1	**PCA 2**	**PCA 3**	**PCA 4**	**PCA 5**	**PCA 6**	**PCA 7**	**PCA 8**
Portfolio 1	0.28	-0.89	0.36	0.03	0.04	-0.01	0.00	-0.02
Portfolio 2	0.36	-0.12	-0.47	-0.66	-0.38	-0.15	-0.15	0.09
Portfolio 3	0.37	-0.02	-0.40	-0.01	0.50	0.34	0.59	0.02
Portfolio 4	0.36	0.03	-0.30	0.35	0.31	0.07	-0.72	-0.18
Portfolio 5	0.36	0.07	-0.14	0.52	-0.31	-0.62	0.31	-0.06
Portfolio 6	0.36	0.16	0.19	0.23	-0.39	0.48	-0.06	0.61
Portfolio 7	0.36	0.26	0.35	-0.13	-0.25	0.29	0.08	-0.72
Portfolio 8	0.37	0.32	0.48	-0.31	0.45	-0.40	-0.06	0.26
% Variance	94.97%	4.26%	0.57%	0.10%	0.04%	0.03%	0.02%	0.02%

The first principal component accounts for about 95% of the common variation in portfolio returns and can be interpreted as the *level factor* since all portfolios load equally on it. The second principal component accounts for the remaining 5% of the common variation and can be interpreted as the *slope factor* since the portfolio loadings increase monotonically from -0.89 for the portfolio containing the repos with the lowest rate to 0.32 for the portfolio containing the repos

[14]The detailed results of the principal component analysis per term type can be found in Appendix A.6.

with the highest rate. It makes sense that the largest part of the common variation in short-term interest rates is explained by the *level factor* for three reasons: First, all repo rates have a common driver, which is monetary policy. Second, in general, repos are less affected by risk and term premia, especially if they benefit from a safe market environment, as in our case. Third, repo rates are relatively sticky. Still, as portfolio returns increase monotonically from the first to the last portfolio, we expect the *slope factor* to be the most plausible candidate to account for the cross-sectional dispersion in short-term interest rates.

We build two risk factors to mimic the explanatory power of the first two principal components: a market factor relating to the fist principal component and a high-minus-low carry factor relating to the second principal component. We define the market factor to be the average repo rate across the repo market universe that represents the average borrowing cost in the repo market[15] and the carry factor to be the high-minus-low carry return that represents the cross-sectional dispersion in repo rates. We compute both factors net of transaction cost. The correlation of the first principal component with our market factor is 0.99, while the correlation of the second principal component with our carry factor is 0.93. Based on these results, we motivate our choice of the market factor and the carry factor as the two risk factor candidates in a linear asset pricing model.

2.2 Methodology

As we want to understand whether our two risk factor candidates are able to explain short-term interest rates, we employ two common asset pricing estimation techniques: a two-stage OLS estimation following Fama and MacBeth (1973) and a GMM estimation following Hansen (1982).

Fama & MacBeth, 1973

In line with the approach introduced by Fama and MacBeth (1973), we follow the "classical" two-stage estimation procedure:

$$R_{n,t} = \alpha_n + \beta_n^{Market} \cdot f_t^{Market} + \beta_n^{HML} \cdot f_t^{HML} + \epsilon_{n,t} \tag{1}$$

$$R_n = \beta_n^{Market} \cdot \lambda^{Market} + \beta_n^{HML} \cdot \lambda^{HML} + \zeta_n \tag{2}$$

In the time-series regression 1, we determine the portfolios' betas, while in the cross-sectional regression 2, we determine the risk premia for the market and the carry factor. In the estimation, n refers to the respective portfolio $n \in [1, .., 8]$. Thus, β_n^{Market} denotes portfolio n's sensitivity to the market factor, β_n^{HML} denotes portfolio n's sensitivity to the carry factor, and λ^{Market} and λ^{HML} represent the respective factor premia. We do not include a constant in the cross-sectional

[15]Our methodology for computing the market factor follows the Standards of the European Money Market Institute (EMMI). The market factor is computed as the volume-weighted average repo rate across the different term types ON, TN, and SN based on the entire universe of GC and special repos, which are included in our empirical analysis.

regression since, from an econometric perspective, the market factor serves as a constant, whereas from an economic perspective, the repo market itself represents a riskless investment. We account for autocorrelation and heteroscedasticity in the error terms in both regressions via the Newey and West (1987) estimator of the covariance matrix.

Hansen, 1982

In line with the GMM approach introduced by Hansen (1982), we consider a linear asset pricing model in which the expected return is equal to the factor premia times the respective betas of each portfolio:

$$E[R_n] = \beta_n^{Market} \cdot \lambda^{Market} + \beta_n^{HML} \cdot \lambda^{HML} \tag{3}$$

Following Cochrane (2009), and by referring to the respective factor $k \in [Market, HML]$, we account for the three moment conditions illustrated in Equation 4.

$$\begin{bmatrix} E(R_{n,t} - \alpha_n - \beta_n^k \cdot f_t^k) \\ E[(R_{n,t} - \alpha_n - \beta_n^k \cdot f_t^k) * f_t^k] \\ E(R_n - \beta_n^k \cdot \lambda^k) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \tag{4}$$

The first two conditions require the error terms of the time-series regression $\epsilon_{n,t}$ to be estimated such that $E(\epsilon_{n,t}) = 0$ and $Cov(\epsilon_{n,t}, \mathbf{f_t^k}) = 0$. The third condition relates to the cross-sectional regression and requires the cross-sectional error term ζ_n to be estimated such that $E(\zeta_n) = 0$. For the estimation, we translate Equation 4 into the following moment conditions:

$$R_{n,t} - \alpha_n - \beta_n^{Market} \cdot f_t^{Market} - \beta_n^{HML} \cdot f_t^{HML} = 0 \tag{5}$$

$$(R_{n,t} - \alpha_n - \beta_n^{Market} \cdot f_t^{Market} - \beta_n^{HML} \cdot f_t^{HML}) \cdot f_t^{Market} = 0 \tag{6}$$

$$(R_{n,t} - \alpha_n - \beta_n^{Market} \cdot f_t^{Market} - \beta_n^{HML} \cdot f_t^{HML}) \cdot f_t^{HML} = 0 \tag{7}$$

$$R_n - \beta_n^{Market} \cdot \lambda^{Market} - \beta_n^{HML} \cdot \lambda^{HML} = 0 \tag{8}$$

Equations 5 and 8 require the error terms of the time-series and cross-sectional regressions to be zero in expectation, and Equations 6 and 7 require the covariances of the error terms of the time-series regressions with the respective factors to be zero in expectation. For $n \in [1, .., 8]$, we derive 32 conditions that must be accounted for in the GMM estimation. Similar to the Fama and MacBeth

(1973) approach, we employ the Newey and West (1987) estimator of the covariance matrix.

2.3 Results

The results of our asset pricing estimations are depicted in Tables 5-7: Tables 5 and 6 report estimates of the factor loadings for the eight portfolios obtained via the FMB and GMM approaches[16], while Table 7 compares estimates of the two risk premia obtained using both approaches.

Table 5: First Stage FMB - Factor Loadings

Portfolio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
α	-0.02	0.00	0.02*	0.03***	0.03***	0.01	0.01	0.01
	(-1.53)	(-0.17)	(1.84)	(3.68)	(4.04)	(1.46)	(1.00)	(1.32)
β^{Market}	0.98***	1.05***	1.04***	1.03***	1.00***	0.98***	0.97***	0.98***
	(87.75)	(54.28)	(93.65)	(176.48)	(143.46)	(81.20)	(92.45)	(100.65)
β^{HML}	-0.84***	-0.08*	0.02	0.07**	0.11***	0.22***	0.32***	0.40***
	(-18.32)	(-1.74)	(0.68)	(2.67)	(5.45)	(8.70)	(11.89)	(11.35)
N	2,049	2,049	2,049	2,049	2,049	2,049	2,049	2,049
adj. R^2	97.30%	98.72%	99.18%	99.29%	99.39%	99.51%	99.30%	98.98%

t statistics in parentheses.
Error-terms are adjusted according to Newey and West (1987).
Optimal number of lags are chosen using the Newey and West Bartlett kernel.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Time-series regressions

Table 5 reports the constants (α_n) and the slope coefficients (β_n^k) of the FMB time-series regressions of each portfolio's return on a constant, the market factor, and the carry factor. The slope coefficients for the market factor are essentially all equal to one for each portfolio, which confirms our expectation that the market factor only explains the level of short-term interest rates. All estimates are highly statistically significant. In contrast, the slope coefficients for the carry factor increase monotonically from -0.84 for the first portfolio to 0.40 for the last portfolio. The first

[16]The detailed estimates of the factor loadings per term type can be found in Appendices A.7 and A.8.

Table 6: First Stage GMM - Factor Loadings

Portfolio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
α	-0.01	0.02***	0.02***	0.02***	0.02***	0.02**	0.02***	0.02***
	(-1.45)	(4.25)	(5.13)	(6.89)	(7.08)	(2.38)	(6.53)	(5.91)
β^{Market}	0.97***	1.06***	1.05***	1.03***	1.00***	0.98***	0.98***	0.99***
	(81.32)	(89.20)	(120.23)	(169.88)	(227.14)	(81.38)	(87.01)	(85.60)
β^{HML}	-0.89***	-0.11***	0.03***	0.09***	0.13***	0.20***	0.28***	0.37***
	(-41.53)	(-11.61)	(3.30)	(8.63)	(12.00)	(9.69)	(28.65)	(30.58)

t statistics in parentheses.

Error-terms are adjusted according to Newey and West (1987).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Second Stage - Risk Premium

	WOTerm		ON		TN		SN	
	FMB	GMM	FMB	GMM	FMB	GMM	FMB	GMM
λ^{Market}	-0.07	-0.07	-0.10*	-0.12**	-0.10**	-0.10**	-0.06	-0.07
	(-1.41)	(-1.64)	(-1.72)	(-2.47)	(-1.98)	(-2.33)	(-1.00)	(-1.52)
λ^{HML}	0.40***	0.39***	0.90***	0.85***	0.39***	0.39***	0.41***	0.42***
	(13.28)	(15.94)	(9.48)	(7.19)	(13.23)	(16.39)	(12.10)	(14.88)
N	16,392	16,392	14,960	14,960	14,960	14,960	14,960	14,960
$TimePeriods$	2,049	2,049	1,870	1,870	1,870	1,870	1,870	1,870
adj. R^2	98.15%	97.73%	87.99%	78.35%	98.06%	95.65%	98.28%	98.42%
χ^2	-	28.59%	-	1.22%	-	49.04%	-	44.13%

t statistics in parentheses.

Error-terms are adjusted according to Newey and West (1987).

Optimal number of lags are chosen using the Newey and West Bartlett kernel.

P-values of χ^2 tests on pricing errors are reported in percentage points.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

two portfolios have betas that are negative and significantly different from zero, while the last five portfolios have betas that are positive and significantly different from zero. Clearly, the first-stage regression results suggest that the carry factor is responsible for explaining the dispersion in short-term interest rates. The adjusted R^2s are relatively high, consistent with the safety attributes of the repo market.[17] We account for autocorrelation and heteroscedasticity in the error terms via the Newey and West (1987) estimator using the Barlett kernel. Table 6 reports the constants (α_n) and the slope coefficients (β_n^k) obtained via the GMM estimation. The GMM results depicted in Tables 6 and 7 go hand in hand, as they are estimated together as part of a single, overidentified estimation. Additional results, including Hansen's J-Test of the overidentifying restrictions, are reported as part of the cross-sectional regressions. Overall, the GMM estimates of the factor loadings are robust and consistent with the results obtained in the first-stage FMB regressions.

Cross-sectional regressions

Table 7 reports the estimates of the risk premia for the market factor and the carry factor obtained using the FMB and GMM approaches. So far, we have introduced the results based on the average repo rate across the term types ON, TN, and SN ("WOTerm"). In Table 7, we also add the results per each term type to highlight differences between the funding-related trading that predominantly takes place in the ON and TN repo market segment and the security-driven trading that is more common in the TN and SN repo market segment. The first two columns of Table 7 show the results relating to the average repo rate across term types. We obtain very similar and consistent results using the FMB and GMM approaches. The market price of the carry factor is highly statistically significant at a level of 0.40% per annum. This means that a portfolio with a sensitivity of one to the carry factor earns a premium of 0.40% per annum. The price is consistent with the average return of the carry factor and thus fulfills the no-arbitrage condition. The market factor has a slightly negative price, consistent with the negative level of short-term interest rates during our sample period. The standard errors on the market factor are large, as it is the carry factor that explains most of the cross-sectional dispersion in short-term interest rates. As all portfolios have a beta close to one with respect to the market factor, the market factor essentially serves as a constant in the cross-sectional regression. For the GMM estimation, Hansen's J-Test of the overidentifying restrictions shows that the null hypothesis that the pricing errors are zero cannot be rejected. The adjusted R^2s of the FMB and GMM regressions prove that most of the development in short-term repo rates can be attributed to the market and carry factors within a linear asset pricing framework.

Columns three to eight in Table 7 extend our analysis by introducing the regression results per each term type. Market participants predominantly trade in the ON and (to a lesser degree)

[17] Koijen et al. (2018), for example, document an R^2 of 89% when considering fixed income carries in bond markets.

TN repo market segments for funding-related purposes, while market participants in the SN repo market segment predominantly trade to obtain a specific collateral. It therefore makes intuitively sense that the market factor that reflects the average borrowing cost in the repo market provides some statistically significant explanatory power in the ON and TN repo market segments. The cross-section in the ON repo market segment is smaller, which explains the low p-value on Hansen's J-Test, as idiosyncratic developments are more difficult to systematically illustrate within a linear factor pricing framework. Overall, our results confirm the notion that a standard, no-arbitrage model with two risk factors, a market factor and a carry factor, is able to explain the price of safe assets: The market factor determines the level of short-term interest rates, while the carry factor accounts for the cross-sectional dispersion in short-term interest rates.

3 Economic Interpretation

We have documented that heterogeneity in one of the world's most secure markets, the repo market, allows for a remunerative carry trade. From the perspective of the safe asset literature, safe assets are imperfect substitutes (Sunderam, 2015), and each of them carries a different convenience yield determined by its safety premium and liquidity benefit, which, in turn, are influenced by the opportunity cost of holding money. Our carry factor thus reflects a portfolio-based convenience premium differential; that is, the spread between repos carrying the highest and lowest convenience. We therefore conduct a time-series regression analysis to assess whether (i) the safety premium, (ii) the liquidity premium, and (iii) the opportunity cost of holding money are able to explain our carry factor.

The first hypothesis to test is whether the carry return increases in the safety premium. The primary source of asset risk stems from the fragility of the fundamental asset value. By holding truly safe assets, economic agents have no reason to produce private information about them and are not exposed to adverse selection. Hence, these assets are "information insensitive" (e.g., Gorton and Pennacchi, 1990; Gorton and Ordonez, 2014; Dang, Gorton, and Holmström, 2015; Dang et al., 2017). When issued by the public sector, a government can back its borrowing with taxation (Krishnamurthy and Vissing-Jorgensen, 2015), which implies that the fundamental value depends on the relative quality of the sovereign resources (Krishnamurthy, He, and Milbradt, 2019). When issued by the private sector, the supply of private safe assets depends on that of the government (Holmstrom and Tirole, 1998). A shortage of public safe assets increases the liquidity premium and induces the private sector to invest in projects that generate liquid assets. However, financial institutions typically cannot issue completely default-free debt, as they can be excessively leveraged (Stein, 2012) and exposed to funding risk and worst-case losses in long-term and illiquid investments (Krishnamurthy and Vissing-Jorgensen, 2015). When uncertainty surges, the provision of private safe assets becomes illiquid and the liquidity premium increases (Moreira and Savov, 2017).[18] In the case of secured debt instruments, the heterogeneity in safety premia also depends on the collateral quality. For instance, some assets provide stable fungibility and (re-)pledgeability, whereas others can experience large increases in haircuts (Gorton and Metrick, 2012).

The second hypothesis to test is whether the carry return increases in the liquidity premium. Krishnamurthy and Vissing-Jorgensen (2012) show that the liquidity premium of U.S. Treasury securities increases with their scarcity, as reflected in a lower public debt to GDP ratio. Additionally, the liquidity premium is endogenously determined as the financial sector responds to the demand for money-like claims. The creation of private safe assets also depends on monetary policy and central bank reserves. A higher demand for monetary services lowers the yields on these claims and induces their supply by the financial sector (Sunderam, 2015). However, this is a "fragile liquidity transformation," as the liquidity provision by the private sector disappears when the environment becomes more uncertain (Moreira and Savov, 2017). Furthermore, even if two assets have the same fundamental value, the asset providing larger liquidity benefits and being subject to smaller haircuts will trade at a higher price (Garleanu and Pedersen, 2011).

The third hypothesis to test is whether the carry return increases in the opportunity cost of holding money, as it affects the liquidity premium. Nagel (2016) shows that the Federal Funds Rate (measuring the opportunity cost) explains the time-variation in the liquidity premium of U.S. Treasury securities. The opportunity cost of holding money is primarily influenced by monetary policy. By raising interest rates, a central bank increases the liquidity premium and the cost of taking leverage for financial institutions (Drechsler, Savov, and Schnabl, 2018).

We follow the previous literature to build our empirical measures. Given that the vast majority of collateral assets is comprised of government bonds, our main risk measure is the difference in ten-year CDS spreads between the countries forming portfolio 8 (high repo rates) and those forming portfolio 1 (low repo rates), weighted by the respective shares of the countries in each portfolio. Figure 4 displays the strong co-movement between our carry factor and the CDS spread difference, thereby providing prima facie evidence that the carry factor is related to the cross-sectional disparity of (sovereign) risk between the Euro-area countries. In the spirit of Krishnamurthy and Vissing-Jorgensen (2012), we capture the liquidity premium by computing the difference in the log of the ratio of the face value of debt to GDP between the countries forming portfolio 8 (high repo rates) and portfolio 1 (low repo rates), weighted by the respective shares of the countries in each portfolio.[19]

[18] Moreover, the maturity of the government debt influences the term premia of public safe assets and the incentive to issue short-term money-like claims by private financial intermediaries (Greenwood, Hanson, and Stein, 2015). When the demand for safe assets increases, the term premia become less relevant, reducing the difference in risk and price between long- and short-term public safe assets (Infante, 2019).

[19] We use static weights (i.e., the average share of a country in a portfolio over time) for the CDS difference, while we use dynamic weights (i.e., the average share of a country in a portfolio during a quarter) for the difference in the log of the ratio of the face value of debt to GDP. Investors do not constantly adjust to changes in perceived sovereign credit risk (which in itself is a dynamic measure), while changes in the supply of sovereign debt (which in itself is a static measure) are incorporated into market dynamics. The results remain robust to a change in the weighting

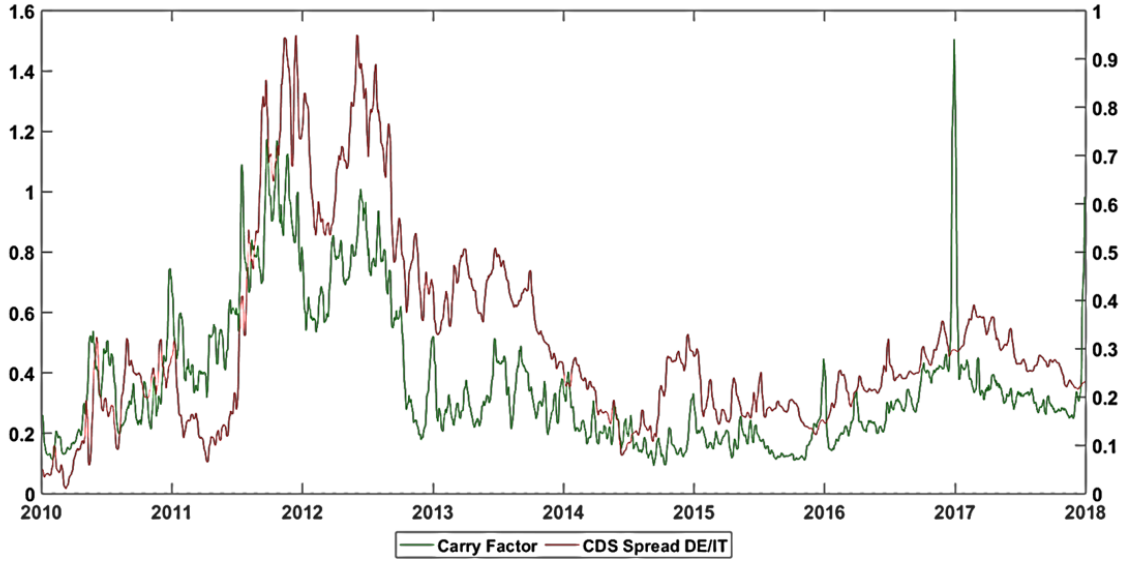


Figure 4: Development of the Carry Factor and the CDS spread between Germany and Italy

The opportunity cost of holding money is measured via the main Euro-area short-term interest rate benchmark, the Euro Overnight Index Average (Eonia).[20] To control for general market frictions and arbitrage constraints, which can be particular relevant in flight-to-quality periods (Longstaff, 2004), we compute deviations from the CIP since short-term interest rates are interconnected with FX rates (Du, Tepper, and Verdelhan, 2018 and Du, Im, and Schreger, 2018). More specifically, we compute the absolute CIP basis between the U.S. dollar and the Euro using the overnight London inter-bank offered rate (Libor).

Table 8 reports the results of the time-series regressions of our carry factor on a constant, the CDS difference between portfolios 8 and 1 ("Risk"), the difference in the log of the ratio of the face value of debt to GDP between portfolios 8 and 1 ("Asset supply"), the Eonia rate ("Opportunity cost"), the absolute U.S. dollar Euro overnight CIP deviations ("Arbitrage Deviation"), and the lagged carry factor ("Carry Lag"). The results for the univariate time series regressions are reported in columns (1) to (4), and the results for the multivariate time series regressions are reported in columns (5) and (6). The error-terms are adjusted for autocorrelation according to Cochrane and Orcutt (1949) following Wooldridge (2015). The regression frequency is quarterly for the time period between 2010 and 2017.

Three main results emerge from our regression analysis. First, the carry factor significantly increases with risk, providing empirical support for the safety premium hypothesis. In the multi-

scheme (see Appendix A.9).

[20]Eonia represents a weighted average of all overnight unsecured transactions in the Euro inter-bank market.

Table 8: Economic Analysis: Safe Asset Dimensions

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.545***				0.485***	0.469***
	(6.63)				(8.15)	(7.05)
Asset supply		0.867**			0.413**	0.438*
		(2.66)			(2.24)	(1.80)
Opportunity cost			0.319**		0.378***	0.377***
			(2.35)		(5.48)	(5.03)
Arbitrage deviation				16.305*	10.883**	11.541**
				(1.83)	(2.34)	(2.30)
Carry lag1						0.060
						(0.65)
Constant	-0.035	0.086	0.372***	0.362***	-0.141**	-0.161**
	(-0.32)	(0.32)	(5.02)	(3.15)	(-2.10)	(-2.07)
N	31	31	31	31	31	30
R^2	0.602	0.197	0.160	0.104	0.829	0.832

t statistics in parentheses.
Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).
Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.
Asset supply is defined as the dynamic weighted log debt/GDP difference between portfolios 8 and 1.
Opportunity cost is defined as Eonia rate.
Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.

variate setting (6), a one percentage point increase in the CDS prices of portfolio 8 relative to the CDS prices of portfolio 1 is associated with an increase in our carry factor by 47 basis points. Second, we find a significantly positive relationship between our carry factor and the relative scarcity of safe assets in portfolio 1. This result is in line with Krishnamurthy and Vissing-Jorgensen (2012) and supports the liquidity premium hypothesis. We find that a one percentage point increase in the difference in the log of the ratio of the face value of debt to GDP between portfolios 8 and 1 is accompanied by an increase in our carry factor by 44 basis points. Third, the carry factor significantly increases with the opportunity cost of holding money. This finding is consistent with Nagel (2016) and supports the idea that the liquidity benefits of near-money assets are more valuable when the opportunity cost of holding money is high. We estimate that an increase in the Eonia rate of one percentage point is associated with an increase in our carry factor of 38 basis points. Similar to Nagel (2016), the supply variable loses part of its explanatory power after accounting for the opportunity cost of holding money. In addition, by controlling for market frictions and arbitrage constraints, we find a positive relationship between the U.S. dollar Euro CIP deviations and our carry factor, which suggests larger convenience premia in distressed markets. An increase in the absolute U.S. dollar Euro overnight CIP deviations by one standard deviation[21] is accompanied by an increase in our carry factor by 3 basis points. Prior information on the carry factor does not provide statistically significant information.

The positive relationship between our carry factor and risk respectively asset supply is graphically illustrated in Figures 5 and 6. Figure 5 graphs the carry factor against the difference in the CDS prices between portfolios 8 and 1 ("Risk"), while Figure 6 graphs the carry factor against the difference in the log of the ratio of the face value of debt to GDP between portfolios 8 and 1 ("Asset supply"). Both Figures provide evidence for the convenience benefits of the assets in portfolio 1. When the risk of assets in portfolio 1 is low compared to assets in portfolio 8 (i.e., a high value of our risk measure), investors value their safety benefits. Similarly, when the supply of assets in portfolio 1 is scarce compared to assets in portfolio 8 (i.e., a high value of our asset supply measure), investors value their liquidity benefits.[22]

To validate our main results, we perform a number of additional tests, which we report in the Appendix and shortly summarize here. First, we conduct various sub-sampling analyses, which clearly show that our main results hold across sub-periods and market segments. In particular, we verify that our results are not only driven by "specialness" (Duffie, 1996), as the carry factor also exists if we only consider general collateral repo transactions. Second, we replicate our economic analysis as reported in Appendix A.10 by employing alternative variables to capture risk (i.e.,

[21] The absolute USD/EUR overnight CIP deviation is on average 0.00184, with a standard deviation of 0.00242.

[22] Distressed market conditions are highlighted since the carry factor tends to be higher during these periods of market uncertainty. Still, the positive relationship between our carry factor and asset supply is clearly visible, even during these periods of stress. We thereby rely on the CDS index of European banks since it captures market stress associated with the issuers of private safe assets, with sovereign risk and risk in the banking sector being directly connected.

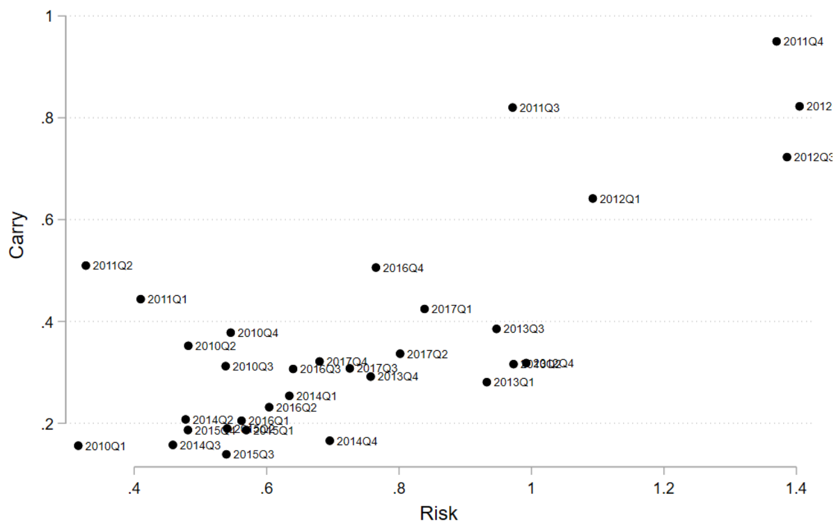
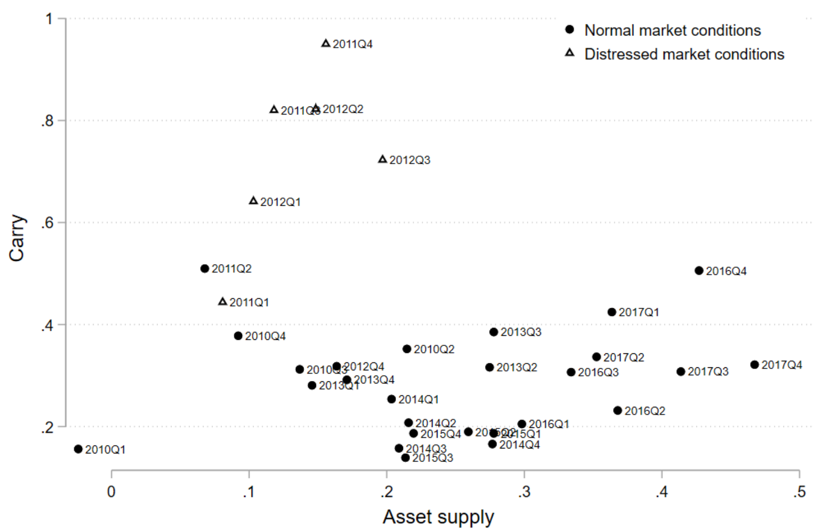


Figure 5: Scatterplot of the Carry Factor against Risk



Distressed market conditions are defined to be periods during which the five-year CDS spread of the European Banking sector is at least one standard deviation above its mean.

Figure 6: Scatterplot of the Carry Factor against Asset Supply

five-year CDS index of European banks), the opportunity cost of holding money (i.e., one-month Euribor and average repo market rate), as well as market frictions and arbitrage constraints (i.e., TED spread, Chicago Board Options Exchange Volatility Index (VIX), and Composite Indicator of Systemic Stress in the Financial System (CISS)). Regarding the current period of unconventional monetary policy, we adjust the debt to GDP ratio for any ECB purchases under the public sector purchase program (PSPP) to account for asset scarcity effects relating to asset supply (see Appendix A.11).

Finally, we expand our analysis by examining the impact of repo market liquidity on our carry factor for two main reasons: First, it provides us with a direct measure of market liquidity for repos rather than a liquidity measure for their underlying collateral assets. Second, it enables us to perform our analysis at a higher frequency than quarterly (as we do not need to use GDP data). Inspired by the approach of Krishnamurthy and Vissing-Jorgensen (2012), we gauge repo market liquidity by computing the difference in the log of the ratio of repo trading volume to debt between the countries forming portfolio 8 (high repo rates) and portfolio 1 (low repo rates), weighted by the respective shares of the countries in each portfolio. For the time-series regressions, we consider the same economic variables of interest, except that the asset supply measure is exchanged for our new repo liquidity measure. The results of this analysis at a monthly frequency are reported in Table 9. We find a significantly negative relationship between our carry factor and a relative increase in the repo trading volume of safe assets in portfolio 1. In the multivariate setting (6), a one percentage point increase in the difference in the log of the ratio of repo trading volume to debt between portfolios 8 and 1 is accompanied by a decrease in our carry factor by 36 basis points. This result highlights that a relative increase in the repo trading volume of the assets in portfolio 1 is accompanied by an increase in the liquidity premium, as reflected by an increase in the carry factor. The remaining results remain qualitatively consistent. Appendix A.12 shows that the results remain robust at a quarterly frequency as well as after adjusting debt levels for ECB purchases under the PSPP.

In sum, our economic analysis corroborates the safe asset hypotheses; that is, the economic determinants of the convenience premium embedded in our carry factor are (i) the safety premium, (ii) the liquidity premium, and (iii) the opportunity cost of holding money.

4 Conclusion

We provide the first systematic asset pricing analysis of one of the main categories of near-money or safe assets, the repurchase agreement. We demonstrate that heterogeneity in repo rates translates into a remunerative carry trade. By going long in a portfolio consisting of repos with the highest rates (via a reverse repurchase agreement) while shorting a portfolio consisting of repos with the lowest rates (via a repurchase agreement), we create a seemingly riskless investment with zero

Table 9: Economic Analysis - Repo Market Liquidity: Monthly Results

	(1)	(2)	(3)	(4)	(5)	(6)
	carry	carry	carry	carry	carry	carry
	b/t	b/t	b/t	b/t	b/t	b/t
Risk	0.274***				0.298***	0.242***
	(3.39)				(4.63)	(4.38)
Repo liquidity		-0.659***			-0.404***	-0.361***
		(-3.99)			(-2.66)	(-2.65)
Opportunity cost			0.262**		0.195**	0.102**
			(2.41)		(2.57)	(2.08)
Arbitrage deviations				7.022***	6.661***	9.159***
				(4.27)	(4.31)	(5.24)
Carry lag1						0.387***
						(4.72)
Constant	0.183**	0.452***	0.377***	0.388***	0.160**	0.051
	(2.03)	(5.97)	(5.11)	(3.72)	(2.55)	(1.41)
N	95	95	95	95	95	94
R^2	0.110	0.146	0.059	0.164	0.442	0.762

t statistics in parentheses.
Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).
Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.
Repo liquidity is defined as the static weighted log repo volume/debt difference between portfolios 8 and 1.
Opportunity cost is defined as Eonia rate.
Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.

net exposure that represents a (cash-neutral) collateral swap. We define this investment strategy as our safe asset carry. The return on this carry, our carry factor, together with a market factor representing the average borrowing cost in the repo market, is able to explain the price of safe assets within a no-arbitrage framework: While the market factor determines the level of short-term interest rates, the carry factor accounts for the cross-sectional dispersion in short-term interest rates. Consistent with the safe asset literature, cross-sectional differences in repo rates are captured by our carry factor, which suggests that market participants value the different convenience premia embedded in safe assets. We provide empirical evidence that our carry factor can be explained by the safety premia and the liquidity benefits of safe assets, which vary with the opportunity cost of holding money.

Our results shed new light on the main market for short-term funding, which is key for an efficient allocation of liquidity, the implementation of monetary policy, and financial stability. Future research could apply our approach to other assets including repos in the United States and investigate whether our carry factor has pricing implications for other asset classes, such as bonds and equities.

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A Appendix

A.1 Country Composition by Portfolio and Year

Table A1.1: Portfolio 1 - Country Composition by Year

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Austria	1.2%	2.3%	2.9%	4.7%	4.2%	5.0%	5.0%	2.9%
Belgium	17.9%	10.9%	10.9%	8.9%	7.7%	13.3%	10.6%	9.8%
Germany	30.7%	28.6%	16.5%	27.5%	22.8%	29.7%	43.5%	53.2%
Spain	3.6%	5.7%	24.5%	26.4%	27.8%	16.8%	10.5%	7.7%
EU	4.0%	1.7%	0.6%	2.3%	1.3%	0.2%	0.1%	0.0%
Finland	3.0%	1.6%	1.1%	1.0%	3.3%	6.2%	6.3%	5.1%
France	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ireland	6.4%	14.1%	15.5%	6.9%	4.9%	3.4%	4.1%	2.7%
Italy	18.3%	15.5%	7.5%	6.1%	15.3%	10.2%	4.9%	7.5%
Netherlands	5.9%	4.8%	3.3%	3.1%	6.2%	6.8%	7.8%	5.6%
Portugal	9.1%	14.5%	17.2%	13.1%	6.4%	8.5%	7.2%	5.5%

The number of portfolio constituents changes across time.

Table A1.2: Portfolio 2 - Country Composition by Year

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Austria	4.3%	5.3%	4.1%	3.6%	5.3%	7.0%	6.9%	5.6%
Belgium	10.3%	13.7%	17.1%	12.7%	11.3%	10.5%	9.8%	8.5%
Germany	34.2%	33.6%	33.0%	32.2%	36.5%	39.4%	40.1%	43.1%
Spain	5.0%	10.4%	12.4%	13.9%	11.9%	11.9%	10.5%	8.8%
EU	0.8%	0.7%	1.0%	0.8%	0.9%	0.5%	0.9%	0.1%
Finland	4.0%	3.9%	2.8%	2.9%	3.7%	6.4%	8.8%	6.9%
France	0.1%	0.3%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Ireland	3.9%	2.2%	2.2%	4.8%	2.6%	1.5%	3.2%	3.9%
Italy	20.8%	12.0%	11.8%	15.1%	14.5%	9.5%	6.0%	10.9%
Netherlands	11.3%	10.4%	11.8%	10.7%	10.5%	10.4%	11.0%	8.7%
Portugal	5.4%	7.3%	3.8%	3.1%	2.8%	2.8%	2.9%	3.5%

The number of portfolio constituents changes across time.

Table A1.3: Portfolio 3 - Country Composition by Year

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Austria	6.2%	5.9%	7.1%	5.8%	7.5%	9.3%	9.4%	9.1%
Belgium	10.3%	12.0%	15.4%	15.6%	13.5%	11.0%	8.1%	8.6%
Germany	38.5%	43.8%	39.1%	33.7%	38.2%	39.1%	40.4%	27.6%
Spain	4.6%	7.3%	6.1%	7.4%	7.3%	7.6%	6.9%	7.8%
EU	0.2%	0.3%	0.1%	0.0%	0.1%	0.1%	0.9%	0.9%
Finland	3.6%	4.1%	5.4%	4.8%	5.8%	8.1%	9.7%	9.3%
France	0.2%	0.2%	0.1%	0.1%	0.3%	0.1%	0.1%	0.0%
Ireland	2.7%	0.9%	0.9%	1.9%	1.5%	1.4%	2.3%	3.0%
Italy	18.4%	9.3%	8.4%	15.6%	12.1%	8.8%	4.8%	10.8%
Netherlands	11.4%	11.8%	16.5%	13.6%	12.3%	12.9%	15.7%	20.5%
Portugal	3.9%	4.5%	1.1%	1.4%	1.6%	1.5%	1.8%	2.4%

The number of portfolio constituents changes across time.

Table A1.4: Portfolio 4 - Country Composition by Year

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Austria	7.0%	10.1%	10.7%	8.7%	10.1%	13.1%	18.5%	17.2%
Belgium	12.5%	13.2%	11.3%	16.1%	14.4%	13.6%	16.1%	17.7%
Germany	42.1%	38.8%	41.8%	35.7%	36.9%	34.4%	23.8%	13.5%
Spain	3.8%	6.1%	3.5%	5.1%	4.4%	6.5%	8.3%	9.2%
EU	0.2%	0.2%	0.0%	0.0%	0.2%	0.1%	0.1%	0.6%
Finland	3.4%	5.2%	8.7%	7.3%	8.3%	7.8%	7.7%	11.0%
France	0.4%	0.4%	0.2%	0.2%	0.5%	0.2%	0.3%	0.2%
Ireland	1.7%	0.5%	0.4%	1.1%	1.1%	1.1%	2.6%	3.1%
Italy	15.2%	8.7%	6.3%	12.4%	10.1%	7.5%	6.3%	13.0%
Netherlands	10.0%	13.3%	16.2%	12.7%	13.2%	14.6%	14.3%	12.6%
Portugal	3.7%	3.4%	0.7%	0.7%	0.9%	1.0%	1.8%	1.9%

The number of portfolio constituents changes across time.

Table A1.5: Portfolio 5 - Country Composition by Year

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Austria	10.8%	10.6%	16.4%	15.3%	12.0%	10.1%	9.9%	13.3%
Belgium	15.9%	21.9%	18.2%	16.3%	20.5%	20.9%	32.9%	25.2%
Germany	28.1%	22.3%	31.8%	27.4%	25.2%	19.0%	6.4%	5.8%
Spain	2.9%	8.3%	4.6%	5.7%	5.5%	11.9%	17.6%	15.8%
EU	0.2%	0.5%	0.3%	0.3%	0.6%	0.9%	0.1%	0.2%
Finland	4.2%	5.6%	9.3%	9.9%	8.9%	6.0%	3.8%	6.0%
France	0.7%	0.8%	1.0%	0.8%	0.9%	1.1%	1.9%	1.2%
Ireland	2.8%	1.1%	0.5%	1.3%	1.4%	2.3%	4.0%	3.5%
Italy	18.8%	13.0%	8.0%	12.7%	12.0%	16.5%	15.7%	22.5%
Netherlands	10.4%	10.9%	9.0%	9.5%	11.9%	9.4%	4.4%	4.4%
Portugal	5.2%	4.9%	0.9%	0.8%	1.2%	2.0%	3.3%	2.3%

The number of portfolio constituents changes across time.

Table A1.6: Portfolio 6 - Country Composition by Year

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Austria	10.5%	6.7%	6.6%	9.2%	7.4%	3.1%	0.8%	2.7%
Belgium	13.1%	11.9%	13.2%	10.5%	12.4%	8.3%	6.1%	9.3%
Germany	13.3%	10.0%	11.6%	13.1%	10.5%	5.0%	1.2%	2.0%
Spain	3.4%	19.3%	15.8%	17.7%	14.2%	19.8%	26.8%	31.7%
EU	0.3%	1.9%	4.3%	3.6%	3.5%	2.8%	1.5%	1.1%
Finland	4.6%	4.2%	3.0%	5.3%	4.3%	1.5%	0.8%	2.0%
France	0.9%	1.4%	3.3%	2.2%	2.2%	1.5%	1.4%	1.5%
Ireland	5.8%	1.4%	1.4%	2.0%	3.3%	4.0%	3.9%	3.7%
Italy	30.3%	31.3%	35.4%	29.4%	35.0%	48.2%	53.4%	41.1%
Netherlands	9.6%	6.0%	3.3%	4.6%	4.7%	2.3%	0.5%	1.4%
Portugal	8.1%	5.8%	2.2%	2.3%	2.6%	3.6%	3.5%	3.5%

The number of portfolio constituents changes across time.

Table A1.7: Portfolio 7 - Country Composition by Year

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Austria	6.2%	2.1%	0.6%	2.4%	1.7%	0.7%	0.1%	0.3%
Belgium	7.7%	3.4%	2.0%	3.0%	2.8%	1.7%	0.5%	1.6%
Germany	5.8%	4.0%	1.9%	4.8%	3.2%	1.3%	0.5%	1.0%
Spain	2.6%	11.6%	11.8%	14.9%	15.1%	13.4%	16.7%	24.6%
EU	0.8%	2.4%	2.4%	3.9%	3.2%	2.1%	1.6%	2.7%
Finland	3.1%	1.7%	0.5%	1.6%	1.1%	0.6%	0.1%	0.4%
France	0.7%	0.9%	1.4%	1.7%	1.4%	0.8%	0.4%	1.0%
Ireland	4.8%	1.5%	1.0%	1.8%	2.7%	3.2%	1.9%	3.1%
Italy	56.6%	67.4%	76.0%	62.0%	65.7%	73.4%	76.3%	61.2%
Netherlands	4.8%	2.2%	0.5%	1.4%	0.8%	0.4%	0.1%	0.3%
Portugal	7.1%	2.9%	1.8%	2.6%	2.4%	2.4%	1.8%	3.7%

The number of portfolio constituents changes across time.

Table A1.8: Portfolio 8 - Country Composition by Year

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Austria	3.8%	0.7%	0.1%	1.1%	0.6%	0.4%	0.1%	0.3%
Belgium	4.2%	1.6%	0.3%	1.1%	0.8%	0.8%	0.2%	0.6%
Germany	9.2%	4.4%	0.6%	1.6%	0.9%	0.9%	1.5%	0.9%
Spain	3.1%	10.9%	15.7%	14.4%	21.9%	21.5%	19.4%	14.8%
EU	9.6%	6.0%	4.7%	3.0%	1.8%	2.4%	2.5%	3.9%
Finland	2.1%	1.3%	0.1%	0.5%	0.4%	0.6%	0.1%	0.1%
France	2.5%	1.8%	0.8%	1.6%	0.8%	0.7%	0.1%	0.3%
Ireland	4.8%	4.3%	2.9%	5.9%	8.0%	12.4%	7.4%	7.6%
Italy	50.9%	65.0%	67.6%	61.1%	53.7%	50.3%	60.5%	62.9%
Netherlands	2.8%	1.1%	0.1%	0.3%	0.3%	0.3%	0.1%	0.1%
Portugal	7.0%	2.8%	7.2%	9.4%	10.7%	9.8%	8.2%	8.4%

The number of portfolio constituents changes across time.

A.2 Carry Return - Market (GC Basket & Special)

Table A2.1: Market - Carry Return (%) W/O Term

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	258	0.3012	0.1833	0.0926
2011	257	0.6850	0.4383	0.2267
2012	256	0.6271	0.3638	0.1855
2013	255	0.3199	0.1963	0.1014
2014	255	0.1958	0.1319	0.0680
2015	256	0.1754	0.1208	0.0651
2016	257	0.3133	0.2375	0.1428
2017	255	0.3486	0.2521	0.1432
avg.		**0.3710**	**0.2406**	**0.1282**

Table A2.2: Market - Carry Return (%) ON

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	234	0.7458	0.4268	0.1803
2011	233	0.7393	0.4988	0.2670
2012	232	0.6084	0.3829	0.1994
2013	231	0.5383	0.3216	0.1655
2014	231	0.4598	0.2905	0.1432
2015	236	0.3579	0.2356	0.1068
2016	237	0.3889	0.2815	0.1471
2017	236	0.4374	0.2935	0.1419
avg.		**0.5339**	**0.3411**	**0.1687**

Table A2.3: Market - Carry Return (%) TN

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	234	0.2967	0.1818	0.0859
2011	233	0.6644	0.4301	0.2047
2012	232	0.5748	0.3319	0.1614
2013	231	0.3056	0.1859	0.0905
2014	231	0.1962	0.1268	0.0606
2015	236	0.1640	0.1154	0.0611
2016	237	0.2951	0.2294	0.1373
2017	236	0.3367	0.2524	0.1444
avg.		**0.3538**	**0.2316**	**0.1183**

Table A2.4: Market - Carry Return (%) SN

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	234	0.2876	0.1702	0.0868
2011	233	0.7330	0.4643	0.2701
2012	232	0.6970	0.4018	0.2094
2013	231	0.3422	0.2109	0.1105
2014	231	0.2102	0.1438	0.0771
2015	236	0.1932	0.1338	0.0744
2016	237	0.3293	0.2453	0.1485
2017	236	0.3577	0.2583	0.1486
avg.		**0.3933**	**0.2534**	**0.1406**

A.3 Carry Return - GC Basket

Table A3.1: GC Basket - Carry Return (%) W/O Term

Year	**Trading Days**	**Top/Bottom 12.5%**	**Top/Bottom 25.0%**	**Top/Bottom 50.0%**
2010	258	0.1067	0.0767	0.0412
2011	257	0.3564	0.2840	0.1735
2012	256	0.1453	0.1272	0.0836
2013	255	0.0937	0.0717	0.0413
2014	255	0.0948	0.0701	0.0402
2015	256	0.0684	0.0559	0.0339
2016	257	0.1201	0.1083	0.0807
2017	255	0.1065	0.0843	0.0584
avg.		**0.1366**	**0.1099**	**0.0692**

Table A3.2: GC Basket - Carry Return (%) ON

Year	**Trading Days**	**Top/Bottom 12.5%**	**Top/Bottom 25.0%**	**Top/Bottom 50.0%**
2010	234	0.0363	0.0211	0.0055
2011	233	0.3226	0.2513	0.1622
2012	232	0.1203	0.1064	0.0791
2013	231	0.0467	0.0400	0.0250
2014	231	0.0518	0.0423	0.0248
2015	236	0.0481	0.0389	0.0238
2016	237	0.0977	0.0915	0.0637
2017	236	0.0943	0.0779	0.0531
avg.		**0.1022**	**0.0837**	**0.0547**

Table A3.3: GC Basket - Carry Return (%) TN

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	234	0.1057	0.0831	0.0462
2011	233	0.3654	0.3014	0.1848
2012	232	0.1578	0.1363	0.0909
2013	231	0.0916	0.0715	0.0406
2014	231	0.0964	0.0749	0.0442
2015	236	0.0741	0.0625	0.0399
2016	237	0.1345	0.1204	0.0911
2017	236	0.1212	0.1042	0.0720
avg.		**0.1433**	**0.1193**	**0.0762**

Table A3.4: GC Basket - Carry Return (%) SN

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	234	0.0960	0.0752	0.0350
2011	233	0.3483	0.2856	0.1557
2012	232	0.1255	0.1099	0.0741
2013	231	0.0711	0.0613	0.0414
2014	231	0.0849	0.0614	0.0319
2015	236	0.0642	0.0478	0.0249
2016	237	0.1103	0.0792	0.0419
2017	236	0.0222	0.0211	0.0113
avg.		**0.1151**	**0.0925**	**0.0519**

A.4 Carry Return - Special

Table A4.1: Special - Carry Return (%) W/O Term

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	258	0.2998	0.1839	0.0927
2011	257	0.6842	0.4361	0.2210
2012	256	0.6474	0.3745	0.1887
2013	255	0.3280	0.1994	0.1025
2014	255	0.1929	0.1296	0.0661
2015	256	0.1742	0.1203	0.0636
2016	257	0.3128	0.2378	0.1422
2017	255	0.3476	0.2520	0.1423
avg.		**0.3735**	**0.2418**	**0.1274**

Table A4.2: Special - Carry Return (%) ON

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	234	NaN	NaN	0.4574
2011	233	0.0795	0.5149	0.1898
2012	232	0.7515	0.4938	0.2258
2013	231	0.6450	0.3664	0.1470
2014	231	0.4360	0.2457	0.0994
2015	236	0.3533	0.2202	0.0857
2016	237	0.3965	0.2848	0.1470
2017	236	0.4383	0.3245	0.1478
avg.		**0.4422**	**0.3496**	**0.1874**

Table A4.3: Special - Carry Return (%) TN

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	234	0.2834	0.1733	0.0806
2011	233	0.6419	0.4103	0.1914
2012	232	0.5834	0.3356	0.1589
2013	231	0.3079	0.1848	0.0881
2014	231	0.1882	0.1204	0.0561
2015	236	0.1622	0.1149	0.0594
2016	237	0.2921	0.2297	0.1366
2017	236	0.3364	0.2520	0.1427
avg.		**0.3491**	**0.2276**	**0.1143**

Table A4.4: Special - Carry Return (%) SN

Year	Trading Days	Top/Bottom 12.5%	Top/Bottom 25.0%	Top/Bottom 50.0%
2010	234	0.2865	0.1686	0.0853
2011	233	0.7246	0.4573	0.2630
2012	232	0.7087	0.4068	0.2099
2013	231	0.3462	0.2125	0.1107
2014	231	0.2083	0.1425	0.0759
2015	236	0.1931	0.1335	0.0732
2016	237	0.3301	0.2455	0.1471
2017	236	0.3559	0.2567	0.1469
avg.		**0.3937**	**0.2527**	**0.1390**

A.5 Bond Portfolio Analysis

Table A5.1: Bond Portfolio Analysis

	Dynamic Buy-and-Hold		**Net Buy-and-Sell**	
Year	Return	St.Dev.	Return	St.Dev.
2010	1.60%	0.01%	4.14%	2.40%
2011	1.41%	0.01%	7.05%	6.68%
2012	2.51%	0.03%	7.24%	8.72%
2013	2.77%	0.01%	1.23%	2.04%
2014	2.59%	0.00%	2.80%	2.11%
2015	2.65%	0.00%	0.78%	3.10%
2016	2.70%	0.00%	6.32%	3.72%
2017	2.71%	0.01%	0.52%	2.83%
avg.	**2.37%**	**0.01%**	**3.76%**	**3.95%**

A.6 Principal Component Analysis - Market (GC Basket & Special)

Table A6.1: Market - Principal Component Analysis ON

	PCA 1	**PCA 2**	**PCA 3**	**PCA 4**	**PCA 5**	**PCA 6**	**PCA 7**	**PCA 8**
Portfolio 1	0.39	-0.92	0.03	0.01	0.00	0.00	0.00	0.00
Portfolio 2	0.33	0.11	-0.85	-0.37	-0.13	-0.03	0.03	0.00
Portfolio 3	0.34	0.14	-0.22	0.63	0.64	-0.08	0.03	-0.02
Portfolio 4	0.35	0.16	0.04	0.32	-0.44	0.45	-0.60	-0.01
Portfolio 5	0.34	0.15	0.14	0.23	-0.41	0.01	0.66	0.43
Portfolio 6	0.35	0.15	0.21	0.00	-0.23	-0.49	0.08	-0.72
Portfolio 7	0.36	0.16	0.28	-0.33	0.17	-0.46	-0.39	0.51
Portfolio 8	0.37	0.16	0.29	-0.45	0.36	0.59	0.21	-0.19
% Variance	64.34%	32.48%	1.64%	0.69%	0.38%	0.19%	0.16%	0.13%

Table A6.2: Market - Principal Component Analysis TN

	PCA 1	**PCA 2**	**PCA 3**	**PCA 4**	**PCA 5**	**PCA 6**	**PCA 7**	**PCA 8**
Portfolio 1	0.28	-0.90	0.33	0.01	0.03	0.02	0.00	-0.02
Portfolio 2	0.36	-0.11	-0.54	-0.64	-0.19	-0.23	-0.23	0.14
Portfolio 3	0.36	-0.01	-0.38	0.05	0.13	0.62	0.56	-0.05
Portfolio 4	0.36	0.04	-0.26	0.38	0.47	-0.54	0.02	-0.37
Portfolio 5	0.36	0.08	-0.10	0.49	-0.14	0.33	-0.66	0.24
Portfolio 6	0.35	0.15	0.19	0.24	-0.47	-0.38	0.43	0.45
Portfolio 7	0.36	0.24	0.34	-0.16	-0.41	0.10	-0.06	-0.70
Portfolio 8	0.38	0.31	0.48	-0.35	0.56	0.07	-0.06	0.30
% Variance	94.01%	4.97%	0.73%	0.12%	0.06%	0.04%	0.04%	0.03%

Table A6.3: Market - Principal Component Analysis SN

	PCA 1	**PCA 2**	**PCA 3**	**PCA 4**	**PCA 5**	**PCA 6**	**PCA 7**	**PCA 8**
Portfolio 1	0.28	-0.90	0.32	-0.01	-0.02	0.02	0.02	0.00
Portfolio 2	0.37	-0.06	-0.44	0.66	-0.08	-0.35	-0.28	-0.16
Portfolio 3	0.36	-0.01	-0.41	0.12	0.05	0.62	0.42	0.35
Portfolio 4	0.36	0.01	-0.33	-0.61	-0.45	-0.39	0.17	0.00
Portfolio 5	0.36	0.06	-0.12	-0.37	0.38	0.34	-0.52	-0.43
Portfolio 6	0.36	0.16	0.20	-0.07	0.57	-0.40	-0.03	0.56
Portfolio 7	0.36	0.25	0.37	0.15	0.11	-0.08	0.57	-0.55
Portfolio 8	0.37	0.30	0.48	0.11	-0.55	0.24	-0.35	0.23
% Variance	94.99%	4.28%	0.60%	0.06%	0.03%	0.02%	0.01%	0.01%

A.7 First Stage FMB - Market (GC Basket & Special)

Table A7.1: First Stage FMB - ON, Market Net

Portfolio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
α	-0.21***	-0.12***	0.01	0.07***	0.12***	0.16***	0.19***	0.20***
	(-3.25)	(-6.76)	(0.52)	(5.34)	(9.25)	(10.87)	(10.64)	(10.79)
β^{Market}	1.00***	0.92***	0.95***	0.96***	0.94***	0.96***	1.00***	1.01***
	(15.49)	(29.85)	(47.35)	(51.81)	(49.86)	(45.12)	(34.87)	(35.32)
β^{HML}	-0.84***	0.00	0.05**	0.06***	0.06***	0.07***	0.08***	0.09***
	(-12.84)	(-0.02)	(2.63)	(4.15)	(4.17)	(4.02)	(3.34)	(3.24)
N	1,870	1,870	1,870	1,870	1,870	1,870	1,870	1,870
adj. R^2	54.15%	83.90%	90.52%	92.63%	92.71%	92.95%	92.02%	91.71%

t statistics in parentheses.
Error-terms are adjusted according to Newey and West (1987).
Optimal number of lags are chosen using the Newey and West Bartlett kernel.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7.2: First Stage FMB - TN, Market Net

Portfolio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
α	-0.02	0.00	0.02*	0.03***	0.03***	0.03***	0.03***	0.03**
	(-1.22)	(0.01)	(1.92)	(4.32)	(5.35)	(3.36)	(2.91)	(2.60)
β^{Market}	0.99***	1.06***	1.05***	1.03***	1.01***	0.98***	0.98***	1.01***
	(56.63)	(46.81)	(80.17)	(137.62)	(146.64)	(89.46)	(96.47)	(94.13)
β^{HML}	-0.90***	-0.08	0.03	0.08***	0.14***	0.23***	0.35***	0.45***
	(-15.47)	(-1.63)	(1.09)	(3.37)	(6.97)	(9.04)	(12.18)	(11.03)
N	1,870	1,870	1,870	1,870	1,870	1,870	1,870	1,870
adj. R^2	95.03%	98.15%	98.87%	98.98%	99.21%	99.26%	99.14%	98.73%

t statistics in parentheses.
Error-terms are adjusted according to Newey and West (1987).
Optimal number of lags are chosen using the Newey and West Bartlett kernel.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7.3: First Stage FMB - SN, Market Net

Portfolio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
α	-0.01	-0.01	0.01	0.02***	0.02***	0.01	0.01	0.01
	(-0.85)	(-1.09)	(1.52)	(2.87)	(4.40)	(1.25)	(0.82)	(1.25)
β^{Market}	0.98***	1.06***	1.03***	1.01***	1.00***	0.98***	0.97***	0.98***
	(81.66)	(76.70)	(113.33)	(166.11)	(191.06)	(98.10)	(90.98)	(89.76)
β^{HML}	-0.83***	-0.02	0.02	0.04	0.10***	0.20***	0.30***	0.36***
	(-17.18)	(-0.72)	(0.49)	(1.61)	(6.54)	(9.82)	(10.48)	(9.71)
N	1,870	1,870	1,870	1,870	1,870	1,870	1,870	1,870
adj. R^2	97.62%	99.03%	99.17%	99.15%	99.70%	99.58%	99.31%	99.01%

t statistics in parentheses.
Error-terms are adjusted according to Newey and West (1987).
Optimal number of lags are chosen using the Newey and West Bartlett kernel.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A.8 First Stage GMM - Market (GC Basket & Special)

Table A8.1: First Stage GMM - ON, Market Net

Portfolio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
α	-0.24***	-0.01	0.06***	0.08***	0.09***	0.13***	0.14***	0.15***
	(-4.00)	(-0.67)	(6.64)	(5.28)	(5.68)	(7.76)	(6.69)	(6.90)
β^{Market}	0.95***	0.98***	0.98***	0.96***	0.92***	0.95***	0.98***	0.99***
	(15.23)	(33.94)	(48.50)	(48.72)	(47.04)	(48.81)	(41.74)	(41.76)
β^{HML}	-0.76***	-0.21***	-0.05***	0.04**	0.09***	0.12***	0.18***	0.20***
	(-12.62)	(-7.96)	(-3.82)	(2.28)	(4.50)	(5.63)	(5.85)	(6.08)

t statistics in parentheses.

Error-terms are adjusted according to Newey and West (1987).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A8.2: First Stage GMM - TN, Market Net

Portfolio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
α	-0.01	0.03***	0.03***	0.03***	0.03***	0.03***	0.03***	0.04***
	(-1.63)	(5.12)	(6.55)	(6.95)	(6.36)	(6.10)	(6.46)	(7.19)
β^{Market}	1.00***	1.07***	1.05***	1.03***	1.01***	0.98***	0.98***	1.01***
	(55.41)	(75.46)	(107.70)	(131.69)	(171.75)	(153.52)	(93.70)	(92.10)
β^{HML}	-0.94***	-0.13***	0.02*	0.10***	0.16***	0.23***	0.33***	0.42***
	(-37.61)	(-9.37)	(1.86)	(7.42)	(11.44)	(17.83)	(26.59)	(24.12)

t statistics in parentheses.

Error-terms are adjusted according to Newey and West (1987).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A8.3: First Stage GMM - SN, Market Net

Portfolio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
α	-0.02***	0.00	-0.01***	-0.01***	0.02***	0.00	0.00	0.01**
	(-3.36)	(-1.64)	(-3.32)	(-2.85)	(4.92)	(0.47)	(0.35)	(2.23)
β^{Market}	0.97***	1.06***	1.02***	1.00***	1.00***	0.97***	0.97***	0.98***
	(95.16)	(107.00)	(99.65)	(103.44)	(200.84)	(175.77)	(119.01)	(124.48)
β^{HML}	-0.80***	-0.05***	0.05***	0.09***	0.09***	0.22***	0.32***	0.38***
	(-35.42)	(-6.04)	(6.01)	(10.15)	(6.97)	(31.43)	(37.39)	(38.36)

t statistics in parentheses.

Error-terms are adjusted according to Newey and West (1987).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A.9 Economic Analysis: Different Weightings

Table A9.1: Economic Analysis: Static Weights

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.545***				0.566***	0.519***
	(6.63)				(9.58)	(7.62)
Asset supply (static weights)		-3.326*			2.668***	3.237***
		(-1.91)			(2.84)	(4.05)
Opportunity cost			0.319**		0.482***	0.506***
			(2.35)		(6.39)	(7.79)
Arbitrage deviations				16.305*	17.099***	20.999***
				(1.83)	(3.50)	(4.33)
Carry lag1						0.153*
						(1.72)
Constant	-0.035	1.138***	0.372***	0.362***	-0.715***	-0.877***
	(-0.32)	(2.85)	(5.02)	(3.15)	(-3.02)	(-4.30)
N	31	31	31	31	31	30
R^2	0.602	0.112	0.160	0.104	0.868	0.926

t statistics in parentheses.
Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).
Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.
Asset supply is defined as the static weighted log debt/GDP difference between portfolios 8 and 1.
Opportunity cost is defined as Eonia rate.
Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.

Table A9.2: Economic Analysis: Dynamic Weights

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.139*				0.057	-0.030
(dynamic weights)	(1.86)				(0.65)	(-0.42)
Asset supply		0.867**			0.594	0.816**
		(2.66)			(1.44)	(2.56)
Opportunity cost			0.319**		0.437***	0.347***
			(2.35)		(3.13)	(4.57)
Arbitrage deviations				16.305*	11.760	19.250**
				(1.83)	(1.42)	(2.46)
Carry lag1						0.694***
						(9.17)
Constant	0.305*	0.086	0.372***	0.362***	0.147	-0.126
	(1.78)	(0.32)	(5.02)	(3.15)	(1.18)	(-1.70)
N	31	31	31	31	31	30
R^2	0.106	0.197	0.160	0.104	0.392	0.896

t statistics in parentheses.
Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).
Risk is defined as the dynamic weighted CDS price difference between portfolios 8 and 1.
Asset supply is defined as the dynamic weighted log debt/GDP difference between portfolios 8 and 1.
Opportunity cost is defined as Eonia rate.
Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.

A.10 Economic Analysis: Robustness

Table A10.1: Economic Analysis - Robustness: Five-Year CDS Spread of European Banking Sector

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.166***				0.146***	0.108***
(CDS Banking Sector)	(5.89)				(6.36)	(4.54)
Asset supply		0.867**			0.702***	1.055***
		(2.66)			(3.11)	(4.49)
Opportunity cost			0.319**		0.215**	0.273***
			(2.35)		(2.50)	(4.50)
Arbitrage deviations				16.305*	12.439**	16.317**
				(1.83)	(2.14)	(2.68)
Carry lag1						0.306***
						(3.01)
Constant	0.024	0.086	0.372***	0.362***	-0.160*	-0.284***
	(0.29)	(0.32)	(5.02)	(3.15)	(-1.98)	(-4.13)
N	31	31	31	31	31	30
R^2	0.545	0.197	0.160	0.104	0.767	0.925

t statistics in parentheses.
Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).
Risk is defined as five-year CDS spread of the European banking sector.
Asset supply is defined as the dynamic weighted log debt/GDP difference between portfolios 8 and 1.
Opportunity cost is defined as Eonia rate.
Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.

Table A10.2: Economic Analysis - Robustness: One-month Euribor

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.545***				0.453***	0.435***
	(6.63)				(7.26)	(6.14)
Asset supply		0.867**			0.421**	0.432*
		(2.66)			(2.10)	(1.74)
Opportunity cost (one-month Euribor)			0.285**		0.294***	0.292***
			(2.73)		(5.38)	(5.07)
Arbitrage deviations				16.305*	11.298**	12.619**
				(1.83)	(2.21)	(2.27)
Carry lag1						0.067
						(0.68)
Constant	-0.035	0.086	0.354***	0.362***	-0.134*	-0.152*
	(-0.32)	(0.32)	(4.88)	(3.15)	(-1.98)	(-2.03)
N	31	31	31	31	31	30
R^2	0.602	0.197	0.205	0.104	0.819	0.835

t statistics in parentheses.
Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).
Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.
Asset supply is defined as the dynamic weighted log debt/GDP difference between portfolios 8 and 1.
Opportunity cost is defined as the One-month Euribor rate.
Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.

Table A10.3: Economic Analysis - Robustness: Average Repo Market Rate

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.545***				0.541***	0.533***
	(6.63)				(7.73)	(7.09)
Asset supply		0.867**			0.349	0.281
		(2.66)			(1.66)	(1.00)
Opportunity cost			0.096		0.315***	0.307***
(avg. repo rate)			(0.61)		(3.54)	(3.21)
Arbitrage deviations				16.305*	12.620**	13.711**
				(1.83)	(2.43)	(2.49)
Carry lag1						0.054
						(0.51)
Constant	-0.035	0.086	0.409***	0.362***	-0.101	-0.108
	(-0.32)	(0.32)	(4.16)	(3.15)	(-1.20)	(-1.12)
N	31	31	31	31	31	30
R^2	0.602	0.197	0.013	0.104	0.764	0.763

t statistics in parentheses.
Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).
Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.
Asset supply is defined as the dynamic weighted log debt/GDP difference between portfolios 8 and 1.
Opportunity cost is defined as the average repo market rate.
Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.

Table A10.4: Economic Analysis - Robustness: TED spread

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.545***				0.403***	0.321***
	(6.63)				(8.70)	(5.58)
Asset supply		0.867**			0.646***	0.794***
		(2.66)			(3.61)	(4.57)
Opportunity cost			0.319**		0.456***	0.468***
			(2.35)		(9.27)	(9.94)
Arbitrage deviations (TED spread)				0.010***	0.007***	0.007***
				(3.11)	(4.75)	(5.05)
Carry lag1						0.147
						(1.64)
Constant	-0.035	0.086	0.372***	0.089	-0.320***	-0.343***
	(-0.32)	(0.32)	(5.02)	(0.61)	(-5.62)	(-6.69)
N	31	31	31	31	31	30
R^2	0.602	0.197	0.160	0.250	0.918	0.949

t statistics in parentheses.
Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).
Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.
Asset supply is defined as the dynamic weighted log debt/GDP difference between portfolios 8 and 1.
Opportunity cost is defined as Eonia rate.
Arbitrage deviations is defined as the TED spread.

Table A10.5: Economic Analysis - Robustness: VIX

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.545***				0.527***	0.518***
	(6.63)				(6.84)	(5.79)
Asset supply		0.867**			0.581***	0.599**
		(2.66)			(2.91)	(2.39)
Opportunity cost			0.319**		0.417***	0.417***
			(2.35)		(4.71)	(4.47)
Arbitrage deviations				0.018***	-0.004	-0.003
(VIX)				(3.49)	(-0.87)	(-0.73)
Carry lag1						0.023
						(0.22)
Constant	-0.035	0.086	0.372***	0.109	-0.141*	-0.151
	(-0.32)	(0.32)	(5.02)	(0.91)	(-1.84)	(-1.60)
N	31	31	31	31	31	30
R^2	0.602	0.197	0.160	0.296	0.794	0.788

t statistics in parentheses.

Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).

Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.

Asset supply is defined as the dynamic weighted log debt/GDP difference between portfolios 8 and 1.

Opportunity cost is defined as Eonia rate.

Arbitrage deviations is defined as VIX.

Table A10.6: Economic Analysis - Robustness: CISS

	(1)	(2)	(3)	(4)	(5)	(6)
	carry	carry	carry	carry	carry	carry
	b/t	b/t	b/t	b/t	b/t	b/t
Risk	0.545***				0.477***	0.452***
	(6.63)				(5.14)	(4.68)
Asset supply		0.867**			0.546***	0.651**
		(2.66)			(2.79)	(2.57)
Opportunity cost			0.319**		0.378***	0.391***
			(2.35)		(4.75)	(4.60)
Arbitrage deviations (CISS)				1.048***	0.048	0.078
				(4.44)	(0.22)	(0.33)
Carry lag1						0.048
						(0.46)
Constant	-0.035	0.086	0.372***	0.210***	-0.155**	-0.184**
	(-0.32)	(0.32)	(5.02)	(3.34)	(-2.09)	(-2.15)
N	31	31	31	31	31	30
R^2	0.602	0.197	0.160	0.405	0.792	0.796

t statistics in parentheses.

Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).

Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.

Asset supply is defined as the dynamic weighted log debt/GDP difference between portfolios 8 and 1.

Opportunity cost is defined as Eonia rate.

Arbitrage deviations is defined as CISS.

A.11 Economic Analysis: ECB PSPP Purchases

Table A11.1: Economic Analysis - ECB PSPP Purchases: Asset Supply

	(1)	(2)	(3)	(4)	(5)	(6)
	carry	carry	carry	carry	carry	carry
	b/t	b/t	b/t	b/t	b/t	b/t
Risk	0.545***				0.486***	0.468***
	(6.63)				(8.30)	(7.16)
Asset supply net		0.836**			0.408**	0.435*
		(2.63)			(2.34)	(1.99)
Opportunity cost			0.319**		0.385***	0.384***
			(2.35)		(5.65)	(5.26)
Arbitrage deviations				16.305*	10.851**	11.625**
				(1.83)	(2.32)	(2.31)
Carry lag1						0.066
						(0.72)
Constant	-0.035	0.069	0.372***	0.362***	-0.146**	-0.166**
	(-0.32)	(0.24)	(5.02)	(3.15)	(-2.21)	(-2.24)
N	31	31	31	31	31	30
R^2	0.602	0.192	0.160	0.104	0.833	0.839

t statistics in parentheses.

Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).

Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.

Asset supply is defined as the dynamic weighted log debt net PSPP/GDP difference between portfolios 8 and 1.

Opportunity cost is defined as Eonia rate.

Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.

A.12 Economic Analysis: Repo Market Liquidity

Table A12.1: Economic Analysis - Repo Market Liquidity: Quarterly Results

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.545***				0.488***	0.506***
	(6.63)				(7.48)	(7.09)
Repo liquidity		-0.907***			-0.244	-0.071
		(-3.02)			(-1.23)	(-0.27)
Opportunity cost			0.319**		0.262***	0.298***
			(2.35)		(3.26)	(3.32)
Arbitrage deviations				16.305*	14.108***	13.543***
				(1.83)	(3.01)	(2.85)
Carry lag1						-0.001
						(-0.01)
Constant	-0.035	0.475***	0.372***	0.362***	-0.011	-0.048
	(-0.32)	(6.39)	(5.02)	(3.15)	(-0.15)	(-0.55)
N	31	31	31	31	31	30
R^2	0.602	0.239	0.160	0.104	0.806	0.801

t statistics in parentheses.

Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).

Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.

Repo liquidity is defined as the static weighted log repo volume/debt difference between portfolios 8 and 1.

Opportunity cost is defined as Eonia rate.

Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.

Table A12.2: Economic Analysis - Repo Market Liquidity: ECB PSPP Purchases - Quarterly Results

	(1) carry b/t	(2) carry b/t	(3) carry b/t	(4) carry b/t	(5) carry b/t	(6) carry b/t
Risk	0.545***				0.477***	0.488***
	(6.63)				(7.72)	(6.93)
Repo liquidity net		-0.916***			-0.328*	-0.217
		(-3.00)			(-1.77)	(-0.84)
Opportunity cost			0.319**		0.247***	0.269***
			(2.35)		(3.55)	(3.36)
Arbitrage deviations				16.305*	14.713***	14.205***
				(1.83)	(3.14)	(2.96)
Carry lag1						0.011
						(0.11)
Constant	-0.035	0.473***	0.372***	0.362***	0.001	-0.023
	(-0.32)	(6.49)	(5.02)	(3.15)	(0.02)	(-0.29)
N	31	31	31	31	31	30
R^2	0.602	0.237	0.160	0.104	0.823	0.811

t statistics in parentheses.
Error-terms are adjusted according to Cochrane and Orcutt (1949) following Wooldridge (2015).
Risk is defined as the static weighted CDS price difference between portfolios 8 and 1.
Repo liquidity is defined as the static weighted log repo volume/debt net PSPP difference between portfolios 8 and 1.
Opportunity cost is defined as Eonia rate.
Arbitrage deviations is defined as U.S. Dollar Euro CIP deviations in absolute terms.