Appendix B. Additional empirical results and robustness tests

This Appendix contains additional empirical results and robustness tests.

B.1. *Sharpe ratios of beta-sorted portfolios*

Fig. B1 plots the Sharpe ratio (annualized) of beta-sorted portfolios for all the asset classes in our sample.

B.2. *Factor loadings*

Table B1 reports returns and factor loadings of US and International equity BAB portfolios.

B.3. Robustness: alternative betas estimation

Table B2 reports returns of BAB portfolios in US and international equities using different estimation window lengths and different benchmark (local and global).

B.4. Robustness: size

Table B3 reports returns of US and international equity BAB portfolios controlling for size. Size is defined as the market value of equity (in US dollars). We use conditional sorts. At the beginning of each calendar month, stocks are ranked in ascending order on the basis of their market value of equity and assigned to one of ten groups from small to large based on NSYE breakpoints. Within each size decile, we assign stocks to low- and high-beta portfolios and compute BAB returns.

B.5. Robustness: sample period

Table B4 reports returns of US and international equity BAB portfolios in different sample periods.

B.6. Robustness: idiosyncratic volatility.

Table B5 reports returns of U.S. and International equity BAB portfolios controlling for idiosyncratic volatility. Idiosyncratic volatility is defined as the one-year rolling standard deviation of beta-adjusted residual returns. We use conditional sorts. At the beginning of each calendar month, stocks are ranked in ascending order on the basis of their idiosyncratic volatility and assigned to one of ten groups from low to high volatility. Within each volatility decile, we assign stocks to low- and high-beta portfolios and compute BAB returns. We report two sets of results: controlling for the level of idiosyncratic volatility and the one-month change in the same measure.

B.7. Robustness: alternative risk free fates

Table B6 reports returns of equity and Treasury BAB portfolios using alternative assumptions for risk-free rates. Table B6 also reports results for BAB factors constructed using one-year and 30-year Treasury bond futures over the same sample period. Using futures-based portfolio avoids the need of an assumption about the risk-free rate because futures' excess returns are constructed as changes in the futures contract price. We use two-year and 30-year futures because in our data, they are the contracts with the longest available sample period.

B.8. Robustness: out-of-sample data from Datastream

We compute the returns of international equity BAB portfolios from an earlier time period than what we consider in the body of the paper. Table B7 reports returns and alphas, and Fig. B1 plots the Sharpe ratios. We see strong out-of-sample evidence.

To compute these portfolio returns, we collect pricing data from DataStream for all common stocks in each of the available countries listed in Table 1 (16 of the 19 countries). The DataStream international data start in 1969, while Xpressfeed Global coverage starts only in 1984, thus allowing us to construct BAB portfolios over a non-overlapping (earlier) sample. For each country, we compute a BAB portfolio and restrict the sample to the period starting from the first available date in Datastream to the start of the Xpressfeed Global coverage. A small overlap can exist in the date ranges between Table 1 and Table B7, but there is no overlap in the corresponding BAB factors. This is because the date ranges refer to the underlying stock return data, but, because we need some initial data to compute betas, the time series of the BAB factors are shorter. Alphas are computed with respect to country-specific market portfolio.

B.9. Robustness: betas with respect to a global market portfolio

Table B8 reports results of global BAB portfolios using beta with respect to a multi asset class global market index. We use the global market portfolio from Asness, Frazzini, and Pedersen (2012). Betas are estimated using monthly data.

B.10. Robustness: value-weighted BAB portfolios

Table B9 reports results for value-weighted BAB factors for US and international equities. The portfolio construction follows Fama and French (1992, 1993, and 1996) and Asness and Frazzini (2012). We form one set of portfolios in each country and compute an international portfolio by weighting each country's portfolio by the country's total (lagged) market capitalization. The BAB factor is constructed using six value-weighted portfolios formed on size and beta. At the end of each calendar month, stocks are assigned to two size-sorted portfolios based on their market capitalization and to three beta-sorted portfolios (low, medium, and high) based on the 30th and 70th percentile. For US securities, the size breakpoint is the median NYSE market equity. For international securities the size breakpoint is the 80th percentile by country. For the international sample we use conditional sorts (first sorting on size, then on beta) to ensure we have enough securities in each portfolio (US sorts are independent). Portfolios are value weighted, refreshed every calendar month, and rebalanced every calendar month to maintain value weights. We average the small and large portfolio to form a low-beta and high-beta portfolio:

$$r_{t+1}^{L} = \left(r_{t+1}^{L,Small} + r_{t+1}^{L,Large}\right)/2$$
$$r_{t+1}^{H} = \left(r_{t+1}^{H,Small} + r_{t+1}^{H,Large}\right)/2$$

We form two BAB factor: a dollar-neutral BAB and beta-neutral BAB. The dollar-neutral BAB is a self-financing portfolio long the low-beta portfolio and short the high-beta portfolio:

$$r_{t+1}^{BAB,\, dollar\, neutral} = r_{t+1}^{L} - r_{t+1}^{H}$$

The beta-neutral BAB is a self-financing portfolio long the low beta portfolio levered to a beta of one and short the high beta portfolio delevered to a beta of one

$$r_{t+1}^{BAB} = \frac{1}{\beta_t^L}\left(r_{t+1}^{L} - r^f\right) - \frac{1}{\beta_t^H}\left(r_{t+1}^{H} - r^f\right) \tag{39}$$

B.11. Beta compression: bootstrap analysis

Fig. B3 investigates the possibility that estimation errors in betas could be a driver of the beta compression reported in Table 10. Table 10's evidence is consistent with Proposition 4: Betas are compressed towards one at times when funding liquidity risk is high. However, this lower cross-sectional standard deviation could be driven by lower beta estimation error variation at such times, rather than a lower variation across the true betas. To investigate this possibility, we run a bootstrap analysis under the null hypothesis of a constant standard deviation of true betas and tests whether the measurement error in betas can account for the compression observed in the data. We run the analysis on our sample of US equities and use monthly data for computational convenience. We compute a bootstrap sample under the null hypothesis of no variation in the cross-sectional dispersion of betas by fixing each stock's beta to his full sample realized beta and by sampling with replacement from the time series distribution of idiosyncratic returns. In the simulated sample, the time series of excess returns for stock i is collected in a vector denoted by $\tilde{r}^i$ given by

$$\tilde{r}^i = \beta_i r^m + \varepsilon^j, \tag{40}$$

where r^m is the vector of market excess return, β_i is the stock's full sample beta, and ε^j is a vector of the time series of idiosyncratic returns for a random stock j, sampled (with replacement) from the distribution of idiosyncratic returns. This yields a sample of returns under the null hypothesis of no time series variation in betas, while at the same time preserving the time series properties of returns, in particular, the cross-sectional distribution of idiosyncratic shocks and their relation to the TED spread volatility (because we bootstrap entire time series of idiosyncratic shocks). We estimate rolling betas on the simulated sample (as described in Section 3) and compute the beta compression statistics of Table 10, Panel A. We focus on the cross-sectional standard deviations, but the results are the same for the mean absolute deviation or interquartile range. We repeat this procedure ten thousand times, yielding a simulated distribution of the statistics in Table 10 in which the time variation of the cross-sectional dispersion in betas is due to estimation error.

Fig. B3 reports the distribution of the difference in cross-sectional standard deviation of betas between high (P3) and low (P1) funding liquidity risk periods, and compares it with the observed value in the data (also using rolling monthly betas). The figure shows that the compression observed in the data is much larger than what could be generated by estimation error variance alone (bootstrapped P-values close to zero). Hence, the beta compression observed in Table 10 is unlikely to be due to higher beta estimation error variance.

Table B2
US and international equities: robustness, alternative betas estimation

This table shows calendar-time portfolio returns of betting against beta (BAB) portfolios for different beta estimation methods. To construct the BAB factor, all stocks are assigned to one of two portfolios: low beta and high beta. The low- (high-) beta portfolio is composed of all stocks with a beta below (above) its country median. Stocks are weighted by the ranked betas (lower beta security have larger weight in the low-beta portfolio and higher beta securities have larger weights in the high-beta portfolio) and the portfolios are rebalanced every calendar month. Both portfolios are rescaled to have a beta of one at portfolio formation. The BAB factor is a self-financing portfolio that is long the low-beta portfolio and shorts the high-beta portfolio. This table includes all available common stocks on the Center for Research in Security Prices database and all available common stocks on the Xpressfeed Global database for the 19 markets listed in Table 1. Alpha is the intercept in a regression of monthly excess return. The explanatory variables are the monthly returns from Fama and French (1993), Carhart (1997), and Asness and Frazzini (2013) mimicking portfolios. Returns and alphas are in monthly percent, *t*-statistics are shown below the coefficient estimates, and 5% statistical significance is indicated in bold. $Short ($Long) is the average dollar value of the short (long) position. Volatilities and Sharpe ratios are annualized. VW: value-weighted. Data for the MSCI World index range from 2003 to 2012

Method	Risk factors	Estimation window (volatility)	Excess return	*t*-statistics excess return	Four-factor alpha	t-statistics alpha	$Short	$Long	Volatility	Sharpe ratio
US, five year correlation, beta with respect to CRSP - VW index	US	One year	**0.70**	7.12	**0.55**	5.59	0.70	1.40	10.7	0.78
US, one year correlation, beta with respect to CRSP - VW index	US	One year	**0.76**	7.60	**0.58**	5.84	0.73	1.49	11.0	0.83
US, five year correlation, beta with respect to MSCI World	US	One year	0.26	1.05	0.29	1.27	0.74	1.33	8.0	0.38
US, one year correlation, beta with respect to MSCI World	US	One year	**0.65**	2.77	**0.66**	2.80	0.70	1.41	8.3	0.93
Global, five year correlation, beta with respect to CRSP - VW index	Global	One year	**0.67**	4.91	**0.32**	2.37	0.89	1.40	8.0	1.00
Global, one year correlation, beta with respect to CRSP - VW index	Global	One year	**0.49**	2.99	0.16	0.92	0.88	1.46	10.0	0.59
Global, five year correlation, beta with respect to MSCI World	Global	One year	0.39	1.11	0.40	1.10	0.92	1.69	11.6	0.41
Global, one year correlation, beta with respect to MSCI World	Global	One year	**0.83**	2.34	0.47	1.31	0.83	1.74	12.7	0.79

Table B3
US and international equities: robustness, size

This table shows calendar-time portfolio returns of betting against beta (BAB) portfolios by size. At the beginning of each calendar month stocks are ranked in ascending order on the basis of their market value of equity (ME, in US dollars) at the end of the previous month. Stocks are assigned to one of ten groups based on NYSE breakpoints. To construct the BAB factor, stocks in each size decile are assigned to one of two portfolios: low beta and high beta. The low- (high-) beta portfolio is composed of all stocks with a beta below (above) its country median. Stocks are weighted by the ranked betas (lower beta security have larger weight in the low-beta portfolio and higher beta securities have larger weights in the high-beta portfolio), and the portfolios are rebalanced every calendar month. Both portfolios are rescaled to have a beta of one at portfolio formation. The BAB factor is self-financing portfolio that is long the low-beta portfolio and short the high-beta portfolio. This table includes all available common stocks on the Center for Research in Security Prices database and all available common stocks on the Xpressfeed Global database for the 19 markets listed in Table 1. Alpha is the intercept in a regression of monthly excess return. The explanatory variables are the monthly returns from Fama and French (1993), Carhart (1997), and Asness and Frazzini (2013) mimicking portfolios. Returns and alphas are in monthly percent, *t*-statistics are shown below the coefficient estimates, and 5% statistical significance is indicated in bold. $Short ($Long) is the average dollar value of the short (long) position. Volatilities and Sharpe ratios are annualized.

Portfolios	Excess return	*t*-statistics excess return	Four-factor alpha	t-statistics alpha	$Short	$Long	Volatility	Sharpe ratio
Panel A: US equities								
Small- ME	**1.11**	5.89	**0.60**	3.37	0.70	1.45	20.5	0.65
ME-2	**0.72**	5.15	**0.38**	2.78	0.69	1.34	15.3	0.56
ME-3	**0.74**	5.16	**0.45**	3.11	0.69	1.31	15.7	0.57
ME-4	**0.62**	5.26	**0.52**	4.37	0.69	1.31	12.9	0.58
ME-5	**0.69**	5.68	**0.51**	4.23	0.69	1.30	13.4	0.62
ME-6	**0.38**	3.13	**0.29**	2.38	0.70	1.29	13.3	0.34
ME-7	**0.36**	2.89	**0.32**	2.68	0.71	1.28	13.5	0.32
ME-8	**0.42**	3.48	**0.44**	3.85	0.72	1.28	13.3	0.38
ME-9	**0.35**	2.84	**0.36**	3.12	0.73	1.26	13.4	0.31
Large-ME	**0.25**	2.24	**0.26**	2.46	0.76	1.25	12.2	0.25
Panel B: International equities								
Small- ME	0.54	1.04	0.47	0.86	0.77	1.48	30.6	0.21
ME-2	0.53	1.53	0.37	1.03	0.81	1.50	20.5	0.31
ME-3	0.44	1.34	0.33	0.95	0.85	1.53	19.3	0.27
ME-4	0.49	1.72	0.35	1.14	0.87	1.52	17.0	0.35
ME-5	0.36	1.29	0.12	0.38	0.88	1.51	16.7	0.26
ME-6	**0.71**	2.67	0.52	1.80	0.88	1.48	15.7	0.54
ME-7	**0.59**	2.19	0.45	1.57	0.88	1.47	15.9	0.44
ME-8	**0.62**	2.82	0.36	1.55	0.87	1.42	13.0	0.57
ME-9	**0.65**	3.25	0.33	1.58	0.86	1.37	11.9	0.66
Large-ME	**0.72**	3.77	0.33	1.67	0.83	1.28	11.3	0.76

Table B4
US and international equities: robustness, sample period

This table shows calendar-time portfolio returns of betting against beta (BAB) factors. To construct the BAB factor, all stocks are assigned to one of two portfolios: low beta and high beta. The low- (high-) beta portfolio is composed of all stocks with a beta below (above) its country median. Stocks are weighted by the ranked betas (lower beta security have larger weight in the low-beta portfolio and higher beta securities have larger weights in the high-beta portfolio) and the portfolios are rebalanced every calendar month. Both portfolios are rescaled to have a beta of one at portfolio formation. The BAB factor is a self-financing portfolio that is long the low-beta portfolio and short the high-beta portfolio. This table includes all available common stocks on the Center for Research in Security Prices database and all available common stocks on the Xpressfeed Global database for the 19 markets listed in Table 1. Alpha is the intercept in a regression of monthly excess return. The explanatory variables are the monthly returns from Fama and French (1993), Carhart (1997), and Asness and Frazzini (2013) mimicking portfolios. Returns and alphas are in monthly percent, *t*-statistics are shown below the coefficient estimates, and 5% statistical significance is indicated in bold. $Short ($Long) is the average dollar value of the short (long) position. Volatilities and Sharpe ratios are annualized.

Sample period	Excess return	*t*-statistics excess return	Four-factor alpha	*t*-statistics alpha	$Short	$Long	Volatility	Sharpe ratio
Panel A: US equities								
1926 - 1945	0.26	1.00	0.21	0.97	0.59	1.18	12.9	0.24
1946 - 1965	**0.53**	4.73	**0.63**	5.37	0.71	1.27	6.0	1.06
1966 - 1985	**1.09**	6.96	**0.87**	5.55	0.69	1.41	8.4	1.56
1986 - 2009	**0.82**	3.50	**0.42**	2.18	0.78	1.67	13.7	0.71
2010 - 2012	0.79	1.95	**1.05**	2.71	0.73	1.38	7.3	1.30
Panel B : International equities								
1984 - 1994	**0.60**	2.47	0.47	1.75	0.85	1.22	7.8	0.93
1995 - 2000	0.13	0.66	0.13	0.68	0.88	1.35	5.9	0.27
2001 - 2009	**0.99**	3.68	0.46	1.91	0.92	1.56	9.7	1.23
2010 - 2012	**0.65**	2.02	0.45	1.42	0.90	1.49	5.8	1.34

Table B5
US and international equities: robustness, idiosyncratic volatility.

This table shows calendar-time portfolio returns of betting against beta (BAB) portfolios by idiosyncratic volatility. At the beginning of each calendar month stocks are ranked in ascending order on the basis of their idiosyncratic volatility and assign to one of ten groups. Idiosyncratic volatility is defined as the one-year rolling standard deviation of beta-adjusted residual returns. To construct the BAB factor, stocks in each volatility decile are assigned to one of two portfolios: low beta and high beta. The low- (high-) beta portfolio is composed of all stocks with a beta below (above) its country median. Stocks are weighted by the ranked betas (lower beta security have larger weight in the low-beta portfolio and higher beta securities have larger weights in the high-beta portfolio), and the portfolios are rebalanced every calendar month. Both portfolios are rescaled to have a beta of one at portfolio formation. The BAB factor is a self-financing portfolio that is long the low-beta portfolio and short the high-beta portfolio. This table includes all available common stocks on the Center for Research in Security Prices database and all available common stocks on the Xpressfeed Global database for the 19 markets listed in Table 1. Alpha is the intercept in a regression of monthly excess return. The explanatory variables are the monthly returns from Fama and French (1993), Carhart (1997), and Asness and Frazzini (2013) mimicking portfolios. Returns and alphas are in monthly percent, *t*-statistics are shown below the coefficient estimates, and 5% statistical significance is indicated in bold. $Short ($Long) is the average dollar value of the short (long) position. Volatilities and Sharpe ratios are annualized.

	Control for idiosyncratic volatility								Control for idiosyncratic volatility changes							
Portfolio	Excess return	t-statistics excess return	Four-factor alpha	t-statistics alpha	$Short	$Long	Volatility	Sharpe ratio	Excess return	t-statistics excess return	Four-factor alpha	t-statistics alpha	$Short	$Long	Volatility	Sharpe ratio
Panel A: US equities																
Low - volatility	**0.36**	3.23	**0.41**	3.73	1.04	1.70	12.3	0.35	**0.84**	5.55	**0.51**	3.36	0.70	1.40	16.6	0.61
P -2	**0.48**	4.30	**0.44**	4.12	0.91	1.52	12.3	0.47	**0.59**	4.56	**0.40**	3.08	0.71	1.38	14.1	0.50
P -3	**0.65**	6.06	**0.59**	5.92	0.86	1.45	11.7	0.67	**0.64**	5.26	**0.50**	4.12	0.72	1.39	13.3	0.58
P -4	**0.70**	6.14	**0.59**	5.82	0.82	1.40	12.4	0.67	**0.59**	5.23	**0.48**	4.29	0.73	1.40	12.3	0.57
P -5	**0.56**	5.10	**0.39**	3.82	0.79	1.36	12.1	0.56	**0.57**	4.68	**0.47**	3.96	0.74	1.41	13.2	0.51
P -6	**0.59**	4.95	**0.43**	3.93	0.76	1.33	13.1	0.54	**0.53**	4.99	**0.55**	5.18	0.73	1.41	11.6	0.55
P -7	**0.77**	6.83	**0.53**	4.97	0.73	1.30	12.3	0.75	**0.68**	6.23	**0.63**	5.72	0.73	1.40	12.0	0.68
P -8	**0.90**	6.54	**0.59**	4.67	0.70	1.27	15.0	0.72	**0.65**	5.78	**0.60**	5.21	0.72	1.38	12.3	0.64
P -9	**0.87**	5.35	**0.48**	3.37	0.66	1.24	17.9	0.59	**0.68**	5.81	**0.55**	4.63	0.70	1.36	12.7	0.64
High volatility	**0.98**	5.80	**0.58**	3.77	0.62	1.20	18.5	0.64	**0.80**	5.45	**0.54**	3.70	0.67	1.35	16.1	0.60
Panel B: International equities																
Low - volatility	**0.35**	2.09	**0.15**	0.92	1.01	1.59	9.9	0.42	0.50	1.60	**0.29**	0.87	0.83	1.45	18.5	0.33
P -2	**0.39**	2.35	**0.25**	1.43	0.96	1.50	9.9	0.48	**0.67**	3.09	**0.39**	1.70	0.86	1.45	12.8	0.63
P -3	**0.53**	2.80	**0.36**	1.76	0.93	1.47	11.3	0.57	**0.46**	2.15	**0.31**	1.36	0.87	1.45	12.5	0.44
P -4	**0.58**	2.97	**0.20**	1.00	0.91	1.45	11.5	0.60	**0.59**	2.74	**0.37**	1.59	0.88	1.46	12.6	0.56
P -5	**0.52**	2.44	**0.22**	0.98	0.88	1.43	12.5	0.50	**0.78**	3.74	**0.58**	2.56	0.88	1.46	12.3	0.76
P -6	0.39	1.47	**0.16**	0.57	0.86	1.41	15.5	0.30	**0.69**	3.27	**0.53**	2.31	0.88	1.46	12.5	0.67
P -7	**0.67**	2.55	**0.41**	1.50	0.83	1.38	15.5	0.52	**0.44**	2.09	**0.16**	0.75	0.87	1.45	12.3	0.42
P -8	**0.90**	2.95	**0.61**	1.96	0.80	1.36	18.0	0.60	**0.75**	3.00	**0.61**	2.32	0.85	1.44	14.7	0.61
P -9	0.60	1.57	**0.50**	1.31	0.75	1.31	22.4	0.32	**0.67**	2.68	**0.51**	1.97	0.83	1.43	14.8	0.54
High volatility	**1.52**	2.31	**1.01**	1.49	0.70	1.28	38.9	0.47	**0.76**	2.04	**0.53**	1.35	0.78	1.39	22.1	0.42

Table B6
Alternative risk-free rates

This table shows calendar-time portfolio returns of betting against beta (BAB) factors. To construct the BAB factor, all stocks are assigned to one of two portfolios: low beta and high beta. The low- (high-) beta portfolio is composed of all stocks with a beta below (above) its country median. Stocks are weighted by the ranked betas (lower beta security have larger weight in the low-beta portfolio and higher beta securities have larger weights in the high-beta portfolio), and the portfolios are rebalanced every calendar month. Both portfolios are rescaled to have a beta of one at portfolio formation. The BAB factor is a self-financing portfolio that is long the low-beta portfolio and short the high-beta portfolio. This table includes all available common stocks on the Center for Research in Security Prices database, all available common stocks on the Xpressfeed Global database for the 19 markets listed in Table 1, the Center for Research in Security Prices Treasury Fama bond portfolios, and two-year and 30-year Treasury bond futures from 1991 to 2012. We report returns using different risk-free rates sorted by their average spread over the Treasury bill. T-bills is the one-month Treasury bills. Repo is the overnight repo rate. OIS is the overnight indexed swap rate. Fed funds is the effective federal funds rate. LIBO is the London Interbank Offered Rate. If the interest rate is not available over a date range, we use the one-month Treasury bills plus the average spread over the entire sample period. Alpha is the intercept in a regression of monthly excess return. The explanatory variables are the monthly returns from Fama and French (1993), Carhart (1997), and Asness and Frazzini (2013) mimicking portfolios. Returns and alphas are in monthly percent, *t*-statistics are shown below the coefficient estimates, and 5% statistical significance is indicated in bold. $Short ($Long) is the average dollar value of the short (long) position. Volatilities and Sharpe ratios are annualized.

Portfolio	spread (Bps)	Excess return	t-statistics excess return	Four-factor alpha	t-statistics alpha	$Short	$Long	Volatility	Sharpe ratio
Panel A: US equities									
T-bills	0.0	**0.70**	7.12	**0.55**	5.59	0.70	1.40	10.7	0.78
Repo	18.2	**0.69**	7.01	**0.54**	5.49	0.70	1.40	10.7	0.77
OIS	18.2	**0.69**	7.01	**0.54**	5.48	0.70	1.40	10.7	0.77
Fed funds	59.3	**0.67**	6.77	**0.51**	5.24	0.70	1.40	10.7	0.74
One-month LIBOR	58.7	**0.67**	6.77	**0.52**	5.25	0.70	1.40	10.7	0.74
Three-month LIBOR	68.3	**0.66**	6.72	**0.51**	5.19	0.70	1.40	10.7	0.74
Panel B: International equities									
T-bills	0.0	**0.64**	4.66	**0.30**	2.20	0.89	1.40	8.1	0.95
Repo	18.2	**0.63**	4.61	**0.29**	2.15	0.89	1.40	8.1	0.93
OIS	18.2	**0.63**	4.61	**0.29**	2.14	0.89	1.40	8.1	0.93
Fed funds	67.7	**0.62**	4.57	**0.28**	2.10	0.89	1.40	8.1	0.93
One-month LIBOR	58.7	**0.61**	4.50	**0.27**	2.04	0.89	1.40	8.1	0.91
Three-month LIBOR	68.3	**0.61**	4.47	**0.27**	2.00	0.89	1.40	8.1	0.91
Panel C: Treasury									
T-bills	0.0	**0.17**	6.26	**0.16**	6.18	0.59	3.38	2.4	0.81
Repo	18.2	**0.12**	4.69	**0.12**	4.59	0.59	3.38	2.5	0.61
OIS	18.2	**0.12**	4.72	**0.12**	4.64	0.59	3.38	2.4	0.61
Fed funds	59.2	**0.06**	2.09	0.05	1.95	0.59	3.38	2.5	0.27
One-month LIBOR	58.7	0.04	1.45	0.04	1.37	0.59	3.38	2.5	0.19
Three-month LIBOR	68.3	0.02	0.61	0.01	0.53	0.59	3.38	2.5	0.08
Bond futures		**0.34**	2.59	**0.39**	2.95	0.58	5.04	6.3	0.65

Table B7
International equities: out of sample, DataStream data

This table shows calendar-time portfolio returns of betting against beta (BAB) factors. To construct the BAB factor, all stocks are assigned to one of two portfolios: low beta and high beta. The low- (high-) beta portfolio is composed of all stocks with a beta below (above) its country median. Stocks are weighted by the ranked betas (lower beta security have larger weight in the low-beta portfolio and higher beta securities have larger weights in the high-beta portfolio), and the portfolios are rebalanced every calendar month. Both portfolios are rescaled to have a beta of one at portfolio formation. The BAB factor is a self-financing portfolio that is long the low-beta portfolio and short the high-beta portfolio. This table includes all available common stocks on the DataStream database for the 19 markets listed Table 1. Alpha is the intercept in a regression of monthly excess return. The explanatory variables are the monthly returns from Fama and French (1993), Carhart (1997), and Asness and Frazzini (2013) mimicking portfolios. Returns and alphas are in monthly percent. A 5% statistical significance is indicated in bold. Volatilities and Sharpe ratios are annualized.

Country	Excess return	*t*-statistics excess	Four-factor alpha	t-statistics alpha	Sharpe ratio	Start	End	Number of months
Australia	0.55	1.20	0.60	1.30	0.33	1977	1990	158
Austria	1.34	1.84	1.42	1.92	0.50	1977	1990	164
Belgium	0.38	1.38	0.26	0.92	0.39	1977	1989	154
Canada	0.65	1.84	0.39	1.11	0.56	1977	1987	131
Switzerland	0.25	1.02	0.04	0.18	0.28	1977	1989	154
Germany	0.35	1.48	0.26	1.07	0.41	1977	1989	154
Denmark	0.22	0.51	-0.06	-0.14	0.14	1977	1990	161
France	**0.82**	2.37	0.66	1.87	0.66	1977	1989	156
United Kingdoı	**0.67**	2.99	**0.68**	3.02	0.66	1969	1989	249
Hong Kong	0.84	1.76	0.68	1.40	0.48	1977	1990	161
Italy	0.31	1.06	0.20	0.68	0.29	1977	1989	155
Japan	**0.93**	2.57	**0.80**	2.17	0.72	1977	1989	154
Netherlands	0.47	1.56	0.32	1.06	0.43	1977	1989	155
Norway	**1.20**	2.03	**1.21**	2.00	0.55	1977	1990	161
Singapore	0.62	1.40	0.65	1.45	0.38	1977	1990	162
Sweden	-1.60	-0.81	-2.15	-1.04	-0.32	1977	1989	79

Table B8
All assets: robustness, betas with respect to a global market portfolio, 1973–2009

This table shows calendar-time portfolio returns. The test assets are cash equities, bonds, futures, forwards or swap returns in excess of the relevant financing rate. To construct the betting against beta (BAB) factor, all securities are assigned to one of two portfolios: low beta and high beta. Securities are weighted by the ranked betas (lower beta security have larger weight in the low-beta portfolio and higher beta securities have larger weights in the high-beta portfolio) and the portfolios are rebalanced every calendar month. Betas as computed with respect to the global market portfolio from Asness, Frazzini and Pedersen (2012). Both portfolios are rescaled to have a beta of one at portfolio formation. The BAB factor is a self-financing portfolio that is long the low-beta portfolio and short the high-beta portfolio. Alpha is the intercept in a regression of monthly excess return. The explanatory variable is the monthly return of the global market portfolio. All bonds and credit includes US Treasury bonds, US corporate bonds, US credit indices (hedged and unhedged) and country bonds indices. All equities included US equities, international equities, and equity indices. All assets includes all the assets listed table 1 and 2. The all equities and All Assets combo portfolios have equal risk in each individual BAB and 10% ex ante volatility. To construct combo portfolios, at the beginning of each calendar month, we rescale each return series to 10% annualized volatility using rolling three-year estimate up to moth t-1 and then equally weight the return series. Returns and alphas are in monthly percent, t-statistics are shown below the coefficient estimates and 5% statistical significance is indicated in bold. $Short ($Long) is the average dollar value of the short (long) position. Volatilities and Sharpe ratios are annualized.

Portfolio	Excess return	t-statistics excess return	Four-factor alpha	t-statistics alpha	$Short	$Long	Volatility	Sharpe ratio
Panel A: Global results								
US equities	**0.77**	5.10	**0.68**	4.59	0.47	1.38	0.10	0.91
International equities	**0.82**	3.45	**0.67**	2.98	0.60	1.49	0.13	0.73
All bonds and credit	**1.33**	2.93	**1.26**	2.74	22.66	25.81	31.99	0.50
All futures	**1.25**	2.45	**1.10**	2.16	1.22	3.02	0.36	0.41
All equities	**0.66**	4.73	**0.53**	4.06			9.71	0.82
All assets	**0.67**	4.21	**0.57**	3.66			11.00	0.73

Table B9
US and international equities: robustness, value-weighted betting against beta factors

This table shows calendar-time portfolio returns of value-weighted betting against beta (BAB) factors. The BAB factor is constructed using six value-weighted portfolios formed on size and beta. We form one set of portfolios in each country and compute an international portfolio by weighting each country's portfolio by the country's total (lagged) market capitalization. At the end of each calendar month, stocks are assigned to two size-sorted portfolios based on their market capitalization and to three beta-sorted portfolios (low, medium and high) based on the 30th and 70th percentile. For US securities, the size breakpoint is the median NYSE market equity. For international securities the size breakpoint is the 80th percentile by country. For the international sample, we use conditional sorts (first sorting on size, then on beta) to ensure we have enough securities in each portfolio (US sorts are independent). Portfolios are value weighted, refreshed every calendar month, and rebalanced every calendar month to maintain value weights. We average the small and large portfolio to form a low beta and high beta portfolio. The dollar neutral BAB is a self-financing portfolio long the low beta portfolio and short the high beta portfolio. The beta-neutral BAB is a self-financing portfolio long the low beta portfolio levered to a beta of one and short the high beta portfolio delevered to a beta of one. This table includes all available common stocks on the Center for Research in Security Prices database and all available common stocks on the Xpressfeed Global database for the 19 markets listed in Table 1. Alpha is the intercept in a regression of monthly excess return. The explanatory variables are the monthly returns from Fama and French (1993), Carhart (1997), and Asness and Frazzini (2013) mimicking portfolios. Returns and alphas are in monthly percent, t-statistics are shown below the coefficient estimates, and 5% statistical significance is indicated in bold. $Short ($Long) is the average dollar value of the short (long) position. Volatilities and Sharpe ratios are annualized. CAPM = Capital Asset Pricing Model.

	Alpha				*t*-statistics							
Universe, method	Excess return	CAPM	Three-factor	Four-factor	Excess return	CAPM	Three-factor	Four-factor	$Short	$Long	Volatility	Sharpe ratio
US, beta neutral	**0.51**	**0.60**	**0.59**	**0.45**	5.22	6.30	6.25	4.72	0.71	1.31	10.77	0.57
US, dollar neutral	0.03	**0.51**	**0.61**	**0.45**	0.20	5.08	6.59	4.88	1.00	1.00	19.20	0.02
International, beta neutral	**0.68**	**0.70**	**0.75**	**0.33**	4.85	4.99	5.31	2.42	0.89	1.44	8.30	0.98
International, dollar neutral	0.23	**0.34**	**0.51**	0.22	1.26	2.61	4.02	1.74	1.00	1.00	10.77	0.26

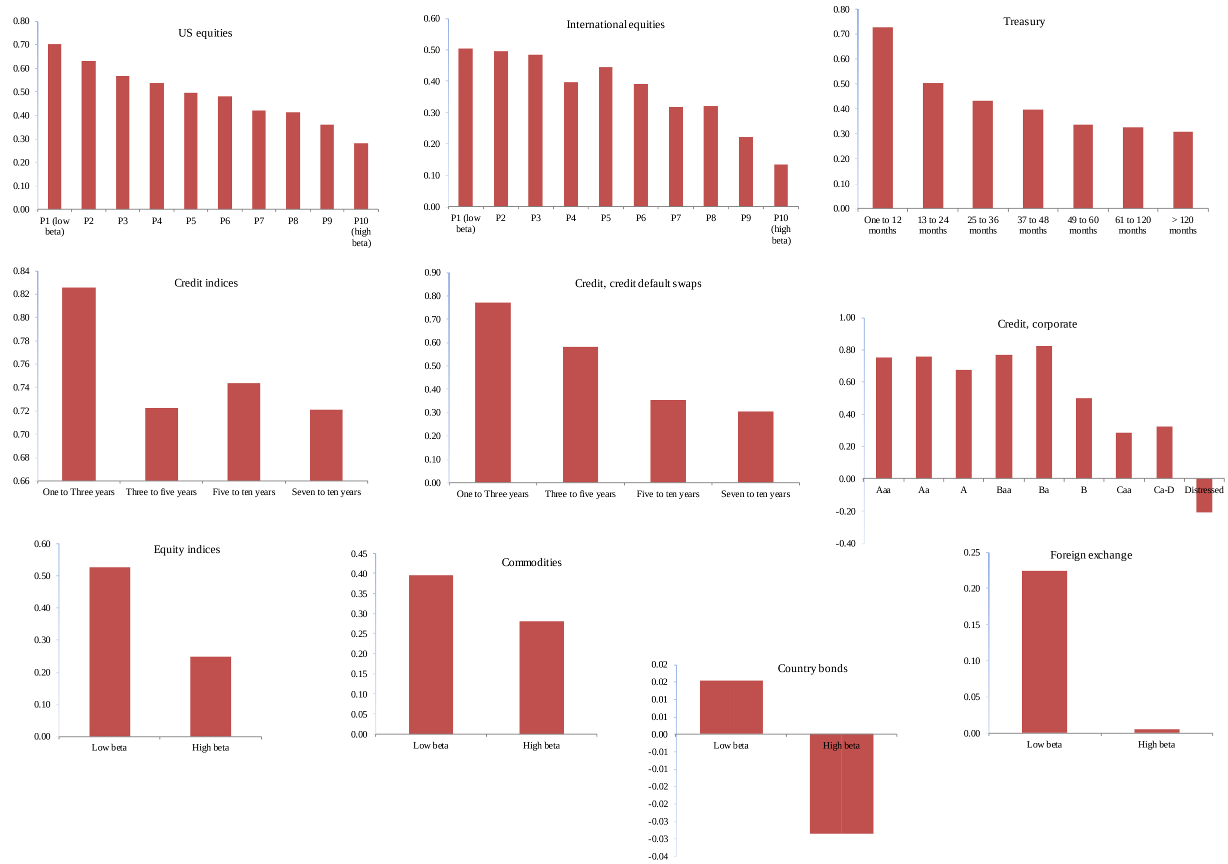

Fig. B1. Sharpe ratios of beta-sorted portfolios. This figure shows Sharpe ratios. The test assets are beta-sorted portfolios. At the beginning of each calendar month, securities are ranked in ascending order on the basis of their estimated beta at the end of the previous month. The ranked securities are assigned to beta-sorted portfolios. This figure plots Sharpe ratios from low beta (left) to high beta (right). Sharpe ratios are annualized.

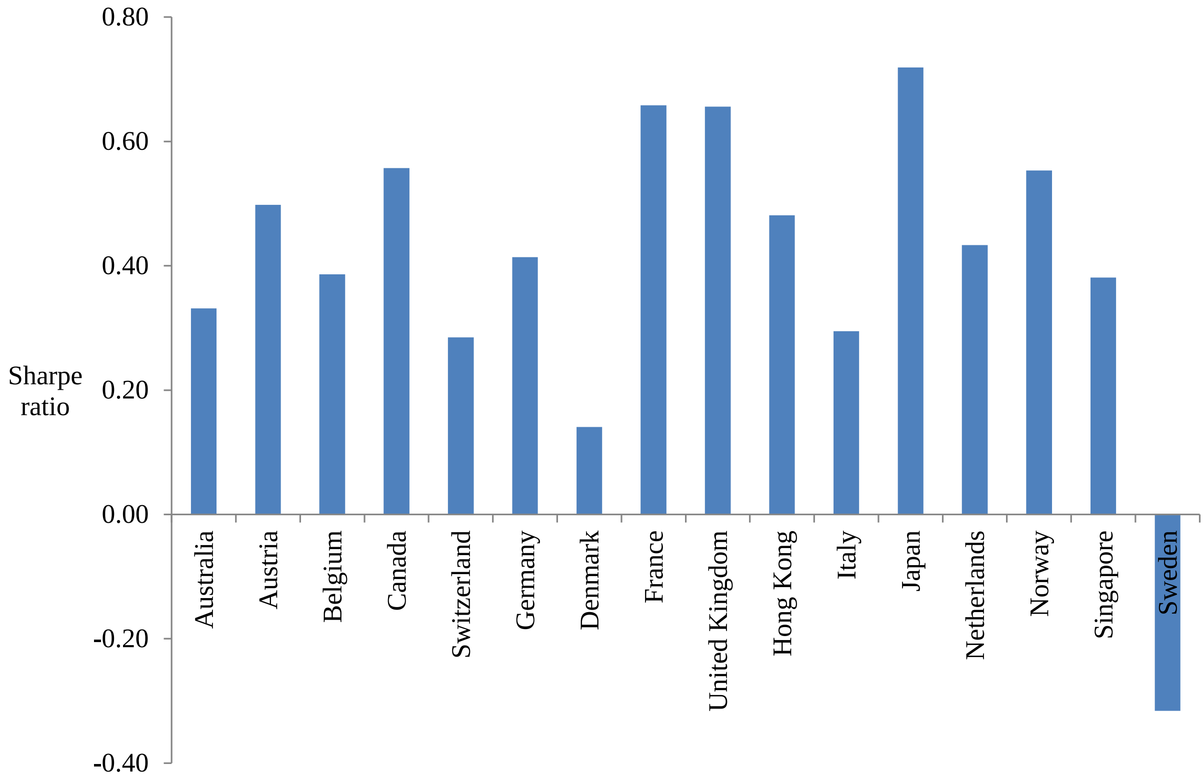

Fig. B2. International equities: out of sample, DataStream data. This figure shows annualized Sharpe ratios of betting against beta (BAB) factors. To construct the BAB factor, all securities are assigned to one of two portfolios: low beta and high beta. Securities are weighted by the ranked betas, and the portfolios are rebalanced every calendar month. Both portfolios are rescaled to have a beta of one at portfolio formation. The BAB factor is a self-financing portfolio that is long the low-beta portfolio and short the high-beta portfolio. Sharpe ratios are annualized.

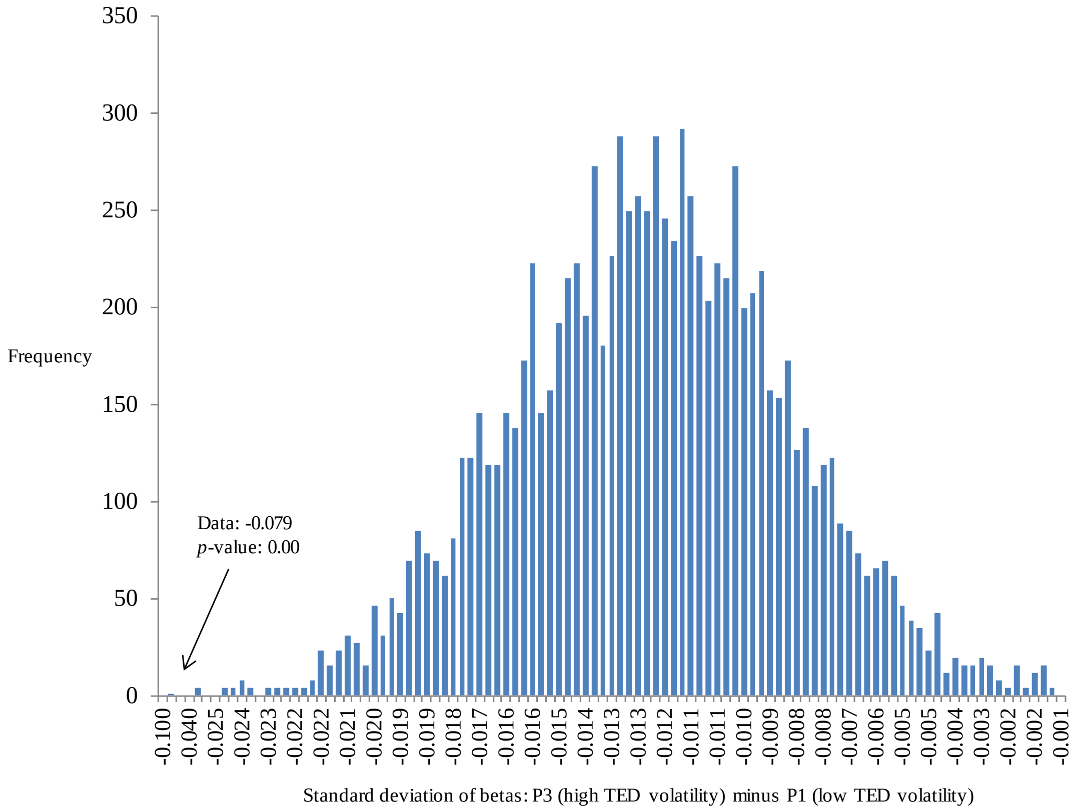

Fig. B3. US equities: beta compression, simulation results. This figure reports the distribution of the difference in cross sectional standard deviation of estimated betas between high (P3) and low (P1) funding liquidity risk periods under the null hypothesis of no time variation in the cross-sectional dispersion of true betas. We compute a bootstrap sample under the null hypothesis of no variation in the cross-sectional dispersion of betas by fixing each stock's beta to its full sample realized beta and sampling with replacement from the time series distribution of idiosyncratic returns. We use monthly data, estimate rolling betas on the simulated sample (as described in Section 2), and compute beta compression statistics of Table 10, panel A. We repeat this procedure ten thousand times. This figure includes all available common stocks on the Center for Research in Security Prices database.

Appendix C. Calibration

We consider a simple calibration exercise to see if the model can generate the quantitative as well as the qualitative features of the data. In particular, a calibration can shed light on what is required to generate the empirically observed flatness of the security market line and BAB performance in terms of the severity of funding restrictions or the cross-sectional dispersion of risk aversions, or both.

For this exercise, we consider the parameterizations of the model that are indicated in Table C1. We consider a single-period version of the model, although it could be embedded into a stationary overlapping generations setting. There are two types of agents, 1 and 2, and the table indicates each agent's leverage constraint given by the (margin requirement) m^i, his "relative risk aversion," and the fraction of agents of type 1. The representative agent of type i is, therefore, assumed to have an absolute risk aversion, which is the relative risk aversion divided by the wealth of that group of agents. The total wealth is normalized to one hundred. Hence, in a calibration in which 50% of the agents are of type 1, the absolute risk aversion will be the relative risk aversion divided by 100 × 0.50 = 50.

The risk-free interest rate is set at $r^f = 3.6\%$ to match the average T-bill rate, and there are two risky assets, each in unit supply. The low-risk asset is denoted asset L, and the high-risk asset is denoted H. We set the expected payment of each risky asset at $100\,(1+r^f)\,/\,2$ so that the total payment is in line with aggregate wealth. Further, we assume the final payoff of asset 1 has variance 40, the variance of asset 2 is 205, and the covariance of these payoffs is 84. These numbers are chosen to roughly match the empirical volatilities and correlations of the asset returns. (The asset returns are endogenous variables so they differ slightly across calibrations.)

The first column of Table C1 has the CAPM benchmark in which no agent is constrained ($m^1 = m^2 = 0$). Naturally, the expected return of the BAB factor is zero in this case. The last column shows, as a benchmark, the empirical counterparts of the outcome variables. As an empirical proxy for asset L, we use the unleveraged low-beta portfolio r^L defined in eq. (17), and, similarly, asset H is the high-beta portfolio r^H. To be consistent with the calibration, we let the market be the average of r^L and r^H (but we could also use the standard value-weighted market).

Columns 2-4 are three calibrations with constrained agents for different parameter values. The parameters are not chosen to maximize the fit but simply illustrate the model's predictions for the BAB return in different economic settings. In the first of these calibrations, both agents are leverage constrained with $m^1 = m^2 = 1$ and the agents differ in their risk aversion. In this calibration, the risk-averse investor requires a higher risk premium, chooses a smaller position, and is not constrained in equilibrium. The more risk-tolerant investor hits his leverage constraint and, therefore, tilts his portfolio toward the high-beta asset, thus flattening the security market line. The BAB portfolio, therefore, has a positive return premium of 4% per year, corresponding to a Sharpe ratio of 0.47. While this calibration naturally does not match all the moments of the data exactly, it gets in the ballpark.

The next calibration with constrained agents considers agents who have the same risk aversion, but one of them has the severe capital constraint that he must keep almost 20% of his capital in cash ($m^1 = 1.2$). While this constraint is binding in equilibrium, the effect on asset prices is very small, and the BAB portfolio has a Sharpe ratio of 0.01.

The last calibration has agents with different risk aversions of which 80% are more risk tolerant and face severe capital constraints. In this calibration, the BAB portfolio has a Sharpe ratio of 0.78, similar to the empirical counterpart.

These calibrations illustrate that severe capital constraints for a sizable fraction of the investors can potentially explain a significant flattening of the security market line with an associated return premium for the BAB portfolio. An interesting (and challenging) project for future research is to more formally calibrate the model using data on the relative sizes of different investor groups, the severity of their capital constraints, and their risk preferences.

Table C1

Model calibrations

The first column is a calibration under the standard capital asset pricing model (CAPM) with no constraints. The next three columns illustrate the model with leverage constraints. The last column shows the same quantities using estimated values from US equities, 1926-2011. The table shows the exogenous variables and the endogenous outcome variables, namely, the annual volatility, excess return, and betas of, respectively, the low-risk (L) asset, the high-risk asset (H), the market portfolio (MKT), and the betting against beta (BAB) factor. The market portfolio in the data is the average of the low-beta and high-beta portfolios for consistency with the calibration.

	Standard CAPM	Constrained agents I	Constrained agents II	Constrained agents III	Data
Exogenous variables					
Risk aversion, agent 1	1	1	1	1	NA
Risk aversion, agent 2	1	10	1	10	NA
Fraction of type 1 agents	Any	50%	50%	80%	NA
Funding constraint, m1	0	1.0	1.2	1.2	NA
Funding constraint, m2	0	1.0	0.0	0.0	NA
Endogenous variables					
Volatility, L	13%	14%	13%	14%	18%
Volatility, H	30%	33%	30%	33%	35%
Volatility, MKT	21%	23%	21%	23%	26%
Volatility, BAB	8%	9%	8%	9%	11%
Excess return, L	3%	9%	3%	10%	11%
Excess return, H	6%	16%	6%	15%	12%
Excess return, MKT	4%	12%	4%	13%	12%
Excess return, BAB	0%	4%	0%	7%	8%
Beta^L	0.6	0.6	0.6	0.6	0.7
Beta^H	1.4	1.4	1.4	1.4	1.3