Creative destruction and asset prices
Online appendix

Contents

1 Results for equal-weighted size and book-to-market sorted portfolios

In the main text we report the results for value-weighted size and book-to-market sorted portfolios. As the following tables show the CDRM and MP-CDRM become more pronounced for equal-weighted portfolios.

Table O-1: Portfolio excess returns of equal-weighted portfolios: descriptive statistics

The table shows the summary statistics for yearly excess returns (in percent) of the 25 size- (vertical) and B/M- (horizontal) sorted portfolios (equal-weighted) from 1927-2008.

	Mean					Std. Dev.				
	Low	2	3	4	High	Low	2	3	4	High
Small	6.9	14.6	16.5	19.8	25.8	41.6	42.8	38.6	47.0	51.0
2	7.3	12.6	14.8	15.0	15.6	35.2	34.0	33.3	35.1	35.1
3	7.9	11.4	12.7	13.1	15.1	30.0	29.3	27.6	28.0	32.4
4	7.9	9.2	10.9	12.2	13.5	24.6	26.1	27.2	28.2	36.6
Big	6.6	8.2	9.1	9.7	10.8	21.3	20.4	24.1	27.0	32.9

Table O-2: CDRM: Time series regression results (equal-weighted portfolios)

The table reports the beta estimates that result from time series regressions of excess returns on the CDRM risk factors. Test assets are the 25 equal-weighted portfolios sorted by size (vertical) and book-to-market value (horizontal). The sample period is 1927-2008, and the sampling frequency is annual. The t-statistics are formulated for the null hypothesis that the true parameter is zero. The table also displays the coefficient of determination of each time-series regression (R^2_{ts}). See main text for more details.

	Low	2	3	4	High	Low	2	3	4	High
			$\hat{\beta}_W$					t		
Small	1.498	1.671	1.451	1.625	1.740	10.79	12.35	11.56	5.78	6.48
2	1.388	1.363	1.310	1.371	1.363	10.39	8.65	8.81	8.40	9.67
3	1.259	1.214	1.165	1.158	1.261	12.16	10.77	13.89	15.80	10.76
4	1.085	1.104	1.172	1.165	1.456	19.23	11.51	13.66	14.26	8.46
Big	0.981	0.931	1.069	1.133	1.277	31.19	24.98	19.03	11.58	9.74
			$\hat{\beta}_N$					t		
Small	-0.237	-0.338	-0.405	-0.522	-0.603	-1.36	-1.97	-2.69	-2.43	-2.40
2	-0.250	-0.249	-0.336	-0.335	-0.305	-1.90	-2.02	-2.49	-2.24	-2.04
3	-0.067	-0.249	-0.219	-0.283	-0.288	-0.63	-2.26	-2.10	-2.51	-1.99
4	0.055	-0.144	-0.176	-0.277	-0.164	0.83	-1.76	-1.84	-2.78	-1.14
Big	0.125	-0.077	-0.128	-0.106	-0.178	2.70	-1.63	-1.68	-1.15	-1.69
			R^2_{ts} (%)							
Small	57.3	68.0	64.5	55.3	54.1					
2	68.9	71.2	69.8	68.9	67.5					
3	76.0	76.7	79.0	76.9	68.0					
4	83.7	78.5	81.7	76.9	69.1					
Big	90.9	90.4	86.4	76.7	66.2					

Table O-3: Cross-sectional regression results (equal-weighted portfolios)

The table reports the λ estimates for the CDRM and the Mimicking Portfolio-CDRM (MP-CDRM) and the benchmark models, the Fama-French model and the CAPM. Test assets are the 25 size- and book-to-market-sorted portfolios (equal-weighted). We use annual data 1927-2008. The table also reports the $p-$value of the $J-$statistic and the cross-sectional OLS coefficient of determination (R^2_{cs}). The values in parentheses are t-statistics for the null hypothesis that the true parameter is zero. $J-$ and $t-$statistics are based on GMM inference. In brackets appear bootstrapped $p-$values for the $t-$statistics and the R^2_{cs} (the null hypothesis is that the model has no explanatory power).

	$\hat{\lambda}_W$	$\hat{\lambda}_{HML}$	$\hat{\lambda}_{SMB}$	$\hat{\lambda}_N$ or $\hat{\lambda}_{\tilde{N}}$	J	R^2_{cs}
CDRM	0.061 (2.52) [1.0 %]			-0.187 (-2.90) [0.5 %]	0.5 %	72.7 % [4.0 %]
MP-CDRM	0.055 (2.19) [2.5 %]			-0.026 (-2.86) [0.1 %]	1.1 %	80.8 % [1.2 %]
Fama-French	0.061 (2.45) [1.4 %]	0.066 (4.05) [<0.1 %]	0.049 (3.28) [0.2 %]		0.4 %	83.3 % [2.1 %]
CAPM	0.096 (4.21) [<0.1 %]				0.2 %	43.6 % [8.3 %]

Table O-4: CDRM: risk compensations (equal-weighted portfolios)

The table shows the estimated expected excess return compensations (in percent) that are associated with market risk ($\hat{\beta}_W \times \hat{\lambda}_W$) and creative destruction risk ($\hat{\beta}_N \times \lambda_N$). Test assets are the 25 equal-weighted portfolios sorted by size (vertical) and book-to-market value (horizontal). The sample period is 1927-2008, and the sampling frequency is annual. The delta method is used to compute the t-statistic for a test that the respective risk compensation is zero.

	Low	2	3	4	High	Low	2	3	4	High
	$\hat{\beta}_W \times \hat{\lambda}_W \times 100$					t				
Small	9.2	10.2	8.9	10.0	10.7	2.43	2.35	2.38	2.14	2.17
2	8.5	8.4	8.0	8.4	8.4	2.32	2.26	2.29	2.26	2.33
3	7.7	7.4	7.1	7.1	7.7	2.38	2.36	2.37	2.42	2.37
4	6.7	6.8	7.2	7.1	8.9	2.43	2.37	2.39	2.43	2.27
Big	6.0	5.7	6.6	6.9	7.8	2.49	2.49	2.46	2.42	2.47
	$\hat{\beta}_N \times \hat{\lambda}_N \times 100$					t				
Small	4.4	6.3	7.6	9.8	11.3	1.27	2.34	3.39	3.23	3.42
2	4.7	4.7	6.3	6.3	5.7	2.09	2.46	3.45	3.24	2.97
3	1.3	4.7	4.1	5.3	5.4	0.68	2.77	2.85	3.21	2.64
4	-1.0	2.7	3.3	5.2	3.1	-0.76	2.03	2.19	3.33	1.35
Big	-2.3	1.5	2.4	2.0	3.3	-2.37	1.64	1.94	1.29	1.76

Table O-5: Mimicking portfolio-CDRM: Time series and cross-sectional regression results (equal-weighted portfolios)

Panel A reports the beta estimates that result from time series regressions of the test assets' excess returns on the invention-mimicking portfolio's excess return, $r^e_{\tilde{N}}$, and the return of the wealth portfolio proxy, r_W. Test assets are the 25 equal-weighted Fama-French portfolios sorted by size (vertical) and book-to-market value (horizontal). The sample period is 1927-2008, and the sampling frequency is annual. The t-statistics are formulated for the null hypothesis that the true parameter is zero. Panel A also displays the coefficient of determination of each time series regression (R^2_{ts}). Panel B reports the estimated lambdas from a cross-sectional regression of average excess returns on the estimated betas, as well as $\Delta\hat{\lambda} = \hat{\lambda}_{\tilde{N},cs} - \hat{\lambda}_{\tilde{N},ts}$, and the associated p-value of a Wald test that $\Delta\hat{\lambda}$ is significantly different from zero. Statistical inference takes into account that the parameters are estimated via three subsequent regressions that yield the mimicking portfolio weights, the beta estimates, and the lambda estimates.

Panel A: Time Series Regressions

	Low	2	3	4	High	Low	2	3	4	High
			$\hat{\beta}_W$					t		
Small	1.430	1.575	1.312	1.437	1.531	8.20	8.14	5.87	4.47	4.45
2	1.322	1.263	1.188	1.230	1.226	8.42	7.02	6.23	5.67	5.43
3	1.234	1.132	1.075	1.056	1.135	12.06	8.31	8.38	7.32	5.66
4	1.094	1.048	1.099	1.082	1.365	17.63	9.64	9.91	7.86	7.25
Big	1.014	0.913	1.017	1.068	1.214	20.52	21.82	14.24	9.37	7.78
			$\hat{\beta}_{\tilde{N}}$					t		
Small	-1.766	-2.489	-3.531	-4.750	-5.298	-1.34	-2.07	-2.66	-2.47	-2.64
2	-1.737	-2.504	-3.079	-3.495	-3.372	-1.65	-2.34	-2.78	-2.80	-2.52
3	-0.626	-2.086	-2.248	-2.574	-3.115	-0.74	-2.49	-3.00	-2.92	-2.40
4	0.253	-1.397	-1.818	-2.153	-2.208	0.43	-2.03	-2.56	-2.43	-1.70
Big	0.882	-0.473	-1.285	-1.573	-1.582	3.00	-1.58	-2.40	-1.81	-1.31
			R^2_{ts} (%)							
Small	60.0	73.1	78.0	72.0	71.5					
2	72.5	80.3	83.7	85.7	83.3					
3	76.7	84.8	90.2	90.6	83.7					
4	83.8	83.3	89.2	85.9	75.5					
Big	93.5	91.1	91.2	82.7	69.9					

Panel B: Cross-Sectional and Time Series λ estimates

$\hat{\lambda}_W$	0.055	$t_{\hat{\lambda}_W}$	2.19
$\hat{\lambda}_{\tilde{N},cs}$	-0.026	$t_{\hat{\lambda}_{\tilde{N},cs}}$	-2.86
$\hat{\lambda}_{\tilde{N},ts}$	-0.017	$t_{\hat{\lambda}_{\tilde{N},ts}}$	-1.85
$\Delta\hat{\lambda}$	-0.010	p-val. $W_{\Delta\lambda}$	33.5 %

Table O-6: Mimicking portfolio-CDRM: risk compensations (equal-weighted portfolios)

The table reports estimated expected excess return compensations (percentage) that are implied by the mimicking portfolio version of the CDRM. Test assets are the 25 portfolios sorted by size (vertical) and book-to-market value (horizontal). The sample period is 1927-2008, and the sampling frequency is annual. The delta method is used to compute the t-statistic for a test that the respective risk-compensation is zero. Statistical inference takes into account that the parameters are obtained by three subsequent regressions that yield the mimicking portfolio weights, the beta estimates, and the lambda estimates.

	Low	2	3	4	High	Low	2	3	4	High
	$\hat{\beta}_W \times \hat{\lambda}_W \times 100$					t				
Small	7.8	8.6	7.2	7.8	8.3	2.10	2.04	2.05	1.90	1.91
2	7.2	6.9	6.5	6.7	6.7	2.04	2.00	2.02	2.00	2.04
3	6.7	6.2	5.9	5.8	6.2	2.08	2.07	2.09	2.11	2.07
4	6.0	5.7	6.0	5.9	7.4	2.09	2.07	2.10	2.13	2.04
Big	5.5	5.0	5.5	5.8	6.6	2.13	2.16	2.17	2.15	2.20
	$\hat{\beta}_{\tilde{N}} \times \hat{\lambda}_{\tilde{N}} \times 100$					t				
Small	4.6	6.5	9.2	12.4	13.8	1.30	2.17	3.11	3.00	3.28
2	4.5	6.5	8.0	9.1	8.8	1.67	2.58	3.35	3.66	3.64
3	1.6	5.5	5.9	6.7	8.1	0.73	2.68	3.45	3.87	3.31
4	-0.7	3.7	4.8	5.6	5.8	-0.44	2.17	3.24	3.26	2.20
Big	-2.3	1.2	3.4	4.1	4.1	-3.34	1.53	2.42	2.29	1.52

2 Results for single-sorted portfolios

Figure O-1 and Figure O-2 illustrate the cross-sectional fit of CDRM, MP-CDRM and the two benchmark models using the excess returns of the single-sorted decile portfolios as test assets. Figure O-1 confirms the well-known result that the CAPM is quite effective in explaining the cross-sectional variation of size sorted portfolios.[1] Panel C and Panel B show that CDRM and the Fama-French model are successful in further reducing the CAPM pricing errors for the small and the large decile. Because the market risk factor can explain the cross-sectional variation of size sorted portfolios remarkably well, the additional factors (*SMB*, *HML* or *pg*) are not statistically significant. Figure O-2 shows that the improvement offered by the CDRM and the Fama-French model is more prominent for book-to-market deciles. Table O-7 shows that the estimates $\hat{\lambda}_N$ and $\hat{\gamma}_N$ retain the negative sign that is consistent with theoretical considerations, albeit estimation precision is reduced. Again, the relative risk aversion estimate implied by the CDRM is plausible from an economic point of view.

[1]Compare Panel A of Figure O-1 with Figure 4 (upper panel) in Cochrane (1996) and the remark in Cochrane (1999): "If all failed models worked that well".

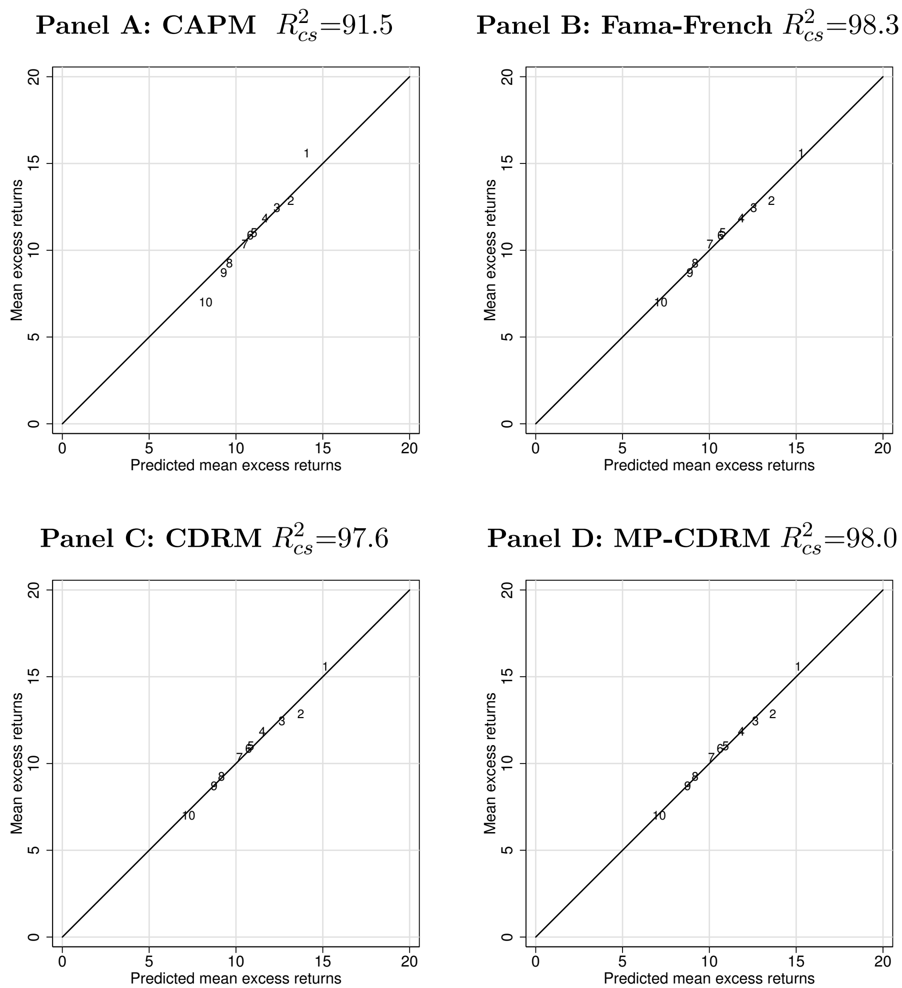


Figure O-1: Predicted vs. actual mean excess returns for the CAPM, Fama-French model, CDRM, and MP-CDRM: size sorted portfolios (single sort)

The four panels compare the predicted and the realized average excess returns (percentage) given by the CAPM (Panel A), the Fama-French model (Panel B), the CDRM (Panel C) and the MP-CDRM (Panel D). The sample period is 1927-2008; the sampling frequency is annual. The test assets are the value-weighted 10 portfolios sorted by market capitalization, where the number denotes the size decile (1=lowest, 10=highest).

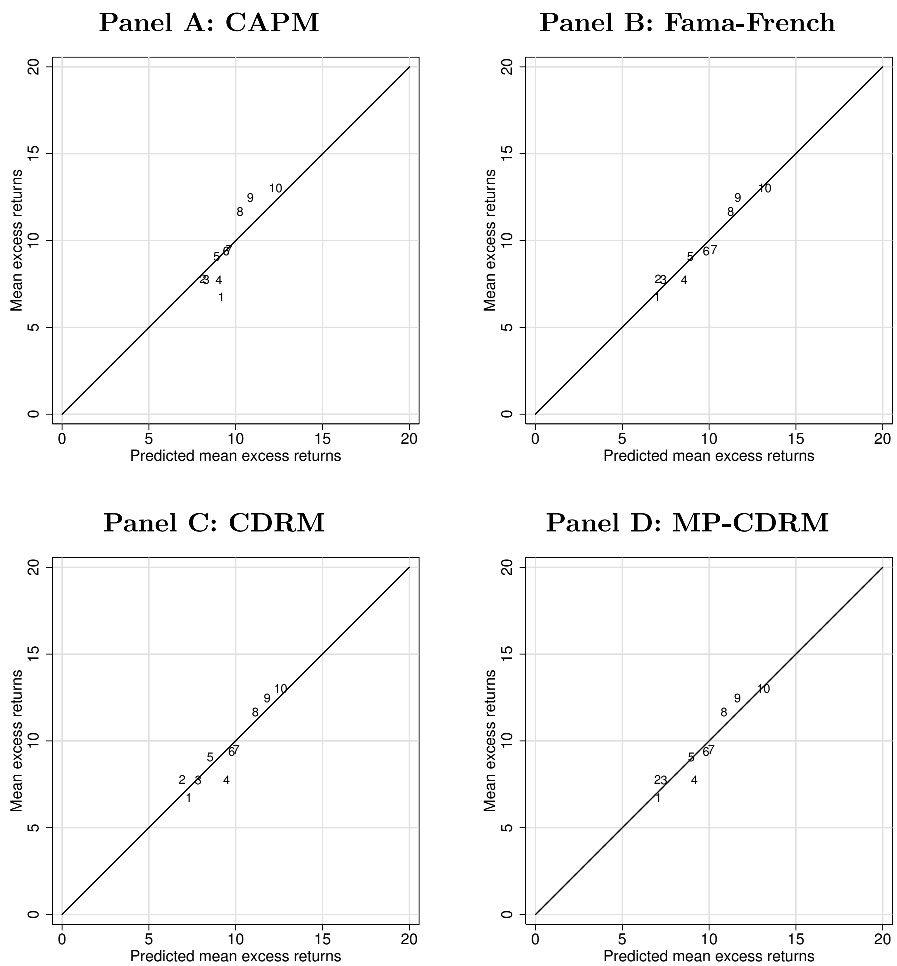


Figure O-2: Predicted vs. actual mean excess returns for the CAPM, Fama-French model, CDRM, and MP-CDRM: Book-to-market sorted portfolios (single sort)

The four panels compare the predicted and the realized average excess returns (percentage) given by the CAPM (Panel A), the Fama-French model (Panel B), the CDRM (Panel C) and the MP-CDRM (Panel D). The sample period is 1927-2008; the sampling frequency is annual. The test assets are the value-weighted 10 portfolios sorted by book-to-market value, where the number denotes the size decile (1=smallest, 10=largest).

Table O-7: Cross-sectional regression and test results: Book-to-market sorted portfolios (single sort)

The table reports the cross-sectional estimation results for the CDRM, the MP-CDRM, and the benchmark models. We report the lambda estimates and the estimates of relative risk aversion (rra) (CDRM and Fama-French model), and γ_N and $\gamma_{\widetilde{N}}$ (CDRM and MP-CDRM). We report the results based on annual data 1927-2008 and use the excess returns of the value-weighted book-to-market sorted portfolios as test assets. We also report the cross-sectional coefficient of determination (R^2_{cs}), the mean absolute pricing error (MAE), the p-values associated with the J-statistic, and the Wald statistic in Equation (16) in the main text. In parentheses are t-statistics for the null hypothesis that the true parameter is 0. The J-and t-statistics are based on GMM inference as outlined in Appendix A.2 in the main text. In brackets appear bootstrapped p-values for the t-statistics, R^2_{cs} and MAE (see Appendix A.3 in the main text).

Book-to-market sorted portfolios, annual data

	$\hat{\lambda}_W$	$\hat{\lambda}_{HML}$	$\hat{\lambda}_{SMB}$	$\hat{\lambda}_N$ or $\hat{\lambda}_{\widetilde{N}}$	$\widehat{rra}$	$\hat{\gamma}_N$ or $\hat{\gamma}_{\widetilde{N}}$	J [%]	R^2_{cs}	$W_{\Delta\lambda}$ [%]	MAE
CDRM	0.082			-0.086	1.744	-4.440	11.7	86.7		0.63
	(3.66)			(-1.36)	(3.07)	(-1.31)		[1.1%]		[1.0%]
	[<0.1%]			[16.5%]	[<0.1%]	[18.6%]				
MP-CDRM	0.081			-0.012		-4.813	23.0	88.9	54.7	0.58
	(3.64)			(-1.67)		(-1.22)		[0.7%]		[0.5%]
	[<0.1%]			[2.7%]		[13.8%]				
Fama-French	0.081	0.041	0.005		2.028		52.3	92.7		0.50
	(3.50)	(1.59)	(0.09)		(2.12)			[0.8%]		[0.7%]
	[<0.1%]	[6.2%]	[95.3%]		[0.9%]					
CAPM	0.090						8.8	69.3		0.87
	(3.976)							[2.2%]		[1.1%]
	[<0.1%]									

3 Pricing of SMB and HML by the CDRM

An alternative way to test whether the CDRM can price *HML* and *SMB* amounts to testing whether the estimated intercepts in a time series regresssion of *SMB* and *HML* on a model's risk factors are significantly different from zero. This idea can be found in Cochrane's 2013 notes on empirical methods in asset pricing. However, to apply the method, all risk factors must be excess returns, which is not the case for the CDRM. We therefore use an MP-CDRM variant, in which the market return r_W is replaced by the market excess return, r^e_W, which results from subtracting the risk-free rate proxy from r_W. The second factor is the excess return of the invention-mimicking portfolio, $r^e_{\tilde{N},t}$. We can then estimate the following two regression equations by OLS,

$$SMB_t = \alpha_S + \beta_{W,S} \cdot r^e_{W,t} + \beta_{M,S} \cdot r^e_{\tilde{N},t} + \varepsilon_{S,t} \qquad \text{(O-1)}$$

$$HML_t = \alpha_H + \beta_{W,H} \cdot r^e_{W,t} + \beta_{M,H} \cdot r^e_{\tilde{N},t} + \varepsilon_{H,t}, \qquad \text{(O-2)}$$

and test for the significance of the estimated intercepts. Of course, we have to account for the fact that the mimicking portfolio weights are estimated. We therefore proceed as described in Appendix A.1.2 in the main text and treat the estimation problem as an instance of GMM. This procedure ensures correct statistical inference on the pricing error estimates $\hat{\alpha}_S$ and $\hat{\alpha}_H$.

Estimation results of the regressions (O-1) and (O-2) are reported in Table O-8. Panel A shows that using only the market excess return as a risk factor (i.e. a static CAPM variant), the estimated pricing error is almost as large as the mean of *HML*. When the invention-mimicking portfolio is included, we obtain a highly significant beta estimate, and the time series R^2 increases from virtually zero to 45 percent. The pricing error estimate $\hat{\alpha}_H$ is considerably reduced and not significantly different from zero (p-value 47.6 percent). Panel B shows that a CAPM specification that uses the market excess return does a better job pricing *SMB*. Including the invention-mimicking portfolio, we obtain a highly significant beta estimate, the pricing error is further reduced, and the R^2 increases from 17 to 52 percent.

Table O-8: MP-CDRM and Fama-French Factors

The table reports the results of time-series regressions of the Fama-French factors *SMB* and *HML* on the market excess return (r_W^e) and the invention-mimicking portfolio ($r_{\tilde{N},t}^e$). The sample period is 1927-2008 at annual frequency. α denotes the intercept of the respective regression. The t-statistics (in parentheses) are formulated for the null hypothesis that the true parameter is zero. Statistical inference takes into account that the weights of the mimicking portfolio are estimated with an initial regression. See appendix A.2.2 in the main text.

	HML		SMB	
r_W^e	0.076	-0.018	0.282	0.196
	(1.03)	(-0.13)	(4.05)	(1.56)
$r_{\tilde{N},t}^e$		-2.142		-1.961
		(-1.88)		(-2.53)
α	0.046	0.017	0.014	-0.012
	(2.76)	(0.76)	(0.91)	(-0.71)
R_{ts}^2	0.01	0.45	0.17	0.52

4 High-minus-low invention beta portfolio

In order to probe the idea of using a high-minus-low invention-beta portfolio as an alternative creative destruction risk factor, we took a short-cut. Using the size and book-to-market sorted portfolios from Ken French's data base, we form a zero-cost portfolio from the highest invention beta and the lowest invention beta Fama-French portfolios. As can be seen from Panel A of Table 3 in the main text, the largest negative invention beta is associated with the small-value portfolio ($\hat{\beta}_N = -0.461$) while the largest positive invention beta is that of the large-growth portfolio ($\hat{\beta}_N = 0.138$). We then consider a "creative destruction hedge (CDH) portfolio" that is long in the highest invention-beta and short in the lowest invention-beta stocks. An alternative CDRM specification uses as a risk factor proxy the excess return of the CDH portfolio, r_{CDH}^e. The parameters of its beta representation:

$$\mathbb{E}[r_i^e] = \beta_{W,i}\lambda_W + \beta_{CDH,i}\lambda_{CDH}, \tag{O-3}$$

and its covariance representation:

$$\mathbb{E}[r_i^e] = \gamma_W \text{cov}(r_i^e, r_W) + \gamma_{CDH} \text{cov}(r_i^e, r_{CDH}^e). \tag{O-4}$$

are estimated using the methods outlined in the main text.

Table O-9: Results for an alternative CDRM specification (creative destruction hedge portfolio)

The table reports the cross-sectional estimation results for a CDRM variant that uses a creative destruction hedge portfolio as a risk factor proxy. We report the lambda estimates of the beta representation (O-3) and the estimates of γ_{CDH} from Equation (O-4). For the results in Panel A, we use the excess returns of the value-weighted size and book-to-market sorted portfolios as test assets. The sample period is 1927-2008, the sampling frequency is annual. For results in Panel B, we complement the test assets by the excess returns of 17 industry portfolios. We also report the cross-sectional coefficient of determination (R^2_{cs}), the mean absolute pricing error (MAE), the p-values associated with the J-statistic, and the Wald statistic in Equation (13) of the main text. In parentheses are t-statistics for the null hypothesis that the true parameter is 0. The J-and t-statistics are based on GMM inference as outlined in Appendix A.2 of the main text. In brackets appear bootstrapped p-values for the t-statistics, R^2_{cs} and MAE (see Appendix A.3 of the main text).

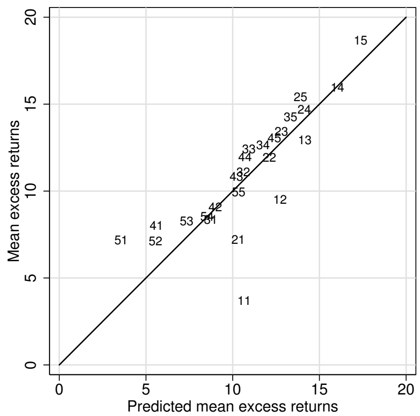
Panel A: Size and book-to-market portfolios

$\hat{\lambda}_W$	$\hat{\lambda}_{CDH}$	$\hat{\gamma}_{CDH}$	J [%]	R^2_{cs}	MAE
0.061	-0.144	-1.404	0.4	58.5	1.53
(2.62)	(-4.24)	(-3.41)		[5.2%]	[1.7%]
[0.8%]	[<0.1%]	[0.1%]			

Panel B: Including industry portfolios

$\hat{\lambda}_W$	$\hat{\lambda}_{CDH}$	$\hat{\gamma}_{CDH}$	J [%]	R^2_{cs}	MAE
0.069	-0.119	-1.012	1.3	37.0	1.71
(2.97)	(-3.61)	(-2.53)		[2.3%]	[0.6%]
[0.2%]	[0.1%]	[1.3%]			

Panel A: size and b/m sorted portfolios



Panel B: including industry portfolios

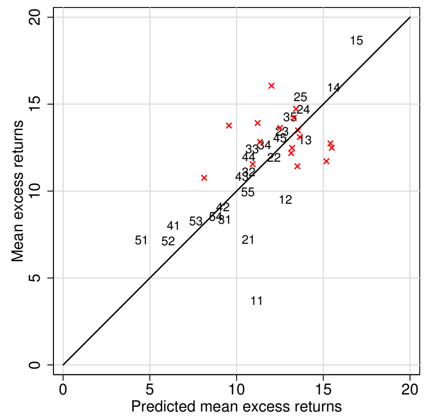


Figure O-3: Predicted vs. actual mean excess returns for an alternative CDRM specification (creative destruction hedge portfolio)

The two panels compare the predicted and the realized average excess returns (percentage) given for the alternative CDRM in Equation (O-3). For the results in Panel A, we use the excess returns of the value-weighted size and book-to-market sorted portfolios as test assets. The first number denotes the size quintile (1=smallest, 5=largest), and the second number refers to the book-to-market quintile (1=lowest, 5=highest). The sample period is 1927-2008, the sampling frequency is annual. For results in Panel B, we complement the test assets by the excess returns of 17 industry portfolios (red crosses)).

Table O-9 shows the estimation results for size and book-to-market sorted portfolios in Panel A. Panel B contains the results based on the augmented set of test assets including industry portfolios. Figure O-3 illustrates the cross-sectional fit. The results for the CDRM variant with the CDH portfolio confirm the findings for the base model reported in the main text. The estimates $\hat{\gamma}_{CDH}$ and $\hat{\lambda}_{CDH}$ are statistically significant from zero, and the cross-sectional fit compared to the CAPM is considerably improved. It is an encouraging result that the alternative risk factor proxy also points at the relevance of invention activity for asset pricing and supports the main storyline of the paper. However, while the cross-sectional performance on the size and book-to-market sorted portfolios is quite good, the basic CDRM remains superior on the industry-augmented set of test assets (compare Table O-9 (Panel B) and Figure O-3 (Panel C) with Table 4 (Panel B) and Figure 3 (Panel C) in the main text).

5 Four factor model with orthogonalized Fama-French factors

By including both the invention activity proxy (pg), the orthogonalized Fama-French factors, and the market return we also consider an ad hoc four factor model with $f = (r_{W,t}, pg, HML_\perp, SMB_\perp)'$, where $HML_\perp$ and $SML_\perp$ are the Fama-French factors orthogonalized with respect to pg and r_W.[2] The four factor model has the beta representation:

$$\mathbb{E}[r_i^e] = \beta_{W,i}\lambda_W + \beta_{N,i}\lambda_N + \beta_{HML_\perp,i}\lambda_{HML_\perp} + \beta_{SMB_\perp,i}\lambda_{SMB_\perp}, \qquad \text{(O-5)}$$

and the covariance representation:

$$\mathbb{E}[r_i^e] = \gamma_W \text{cov}(r_i^e, r_W) + \gamma_N \text{cov}(r_i^e, pg) + \gamma_{HML_\perp} \text{cov}(r_i^e, HML_\perp) + \gamma_{SMB_\perp} \text{cov}(r_i^e, SMB_\perp). \qquad \text{(O-6)}$$

which we estimate using the methodology outlined in the main text.

[2]More precisely, we regress both SMB and HML, respectively, on pg and r_W and a constant and obtain $SMB_\perp$ and $HML_\perp$ as the residuals of the respective regression plus the estimated constant (see Cochrane, 2013)

Table O-10: Four factor model with orthogonalized Fama-French factors)

The table reports the cross-sectional estimation results for the CDRM, the MP-CDRM, and the benchmark models for the four factor model in Equations (O-5) and (O-6). We report the lambda estimates and the gamma estimates using annual data 1927-2008. For the Panel A results, we use the excess returns of the value-weighted book-to-market sorted portfolios as test assets. For the Panel B results, we complement these test assets by the excess returns of 17 industry portfolios. We also report the cross-sectional coefficient of determination (R^2_{cs}), the mean absolute pricing error (MAE), the p-values associated with the J-statistic. In parentheses are t-statistics for the null hypothesis that the true parameter is 0. The J-and t-statistics are based on GMM inference as outlined in Appendix A.2 in the main text and applied to the four factor model. In brackets appear bootstrapped p-values for the t-statistics, R^2_{cs} and MAE. The null hypothesis for the latter two is that the model has no explanatory power

Panel A: Size and book-to-market sorted portfolios

$\hat{\gamma}_W$	$\hat{\gamma}_N$	$\hat{\gamma}_{HML_\perp}$	$\hat{\gamma}_{SMB_\perp}$	J [%]	R^2_{cs}	MAE
1.598	0.172	3.001	1.107	0.8	70.0	1.43
(3.07)	(0.06)	(2.95)	(1.01)		[11.1%]	[7.2%]
[0.2%]	[97.1%]	[0.2%]	[40.4%]			
$\hat{\lambda}_W$	$\hat{\lambda}_N$	$\hat{\lambda}_{HML_\perp}$	$\hat{\lambda}_{SMB_\perp}$			
0.068	0.000	0.055	0.018			
(2.96)	(0.01)	(2.94)	(0.97)			
[0.3%]	[99.8%]	[0.1%]	[42.4%]			

Panel B: Including industry portfolios

$\hat{\gamma}_W$	$\hat{\gamma}_N$	$\hat{\gamma}_{HML_\perp}$	$\hat{\gamma}_{SMB_\perp}$	J [%]	R^2_{cs}	MAE
1.430	-6.664	1.153	-0.706	0.2	56.6	1.29
(2.57)	(-1.95)	(1.01)	(-0.54)		[2.4%]	[0.1%]
[1.3%]	[7.8%]	[42.5%]	[75.8%]			
$\hat{\lambda}_W$	$\hat{\lambda}_N$	$\hat{\lambda}_{HML}$	$\hat{\lambda}_{SMB}$			
0.073	-0.127	0.021	-0.012			
(3.14)	(-1.99)	(1.11)	(-0.55)			
[0.3%]	[7.2%]	[41.7%]	[75.7%]			

Panel A of Table O-10 shows that when estimated on the size and book-to-market portfolios, the orthogonalized HML appears helpful in pricing the assets, $\gamma_{HML_\perp}$ is significantly different from zero, while $\hat{\gamma}_N$ is clearly not. Moreover, the significant lambda estimates indicate that the orthogonalized Fama-French factors appear as priced risk factors, while $\hat{\lambda}_N$ is not significantly different from zero. The cross-sectional R^2_{cs} of the four factor model is almost the same as that of the Fama-French model (compare Panel A of Table 4 in the main text). This result indicates that patenting growth *pg* does not add explanatory power beyond *HML* and *SMB* if the Fama-French portfolios are used as test assets. However, the result changes considerable if we augment set of test assets by industry portfolios (see Panel B in Table O-10). In this case, *pg* dominates the orthogonalized Fama-French factors. Compared to the CDRM estimation on the industry-augmented test assets, $\hat{\gamma}_N$ and $\hat{\lambda}_N$ change only marginally, with a slightly reduced estimation precision: compare Panel B in Table O-10 with Table 4 (Panel B) in the main text. On the other hand, the lambda estimates associated with the orthogonalized Fama-French factors are considerably reduced, and $\hat{\gamma}_{HML_\perp}$, $\hat{\gamma}_{SMB_\perp}$, $\hat{\lambda}_{HML_\perp}$, $\hat{\lambda}_{SMB_\perp}$ are not significantly different from zero at conventional levels. It is interesting to see how the invention activity risk factor dominates the Fama-French factors when the test assets are extended. The result is the same when the original Fama-French factors are used instead of the orthogonalized factors.

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