Is the Risk of Creative Destruction Priced in the Financial Markets?

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Abstract

This paper examines whether the risk of creative destruction is priced in asset markets. Creative destruction is the process whereby new firms, wielding better technology, displace incumbents. As proxies for creative destruction, variables such as venture capital returns, growth in the amount of venture capital invested, and the growth in the number of IPOs, are used. It is found that each of these three variables have some pricing power for the size and value factors in the Fama-French Three Factor Model. Returns to venture capital the expected effect, in that high returns correlate with negative payoffs to small and value firms. However, growth in IPOs and venture captial invested have the opposite effect. This is justified in the context of Helpman and Trajtenberg's [1994] model on technological revolutions; high VC investments and IPO growth occurs after the innovation

has been factored into prices, when high economic growth prevails. Small and value firms that have outlasted the technological revolution thus enjoy a 'survival premium', as past pessimism of their prospects fades.

1 Introduction

The failure of the Capital Asset Pricing Model to account for the cross-sectional stock returns has long been remarked upon. Fama and French [1992] found that size, earnings-price, debt-equity and book-to-market ratios are significant determinants of stock returns, contradicting the CAPM prediction the returns depend only on the excess return of the market portfolio.

This finding that size and book-to-market ratios can affect the stochastic behaviour of earnings led Fama and French to develop the Three-Factor Model, in which returns depend on the excess return of the market portfolio, and the HML and SMB factors. HML represents the return on a portfolio long in high-growth stocks and short in low-growth stocks, thereby capturing the variation in book-to-market ratios). SMB represents the return on a portfolio long in small capitalisation stocks and short in large company stocks Grammig and Jank [2010].

However, HML and SMB are problematic, as they fail to pin down which macroeconomic or state variables causing this common variation in returns which is independent of the market and carries a different premium from market risk [Fama and French, 1993]. As HML/SMB do not represent any underlying macroeconomic variable, their inclusion is arbitrary and motivated by empirical experience; they thus have no role in asset pricing theory

[Fama and French, 1992].

Efforts have been made to identify this underlying macroeconomic risk. A study this paper will focus on reviewing is that of Grammig and Jank [2010], who posit that innovation, or creative destruction, is the risk factor that is represented by HML and SMB; they find that patent growth, representing innovation, is a highly significant risk factor to aggregate stock returns.

This paper widens their approach, and extends the analysis to other variables linked to innovation; the rate of return on venture capital, growth in initial public offerings, and growth in the number of venture capital funds. The intuition behind analysing venture capital (VC) as a proxy for invention is that while patents may account for the creation of technology, the technology needs to be commercialised before it can displace incumbent firms; while Grammig and Jank [2010] may capture the creation, commercialisation and hence venture capital is needed to ensure destruction.

We find that returns to venture capital has significant pricing power, and has a similar effect to patent growth in that high VC returns represent a displacement risk to both small and low-growth firms. While high levels of venture capital returns represent an aggregate negative payoff to stocks, we find that growth in the number of IPOs and VC funds has the opposite effect. Nevertheless, from the time-series analysis we will see that increasing amounts of venture capital disbursement tend to have negative effect on small-firms only, while high growth in the number of IPOs negatively affect only large firms.

This essay proceeds as follows. Firstly, we will look at the prior literature on the relationship between innovation and fundamental asset risk, and the relation between venture capital and innovation. Then, we will outline the empirical approach, along with a description of the dataset. We will then analyse the empirical results, and conclude with comment on possible extensions.

2 Literature Review and Interpretation

In reaction to the failure of the CAPM model to explain adequately the cross-section of stock returns, Fama and French developed the Three-Factor Model. The model generally has strong predictive power; R^2's in the range of 0.80 are common. However, the HML and SMB factors fail to identify the fundamental risk that requires a higher return on small and/or low-growth assets.

2.1 HML and SMB as Proxies for Creative-Destructive Risk

HML and SML capture the pattern whereby firms that are small in size, or have a high book-to-market value, tend to earn greater returns than those predicted by CAPM. The implication here is that these firms face a risk that is not faced by the average or representative firm. Though the aggregate macroeconomic risk represented by these factors has not been identified theoretically, various efforts have been made to identify it empirically.

Grammig and Jank [2010] support the view that HML and SMB proxy for the risk of creative destruction. Helpman and Trajtenberg [1994] describe creative destruction is the process by which economic growth is caused by the creation and improvement of general purpose technologies, such as the steam engine, electricity or microelectronics. They develop a model in which growth occurs through two-stage cycles. The first stage is marked by slow-growth; the innovation has been discovered, but not enough complementary products have been developed that enable it to deliver productivity gains. Such complements are created by the second-stage, which is consequently marked by high growth rates.

We can say that a firm is creatively destroyed if a new product is invented that displaces the incumbent from their market. In this framework, the firms most at risk from creative destruction are small firms, with a high-book-to-market value; exactly the characteristics HMl and SMB capture. HML and SMB thus represent the premium investors require to invest in these risky firms.

This view can be supported by a number of prior studies. For example, Chan and Chen [1991] find that firms with a low market value and a high book-to-market ratio are firms under distress, are less productive, and thus have a higher probability of default. This implies that such marginal firms would be unable to cope with further competition from new products, which emerge over time.

In addition, Liew and Vassalou [2000] find that HML and SMB contain significant information about future GDP growth; their study shows that HML and SMB can forecast future economic growth in some countries, even with other common business-cycle variables included in the regressions. Vassalou [2003] concludes that the HML and SMB factors seem to represent mostly information related to future GDP growth. This finding supports the view that technological progress, which raises future economic growth, is related to the HML and SMB factors. This is also in line with Hsu

[2009], who find that technological innovations increase the aggregate level of expected stock returns; more concretely, patent and R+D shocks have positive explanatory power for U.S. returns and risk premia.

2.2 Empirical Analysis of Creative-Destructive Risk

Grammig and Jank [2010] propose that creative destruction is the unidentified risk, as technological change is more likely to displace small and value firms. They use patents issued as a proxy for invention growth, and find that a model including market return and and invention growth has large explanatory power for the cross-sectional variation in stock returns, successfully pricing HML and SMB in the process.

However, their paper has a problem in that it is not entirely correct to say that patent growth prices both HMB and SML; rather the regression conatined in Table 7 regressions clearly imply that patent growth is a fourth factor. The inclusion of patent growth in regressions with SMB and HML never render these latter variables insignificant; if the authors were aware of this, it is not mentioned. Rather, the variable representing the excess return on the market portfolio is rendered insignificant by the inclusion of patent growth. It thus cannot then be said that it prices HML and SMB; the three coexist peacefully in all specifications, so it is a fourth factor.

2.2.1 Other Proxies for Creative-Destructive Risk

Given that patent growth fails to identify the fundamental risk being HML and SMB, we must turn to other variables that represent innovation or creative destruction. One such variable is venture capital returns. The interpretation here is that if a wave of technological progress is underway, then innovative firms would be expected to do well in the market. Economically, this will first be expressed through high VC returns, as these firms valuations will increase before actual market growth occurs. A study by Nicholas [2008] lends credence to the claim that a firm's valuation will accurately reflect the value of its intellectual capital. He found in the U.S. stock market of the 1920's, market values were high as investors were pricing intangible assets such as patents. Using patent citations to identify the technological significance of inventions, his results show that investors were sophisticated in their market pricing decisions.

High VC returns may be indicative of the first phase in Helpman and Trajtenberg [1994]'s model, in that the innovation has occurred, but has not yet caused economic growth. Thus, above-average venture capital returns should serve as a risk factor, as it indicates that new firms are performing well, and so should be better placed to displace weak incumbents.

Secondly, we look at the growth in the number of VC funds as a risk factor. The motivation here is that large amount of funds going into new innovative firms should increase the risk to the marginal firms the new firms intend to displace. In addition, high amounts of VC investment may raise the rate of invention; for example, Kortum and Lerner [1998] find that the amount of venture capital activity increases the rate of patenting significantly, estimating that venture capital accounts for over 15 percent of industrial innovations.

Alternatively, Hirukawa and Ueda [2011] note that TFP or knowledge growth is associated with future venture capital investment; that is, the venture capital investment occurs only after the innovation has already been achieved. Thus, changes in the amount of venture capital disbursed should not significantly raise the risk faced by small and low-growth firms, as it comes after the innovation has already been accomplished. If these claims are true, we should find that changes in the amount of venture capital should not present a risk to firms susceptible to displacement, as the innovative process has already occurred and should be factored into the price of stocks.

However, this does not imply that the returns on venture capital would not serve as a factor. For example, venture capital that is early in the innovation process would earn quite a high return, as new firms displace old firms in the marketplace, acquiring market share in the process. The consequent high return would then cause the rise in the subsequent amount and number of venture capital disbursements, even though the innovative threat has already materialised and been factored into prices. Testing the growth in VC funds as a factor should allow us to determine whether it poses a threat to marginal firms, and thus whether it comes before or after investment.

Lastly, we will analyse the growth in the number in IPOs as a factor, for reasons similar to growth in the number of VC funds. IPOs may pose a risk factor to marginal firms, in that they may represent the rise of new firms. Alternatively, they may represent the end of the technological revolution, in that the new firms have matured and their effect on other firms has been realised; thus they may no longer be innovative, and therefore not pose a creative-destructive risk. Such a finding would be in line with what Bernstein [2012], who finds that going public leads to a 50 percent decline in innovation. However, in his study this decline is relative to firms who stayed private; the decline in internal innovation occurs as skilled inventors leave the firm, and the productivity of the remaining inventors declines.

3 Empirical Approach

In this paper, three variables will be tested to evaluate whether they are risk factors. The three variables are venture capital returns, the number of VC funds, and growth in the number of IPOs. All variables are expressed in terms of percent. Yearly growth rates are taken to demean the upward secular trend in many of these variables. For example, the amount of venture capital disbursed for U.S. manufacturing industries increased steadily, in 1992 dollars, from 13 million in 1965 to 469 million in 1992. A similar trend prevails for growth in the number of VC firms and funds.

We test to see whether these are risk factors through the use of two-pass regressions. First, time series regressions are run, where we calculate the betas corresponding to the dependent variables. For each candidate factor C, we estimate four models, for each year i as follows:

$$
\begin{aligned}
r_i &= \beta(MKT_i) + b_c(C_i) && (1) \\
r_i &= \beta(MKT_i) + b_s(SMB_i) + b_c(C_i) && (2) \\
r_i &= \beta(MKT_i) + b_h(HML_i) + b_c(C_i) && (3) \\
r_i &= \beta(MKT_i) + b_h(SMB_i) + b_h(HML_i) + b_c(C_i) && (4)
\end{aligned}
$$

The betas from the time series regressions are then stored and regressed on the average returns of the 25 portfolios. The result is 4 cross-sectional regression per candidate factor, all of which are given in the appendix.

4 Description of the Dataset

All data relating to the Fama-French factors was taken from Kenneth French's website [French, 2012]. The data describes the returns on 25 Portfolios Formed on Size and Book-to-Market, with annual average value-weighted returns. Data on patents granted is taken from the Table of Issue Years and Patent Numbers, provided by the United States Patent and Trademark Office. Data on the amount of venture capital disbursements is taken from Kortum and Lerner [1998].

Data on venture capital returns, and the number of venture capital funds, is taken from the U.S. Venture Capital Index and Selected Benchmark Statistics compiled and provided by Cambridge Associates LLC [2012]. The return data is pooled return on all funds, based on Inception IRR Based on Fund Industry. The number of funds data is the total number of funds in the All Funds category, from where the pooled return described previously was taken. Data on IPOs is taken from statistics compiled by Ritter [2013].

As explained by Grammig and Jank [2010], a long-run, low-frequency dataset is optimal as each of the proxies we use may be subject to measurement error. For example, IPOs or patent approvals may predominatly happen in one part of the year, which would distort our results. In addition, technological waves would occur over a number of years, which annual data can capture well - in effect, we reduce the possibility for error, while not losing any explanatory power.

In our data, the mean market excess return (MKT) is 7.9 percent; this is the equity premium. The premium of a size and value investment strategy id 3.7 percent for SMB and 4.7 percent for HML. VC returns have a mean of 23.2 percent, and it's variance is approximately equal to its mean. The Fund

Figure 1: A List of Independent Variables

Name	Label	Year Coverage
MKT	Excess return on the market portfolio	1927-2011
SMB	SMB: Small minus Big	1927-2011
HML	HML: High minus Low	1927-2011
PAG	Growth in patents granted	1927-2011
VCR	Returns to venture capital	1981-2011
FUNDG	Growth in the number of VC funds	1981-2010
IPOG	Growth in the number of IPOs	1973-2008

Growth and IPO growth factors have means of 14 and 31.7 percent respectively, and along with the MKT, HML and SMB factors, are considerably volatile.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
MKT	7.935	20.843	-45.44	57.2	85
SMB	3.658	14.215	-29.79	54.07	85
HML	4.735	13.947	-34.24	40.05	85
PAG	2.445	7.511	-16.015	25.075	84
VCR	23.264	27.645	-0.930	102.96	30
FUNDG	14.0	45.9	-0.656	1.545	29
IPOG	31.7	107.4	-0.869	4.613	31

5 Empirical Results

Firstly, we will examine the cross-sectional results to see which factors have pricing power. Then, we will analyse the time-series results to see how these variables price different types of portfolios.

Table 2: Correlation between Factors

	MKT	SMB	HML	PAG	VCR	IPOG	FUNDG
MKT	1						
SMB	0.16	1					
HML	-0.30	0.09	1				
PAG	-0.12	-0.28	-0.09	1			
VCR	0.28	-0.23	-0.29	-0.21	1		
IPOG	0.36	0.29	-0.04	-0.46	-0.04	1	
FUNDG	0.23	0.11	0.25	-0.24	0.08	0.60	1

5.1 Cross-Sectional Results

First, to establish a benchmark by which subsequent results may be evaluated, the four models in Table 6 were estimated. We see that the standard CAPM has poor explanatory power, as the R^2 is equal to 21.3 percent. With the inclusion of the HML factor, the R^2 rises to 61.7 percent, while the SMB factor raises the R^2 to just 22.5 percent. It is clear that the SMB factor, without the HML factor, fails to add much explanatory power. Estimating the Fama-French Three Factor Model, which is model (4) in Table 1, we see that it has an R^2 of 76.9 percent. Now, we will examine how the addition of each of the candidate factors improve the models previously described.

5.1.1 Growth in Patents Granted

The addition of the patent growth factor, PAG, onto the Standard CAPM increases explanatory power to 56.5 percent. The factor is highly significant. With the addition of the HML factor, explanatory power increases to 78.3 percent, and all factors together raises explanatory power to 88.9 percent. The patent growth factor is highly significant across all models.

However, as all three - patent growth, HML and SMB - remain significant when included in the same model, the patent growth factor cannot truly be said to price either HML or SMB.

5.1.2 Returns on Venture Capital

This factor is significant at the 1 percent level when added to the standard CAPM model, and increases explanatory power increases to 48.2 percent; an increase of 26.9 percent over the CAPM model. When HML is included, venture returns remains significant at the 5 percent level, and model explanatory power increases to 65.8 percent. However, the addition of SMB only raises explanatory power by around 5 percent, while the venture return factor becomes insignificant. As SMB and venture capital returns cannot be simultaneously significant, we can say the venture returns price the risk represented by SMB; albeit weakly, as SMB renders venture capital returns insignificant in both models where they are included together, rather than the other way around.

The beta loading on venture returns is negative in all regressions. Thus, we can infer that stocks that are particularly sensitive to TFP shocks tend to have lower returns on average, when patent generation is high.

5.1.3 Growth in the Number of IPOs

When the IPO factor is added to the standard CAPM model, it greatly increases the R^2 to 72 percent, while the factor is highly significant at the 0.1 percent level. With the addition of HML, model explanatory power increases to 76.7 percent; a modest increase in comparison to the situation where HML is introduced alone into the Standard CAPM. It can therefore be said that IPO has absorbed much of the explanatory power of HML.

Table 3: Venture Capital Returns

	(1)	(2)	(3)	(4)
MKT	-18.08***	-4.840	-12.32**	-5.590
	(-4.92)	(-1.01)	(-3.64)	(-1.26)
VCR	-31.44**	-16.92*	-6.078	-5.093
	(-3.67)	(-2.09)	(-0.61)	(-0.55)
HML		6.426***		5.750***
		(6.92)		(6.33)
SMB			3.107***	3.090***
			(4.09)	(4.40)
CONS	29.62***	16.03**	23.79***	16.85***
	(9.82)	(3.50)	(8.09)	(3.98)
N	25	25	25	25
adj. R^2	0.482	0.658	0.661	0.710

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Interestingly, it seems again the SMB is the risk factor being priced, as both its inclusion in any model renders the IPO factor insignificant. Despite this, the IPO factor adds far greater explanatory power than the SMB factor, as can be seen from the models in Table 1.

In short, it could be said that IPOG prices SMB, and soaks up much of HML's explanatory power. However, the results, though promising, are not perfect. For example, in specification (2), Table 6, the market return is insignificant, while the constant is significant; both these facts are contrary to standard predictions in asset-pricing theory.

5.1.4 Growth in the Number of VC Funds

Growth in the number of VC funds, FUNDG, is meant to proxy for the growth in the level amount of venture capital being invested. It performs

Table 4: **Growth in Number of IPOs**

	(1)	(2)	(3)	(4)
MKT	-8.471***	-2.516	-9.826**	-3.380
	(-4.25)	(-0.80)	(-3.80)	(-0.88)
IPOG	113.6***	95.19***	81.27	81.09
	(5.37)	(4.56)	(1.84)	(1.98)
HML		5.864***		5.831***
		(7.72)		(7.48)
SMB			3.394***	3.311***
			(4.82)	(5.07)
CONS	19.60***	13.55***	20.90***	14.39**
	(10.14)	(4.32)	(8.38)	(3.77)
N	25	25	25	25
adj. R^2	0.720	0.767	0.717	0.758

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

well in three of the four specifications. When introduced into the benchmark CAPM, it increases explanatory power to 64 percent, and is highly significant. On introducing the SML factor, the R^2 increases to 70.5 percent, and both are significant. Introducing HML when the fund growth factor is already present decreases explanatory power, though both are significant. When all factors are included, FUNDG becomes insignificant. We can thus reach a tentative conclusion that the growth in the number of VC funds partly prices mainly HML, and partly SMB.

5.1.5 Other Factors

Some other factors, not reported here, we also tested. When a factor representing the growth in the number of VC firms is added onto the Standard CAPM, scarcely any explanatory power is added even though the variable

Table 5: Growth in Number of Venture Capital Funds

	(1)	(2)	(3)	(4)
MKT	5.879	6.293	-1.771	-1.357
	(1.67)	(1.76)	(-0.39)	(-0.30)
FUNDG	65.64***	52.66*	39.17*	26.18
	(4.99)	(2.60)	(2.42)	(1.23)
HML		5.595***		5.523***
		(5.85)		(6.41)
SMB			3.006***	3.021***
			(4.24)	(4.25)
CONS	7.198	6.505	13.95**	13.26**
	(1.98)	(1.74)	(3.24)	(3.03)
N	25	25	25	25
adj. R^2	0.640	0.635	0.705	0.703

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

is significant at the 1 percent level. It is significant in no other specification. Similarly, the factor representing the growth in VC disbursed is significant in no specification. The low explanatory power of these variables may be due to low year coverage, and the fact that they are limited to venture capital regarding manufacturing industries.

5.2 Time-series results

From the above, we see that venture capital returns, growth in the number of VC funds, and growth in the number of IPOs all have significant explanatory power for size and value factors. However, they may have different effects on different types of firms.

To assess the exact nature of their impact, the beta estimates from the time series regressions are presented and discussed below. Dependent variables are the excess market return, and the candidate factor. HML and SMB do not feature in any of the regressions. The test assets used are the 25 portfolios sorted by book-to-market value (horizontally) and size (vertically).

5.2.1 Returns to Venture Capital

Firstly, it is clear that high VC returns has a highly negative and significant effect on low-growth firms of all sizes. It is worth noting that the beta point estimates on the five low-growth portfolios have similar point estimates to Grammig and Jank [2010], and with far greater statistical significance. Furthermore, it seems that firms experiencing high-growth are more resistant to the risk posed by high VC returns, given the lower and less significant point estimates.

These observations aside, it seems that there is more consistent variation across the Small-Big dimension; in general, the bigger the firm, the less exposed it is to negative risk represented by VC firms. No similar generality can be made across the HML axis. It is in this manner that returns to venture capital are better able to price SMB, as small firms are negatively affected by high VC returns. This finding is consistent with the cross-section result.

5.2.2 Growth in the No. of VC Funds and IPOs

First, the pattern of betas here indicates that large firms are negatively affected by a high number of IPOs, though the effect is not statistically significant. We also see increased returns for portfolios of smaller firms, and

Table 6: Time Series Betas for VC Returns

	Low	2	3	4	High
Small	-0.27*	-0.18′	-0.11	-0.03	-0.10
2	-0.15*	-0.14′	-0.07	0.03	-0.06
3	-0.15*	-0.08	0.02	-0.03	-0.90
4	-0.15*	-0.02	-0.02	-0.07	-0.12
Big	0.04	0.09*	0.07	0.08	0.04

* for $p < 0.05$, ′ for $p < 0.10$

for portfolios of high-growth firms, verifying our finding in the cross-section that IPOs has pricing power for HML and SMB.

Second, there is evidence, significant at the 10 percent level, that high growth in the number of VC funds positively affects portfolios comprised of firms experiencing moderate-to-high growth. In addition, stocks with low book-to-market value are severely and negatively affected by the a high fund growth. Finally, it is perceptible that small firms, other than those of low book-to-market value, seem to do better when fund growth is high.

From these results, we can interpret from this that growth in the amount of VC invested has some pricing power for both HML and SMB; this is contrary to the cross-sectional results, which indicated that only HML was priced.

6 Conclusion

From the above analysis, a number of conclusions may be drawn. First, the returns to venture capital, and growth rates of IPOs and the number of VC funds can all price some of the risk represented by HML and SMB.

High VC returns acts in the manner expected; firms that have the char-

Table 7: Time Series Betas for Growth in No. of VC Funds

	Low	2	3	4	High
Small	-6.97	1.05	5.90	8.15	9.23
2	-5.24	1.24	5.25	$10.63'$	$13.58'$
3	-5.60	$7.58'$	$8.42'$	5.16	9.49
4	-3.76	2.33	4.48	4.49	3.21
Big	-4.72	0.54	4.01	5.65	7.22

* for $p < 0.05$, $'$ for $p < 0.10$

Table 8: Time Series Betas for Growth in IPOs

	Low	2	3	4	High
Small	1.70	3.51	4.58	3.39	5.04
2	2.14	2.19	3.65	4.22	4.12
3	1.89	$3.23'$	3.96^{*}	3.56	2.58
4	2.01	1.27	2.66	2.08	1.72
Big	-1.03	-1.46	-0.74	0.41	0.52

* for $p < 0.05$, $'$ for $p < 0.10$

acteristics of marginal firms (small with a low book-to-market value) tends to do very poorly while VC returns are high. Thus, we help confirm the theory that the premium earned by these firms is due to the fact that they are exposed to creative-destructive risk; when technological waves come along, they are the first to be swept away. Thus, investors require a higher return in normal times to compensate for this risk.

Secondly, we see that the IPOs and the number of VC funds in operation have quite a different effect on the returns of the stocks of marginal firms. High numbers of IPOs and VC funds opening imply good returns for small stocks, and high growth stocks, relative to other stocks. This implies that the amount of VC invested and IPOs pose no innovative risk to business. This is consistent with the literature in two ways. First, we verify Bernstein [2012]'s finding that IPOs are not associated with increases in innovation.

Thirdly, we have perhaps determined that high IPOs and VC fund openings are symptomatic of the second stage in Helpman and Trajtenberg [1994]'s model, in that there is no further innovative risk (or it has already been priced), and that economic growth is high, resulting in good returns for all stocks. That some marginal stocks also do well may be indicative of a 'survival dividend', whereby firms that survive, and thereby escaped the high probability of displacement, recoup some of their lost value due to newfound positive sentiment.

Overall, these results are highly supportive of the fact that HML and SMB represent the risk presented by creative destruction, and also allude to the possibility of time variation in how these variables interact with stock returns.

7 Possible Extensions

To extend this analysis, a number of avenues could be taken.

Firstly, a Generalised Method of Moments estimator could be used which would check the robustness of the results described above; this would be particularly valuable given the borderline significance seen in some of the above regressions.

Secondly, growth in the number of newly-incorporated companies could be examined as a factor, as this may be symptomatic of creative destruction and innovation.

Thirdly, data could be collected over a longer time-period. The data-coverage for the variables on venture capital and IPOs is relatively short when compared to the patent data coverage (30 years versus 84 years). A longer time series would result in more robust results, as a greater sample size reduces the bias and variance in the estimates of the standard OLS estimator.

Fourthly, a wider range of portfolios may be used. In this paper, the only portfolios used were those 25 Portfolios Sorted on Size and Book-to-Market Value. A larger number of portfolios may be used which would strengthen the consistency of the cross-sectional results. Conversely, different types of portfolios may be used, such as those formed according to industry, which would test how broadly these results apply.

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8 Code

```
rm(list=ls())

library("foreign")
library("AER")
require(ggplot2)

factors <- read.dta("innovation_factors.dta")
N <- length(factors$vc_returns)
factors$vc_returns_l1 <- c(NA, factors$vc_returns
    [1:(N-1)])

factors$g_ipo <- factors$g_ipo*100
factors$g_fund_no <- factors$g_fund_no*100
fin_factors <- write.dta(factors, "final_factors.dta
    ")
candidate_factors <- c(names(factors)[6:17], "
    vc_returns_l1")

pfs_25 = names(factors)[18:42]
ind_10 = names(factors)[43:54]
mom_12 = names(factors)[55:64]

capm_model <- sl ~ mktrf
hml_model <- sl ~ mktrf + hml
```

```
smb_model <- sl ~ mktrf + smb
ff3f_model <- sl ~ mktrf + hml + smb

pfs_25_matrix <- as.matrix(factors)[,18:42]
pfs25_means <- colMeans(pfs_25_matrix)
list_of_models <- c(capm_model, hml_model, smb_model
    , ff3f_model)

change_dep_var <- function(new_dep_var, model) {
  new = reformulate(".", new_dep_var)
  update(model, new)}

add_ind_var <- function(new_var, model){
  new = reformulate(c('.', new_var))
  update(model, new)
}

ts_analysis <- function(portfolios=pfs_25, formula=
    hml_model, factor=NULL){
  this_formula <- formula
  if(!missing(factor)){
  this_formula <- add_ind_var(factor, formula)
  }

model_list <- lapply(portfolios, change_dep_var,
    this_formula)
lapply(model_list, lm, data=factors)}

drop_intercept <- function(data){
  colnames(data)[1] <- 'intercept'
```

```
  data_2 <- subset(data, select=-c(intercept))
  return(data_2)
  }

beta_extract <- function(regression_series){
  coef_list <- lapply(regression_series, coef)
  start <- coef_list[[1]]
  J=length(coef_list)
  for(i in 2:J){
    start <- rbind(start, coef_list[[i]])}
  return(drop_intercept(start))
  }

count <- 0

add_subscript <- function(beta_set){
  var_names <- colnames(beta_set)
  thing = paste(var_names, count, sep="_")
  count <<- count + 1
  return(thing)
  }



all_time_series <- lapply(list_of_models,
   ts_analysis, portfolios=pfs_25, factor='
   vc_returns')

merge_betas_for_factor <- function(this_factor, k=0)
   {
```

```
  all_time_series <- lapply(list_of_models,
     ts_analysis, portfolios=pfs_25, factor=
     this_factor)
  start <- beta_extract(all_time_series[[1]])
  colnames(start) <- add_subscript(start)
  J = length(all_time_series)
  for(j in 2:J){
    betas_to_bind <- beta_extract(all_time_series[[j
       ]])
    colnames(betas_to_bind) <- add_subscript(
       betas_to_bind)
    start <- cbind(start, betas_to_bind)
  }
  return(start)
  }

t <- ts_analysis(factor='vc_returns')

cs <- merge_betas_for_factor('vc_returns')

all_cs_results <- function(list_of_factors){
  start <- merge_betas_for_factor(list_of_factors
     [0])
  m <- 1
  J = length(list_of_factors)
  for(j in 2:J ){
    start <- cbind(start, merge_betas_for_factor(
       list_of_factors[j], k=m))
    m <- m + 1
  }
```

```
  return(start)
  }

all_cs <- all_cs_results(candidate_factors)
cs_data_less_means <- data.frame(all_cs)
cs_data <- cbind(pfs25_means, cs_data_less_means)

write.dta(cs_data, file="cs_data.dta")
write(cs_data, file="cs_data")
```

Listing 1: R Code.

```
use "Z:\home\sheefrex\code\occam\cs_data.dta", clear

cd "Z:\home\sheefrex\code\occam"
est clear

eststo: reg pfs25_means mktrf_4
eststo: reg pfs25_means mktrf_5 hml_5
eststo: reg pfs25_means mktrf_6 smb_6
eststo: reg pfs25_means mktrf_7 hml_7 smb_7

esttab using cs01.tex, ar2 compress booktabs title(
    Cross Sectional Estimates - Standard CAPM and
    Fama-French Models \label{tab1})
est clear


eststo: reg pfs25_means mktrf_8 gt_8
eststo: reg pfs25_means mktrf_9 hml_9 gt_9
```

```
eststo: reg pfs25_means mktrf_10 smb_10 gt_10
eststo: reg pfs25_means mktrf_11 hml_11 smb_11 gt_11

esttab using cs02.tex, ar2 compress booktabs title(Cross Sectional Estimates -  Trademarks Issued Growth\label{tab1})
est clear

eststo: reg pfs25_means mktrf_12 gp_12
eststo: reg pfs25_means mktrf_13 hml_13 gp_13
eststo: reg pfs25_means mktrf_14 smb_14 gp_14
eststo: reg pfs25_means mktrf_15 hml_15 smb_15 gp_15

esttab using cs03.tex, ar2 compress booktabs title(Cross Sectional Estimates - Patent Application Growth \label{tab1})
est clear


eststo: reg pfs25_means mktrf_16 g_pg_16
eststo: reg pfs25_means mktrf_17 hml_17 g_pg_17
eststo: reg pfs25_means mktrf_18 smb_18 g_pg_18
eststo: reg pfs25_means mktrf_19 hml_19 smb_19 g_pg_19

esttab using cs1.tex, ar2 compress booktabs title(Cross Sectional Estimates - Patents Granted Growth \label{tab1})
est clear
```

```
eststo: reg pfs25_means mktrf_20 r_ad_g_20
eststo: reg pfs25_means mktrf_21 hml_21 r_ad_g_21
eststo: reg pfs25_means mktrf_22 smb_22 r_ad_g_22
eststo: reg pfs25_means mktrf_23 hml_23 smb_23
    r_ad_g_23

esttab using cs2.tex, ar2 compress booktabs title(
    Cross Sectional Estimates - Real Advertising
    Growth \label{tab1})
est clear

eststo: reg pfs25_means mktrf_24 tradestock_24
eststo: reg pfs25_means mktrf_25 hml_25
    tradestock_25
eststo: reg pfs25_means mktrf_26 smb_26
    tradestock_26
eststo: reg pfs25_means mktrf_27 hml_27 smb_27
    tradestock_27

esttab using cs3.tex, ar2 compress booktabs title(
    Cross Sectional Estimates - Trademark Stock
    Growth \label{tab1})
est clear

eststo: reg pfs25_means mktrf_28 g_rd_exp_28
eststo: reg pfs25_means mktrf_29 hml_29 g_rd_exp_29
eststo: reg pfs25_means mktrf_30 smb_30 g_rd_exp_30
eststo: reg pfs25_means mktrf_31 hml_31 smb_31
```

```
    g_rd_exp_31

esttab using cs4.tex, ar2 compress booktabs title(
    Cross Sectional Estimates - Growth in R&D
    Expenditure \label{tab1})
est clear

eststo: reg pfs25_means mktrf_32 g_vc_firm_32
eststo: reg pfs25_means mktrf_33 hml_33 g_vc_firm_33
eststo: reg pfs25_means mktrf_34 smb_34 g_vc_firm_34
eststo: reg pfs25_means mktrf_35 hml_35 smb_35
    g_vc_firm_35

esttab using cs5.tex, ar2 compress booktabs title(
    Cross Sectional Estimates - Growth in Number of
    VC Firms\label{tab1})
est clear



eststo: reg pfs25_means mktrf_36 g_vc_amount_36
eststo: reg pfs25_means mktrf_37 hml_37
    g_vc_amount_37
eststo: reg pfs25_means mktrf_38 smb_38
    g_vc_amount_38
eststo: reg pfs25_means mktrf_39 hml_39 smb_39
    g_vc_amount_39

esttab using cs6.tex, ar2 compress booktabs title(
    Cross Sectional Estimates - Growth in the Amount
    of Venture Capital Disbursed \label{tab1})
```

```
est clear

eststo: reg pfs25_means mktrf_40 vc_returns_40
eststo: reg pfs25_means mktrf_41 hml_41 vc_returns_41
eststo: reg pfs25_means mktrf_42 smb_42 vc_returns_42
eststo: reg pfs25_means mktrf_43 hml_43 smb_43 vc_returns_43

esttab using cs7.tex, ar2 compress booktabs title(Cross Sectional Estimates - Venture Capital Returns \label{tab1})
est clear

eststo: reg pfs25_means mktrf_44 g_ipo_44
eststo: reg pfs25_means mktrf_45 hml_45 g_ipo_45
eststo: reg pfs25_means mktrf_46 smb_46 g_ipo_46
eststo: reg pfs25_means mktrf_47 hml_47 smb_47 g_ipo_47

esttab using cs8.tex, ar2 compress booktabs title(Cross Sectional Estimates - Growth in Number of IPOs \label{tab1})
est clear



eststo: reg pfs25_means mktrf_48 g_fund_no_48
eststo: reg pfs25_means mktrf_49 hml_49 g_fund_no_49
eststo: reg pfs25_means mktrf_50 smb_50 g_fund_no_50
```

```
eststo: reg pfs25_means mktrf_51 hml_51 smb_51
   g_fund_no_51

esttab using cs9.tex, ar2 compress booktabs title(
   Cross Sectional Estimates - Growth in Number of
   Venture Capital Funds \label{tab1})
est clear

eststo: reg pfs25_means  mktrf_52 vc_returns_l1_52
eststo: reg pfs25_means mktrf_53 hml_53
   vc_returns_l1_53
eststo: reg pfs25_means  mktrf_54 smb_54
   vc_returns_l1_54
eststo: reg pfs25_means mktrf_55 hml_55 smb_55
   vc_returns_l1_55

esttab using cs10.tex, ar2 compress booktabs title(
   Cross Sectional Estimates - Growth in Number of
   Venture Capital Funds \label{tab1})
est clear

clear
```

Listing 2: Stata Code.