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The Size Premium and Macro Volatility Risks: Evidence from US and UK Equity Markets

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Abstract

The size effect is alive well but visible only when the economy is in high volatility regimes. This paper develops variant conditional asset pricing tests for the size effect with independent business cycle and volatility regimes, and shows that the size effect is present conditionally during the high volatility regimes. This result is robust across two countries (US and UK) with various specifications and the January effect. An economic rationale for the relation between the size premium and macro volatility risk is provided through the capital market imperfection hypothesis.

Keywords: The Size Premium, Great Moderation, Volatility Regime Switching, Capital Market Imperfections

JEL Classification: E32, E52, G12

1 Introduction

Banz (1981) first reports that small-capitalization firms on the New York Stock Exchange (NYSE) earned higher average returns than is predicted by the CAPM from 1936 to 1975. Fama and French (1993) adopt this empirical fact and develop their three-factor asset pricing model with the market excess return (RMRF) and two mimicking portfolios based on market capitalization (SMB) and book-to-market (HML). The Fama-French model has become an industry standard because it can explain the average return variations across portfolios formed on many different characteristics. Fama and French interpret their two mimicking portfolios as risk factors capturing a risk premium for the relative distress of firms in the context of ICAPM while the underlying economic source of the risk premium has not yet fully understood. Further, the same empirical findings are documented with international data, and as a result, international Fama-French three-factor models are developed (see for instance, Griffin (2002) and Bekaert, Hodrick, and Zhang (2009)).

van Dijk (2011) surveys the literature on the size effect and identifies two seemingly contradictory developments in research since the late 1990s; many theoretical models are developed to explain the size effect (e.g. Berk, Green, and Naik (1999)), but most of the empirical studies find that the size effect has disappeared since the early 1980s. For example, Horowitz, Loughran, and Savin (2000) report that US small firms did not earn higher average realized returns than big firms after its discovery in 1980, and Dimson and Marsh (1999) find the similar phenomenon for the UK data. Schwert (2003) asserts that “it seems that the small-firm anomaly has disappeared since the initial publication of the papers that discovered it.” It is well known that if the anomalies are a result of data snooping bias, these are expected to disappear in the data soon after they have been reported. If this is indeed the case, the SMB factor may not be interpreted as a systematic risk factor to generate a risk premium in the rational asset pricing model.

Interestingly, Hou and van Dijk (2010) argue that the size effect exists in ex ante expected returns but might not be visible in realized returns. They show that small firms experience large negative profitability shocks after the early 1980s, while big firms experience large positive shocks. After filtering out this noise, they find a robust size effect in expected returns, and ask for a revival of academic research on the size effect. Based on the careful summary of the literature, van Dijk (2011)(p3263) also argues “it is premature to conclude that the size effect has gone away...whether and how existing models can be reconciled with known patterns in the returns on small and large stocks is not clear”. Finally Fama and French (2015) show the evidence for the size effect in US market using their five-factor model.

This paper documents a new stylized fact on the size effect to resolve this seemingly puzzling issue. Specifically, motivated by Lettau, Ludvigson, and Wachter (2008), this paper develops conditional asset pricing tests using regime switching models for the growth rate of US industrial production and the US or UK size premium. As a result, mean and volatility regimes are separately identified. The estimated mean regimes are closely tracking business cycle patterns, and the volatility regimes pick up the so-called great moderation from 1984 to 2007. While it is often said that recessions coincides with the high volatility regimes, the correlation of two regimes in US are moderate (e.g. 0.26 since July 1963).

The empirical findings from these conditional tests unequivocally indicate that the US or UK SMB factor earns a significant risk premium only in uncertain macroeconomic states (measured as high-volatility regimes of industrial production growth), even though it has almost zero risk premium unconditionally. This new stylized fact on the relation between the size premium and macro volatility risks is quite robust across various specifications and with the January effect. Arguably, the so-called “Great Moderation” coined by Ben Bernanke (or low macro volatility regimes) has effectively masked the size

effect until recently. Kim and Nelson (1999) and McConnell and Perez-Quiros (2000) show that US output volatility had declined substantially in the early 1980s. This period coincides with the initial publication of the size effect. However, the size effect has been resurrected since the recent financial crisis coupled with uncertain economic environment. For example, the average monthly size premium for US was 1.615% during 2008.

Interestingly, recent empirical asset pricing studies also emphasize the role of macroeconomic volatility movements in determining risk premia. For example, Boguth and Kuehn (2013) show that time-variation in consumption volatility is a negatively priced source of risk for various test portfolios. Bansal, Kiku, Shaliastovich, and Yaron (2013) also find that macroeconomic volatility risks (measured as realized variance of industrial production growth) carry a sizeable positive risk premium and help explain the cross-section of expected equity returns. Further, the empirical findings of this paper suggest that the changing macroeconomic volatility has an important implication on the changing size premium. While it is not yet fully understood why macro volatility risks are important for understanding risk premia, we have one good theoretical explanation on the size premium. Perez-Quiros and Timmermann (2000), based on the imperfect capital market theories, claim that small firms with little collateral do not have the same access to credit markets that are enjoyed by large firms, and argue that the high returns to small firms (SMB) might be compensation for taking this credit-related risk because small firms are more affected by tight credit market conditions interpreted as recession periods.

Perhaps, in well-developed US and UK financial markets, recession itself would not hamper raising capitals for the small-sized firms unless it coincides with the high uncertainty. While the lack of data makes it difficult to test this hypothesis directly, there are some indirect evidence to support this line of arguments. First, using OECD data, Men-

dicino (2007) documents a negative and significant relation between credit market size (financial depth) and the volatility of output, consumption, investment, investment in residential properties and housing prices. Tang and Yan (2010) find that average credit default swap (CDS) spreads are increasing in GDP growth volatility. Further, Baum, Caglayan, and Ozkan (2009) report the potentially adverse effects of macroeconomic volatility on the allocation of banks' lending behavior. This adverse effects would affect small firms significantly because small firms are more dependent on bank loans while large firms have better access to direct sources of credit such as commercial paper (e.g. Gertler and Gilchrist (1994)). Finally the credit crunch induced by higher macroeconomic volatility could hit small firms with less collateral the hardest while larger firms were less affected by renegotiating their loans or using commercial paper or corporate bonds (e.g., Holmstrom and Tirole (1997)).

The rest of the paper is organized as follows: Section 2 discusses the empirical models; Section 3 describes the data; Section 4 presents the estimation results; and Section 5 concludes.

2 Empirical Models

This section develops empirical methods used to test the existence of the size premium; the first subsection briefly describes a regime switching model with mean and volatility regimes for the US industrial production growth, and the second subsection explains how to test whether a factor is redundant unconditionally. The third subsection combines these two models and presents the main econometric specifications for conditional asset pricing tests.

2.1 Regime Switching Model

Consider a time-series of observations on the industrial production (Y_t) and let lowercase letters denote log variables, that is, the growth rate of industrial production becomes $\Delta y_t \equiv \log Y_t / Y_{t-1}$. A regime switching model of Δy_t takes the form,

$$\Delta y_t = \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t)) \quad (2.1)$$

where S_t and V_t are latent state variables for the states of mean and variance.

I assume that the probability of changing mean states is independent of the probability of changing volatility regimes following Lettau, Ludvigson, and Wachter (2008). It follows that there are two mean regimes, $\mu_t \equiv \mu(S_t) \in \{\mu_l, \mu_h\}$ and two volatility regimes, $\sigma_t \equiv \sigma(V_t) \in \{\sigma_l, \sigma_h\}$, where l denotes the low regime and h the high regime. I denote the transition probabilities of the Markov chains as

$$P(\mu_t = \mu_h | \mu_{t-1} = \mu_h) = p_{hh}^\mu, P(\mu_t = \mu_l | \mu_{t-1} = \mu_l) = p_{ll}^\mu$$

and $P(\sigma_t = \sigma_h | \sigma_{t-1} = \sigma_h) = p_{hh}^\sigma, P(\sigma_t = \sigma_l | \sigma_{t-1} = \sigma_l) = p_{ll}^\sigma$

where the probabilities of transitioning between regimes are denoted $p_{hl}^\mu = 1 - p_{ll}^\mu$ and $p_{lh}^\mu = 1 - p_{hh}^\mu$ for the mean regime, and $p_{hl}^\sigma = 1 - p_{ll}^\sigma$ and $p_{lh}^\sigma = 1 - p_{hh}^\sigma$ for the volatility regimes.

Since the state variables S_t and V_t are latent, information about the unobserved regime must be inferred from observations on the data. Such inference is provided by estimating the filtered or smoothed probability of being in state of S_t and V_t conditional on estimates of the model parameters and the data. Specifically, the posterior probability is computed as $P[S_t = j | D_s, \hat{\Theta}]$ and $P[V_t = j | D_s, \hat{\Theta}]$, where $\hat{\Theta}$ is the maximum likelihood estimate of parameters in the model and D_s denotes observations available through time s ($Y_1, \dots, Y_s$). The filtered probability is computed by using observations up to time t (D_t), and the smoothed probability is calculated with the whole sample

data (D_T). Recently Bai and Wang (2011) articulate that the above model with two mean states and two variance states can be viewed as a restricted version of the Hamilton (1989) model with four states. They explain detailed estimation algorithms and show that this restricted model provides good estimates for the recession probabilities with quarterly data. All the parameters in the regime switching models proposed in this paper are estimated using maximum likelihood constructed with filtered probabilities of S_t and V_t following Bai and Wang (2011)'s approach.

2.2 Unconditional Asset Pricing Tests on the Size Premium

2.2.1 United States

Motivated by the dividend discount valuation model, Fama and French (2015) develop a five-factor asset pricing model that adds profitability and investment factors to the market, size, and value-growth factors of the Fama and French (1993) three-factor model. They document that the size effect can be present when it is tested with the five-factor version of their model. Therefore, their five-factor model is used as the basis for the empirical investigation.¹

The Fama and French (2015) five-factor model is given as

$$E(R_{US,i}) = \gamma_0 + \beta_{i,M}(R_{USrm,t} - R_{USrf,t}) + \beta_{i,h}R_{UShml,t} + \beta_{i,s}R_{USsmb,t} + \beta_{i,r}(R_{USrmw,t}) + \beta_{i,c}(R_{UScma,t})$$

where $E(R_{US,i})$ is the return of asset i in US, and γ_0 is the US zero beta rate. $R_{USrm,t} - R_{USrf,t}$ is the US market portfolio excess return, $R_{UShml,t}$ is the return on the USHML, $R_{USsmb,t}$ is the return to the USSMB, $R_{USrmw,t}$ is the return on the USRMW, and

¹I thank an anonymous referee for pointing out this important point and suggesting the five-factor model as the benchmark. The five-factor model is also estimated with the January dummy because Keim (1983) documents that the size premium is mostly attributable to large abnormal returns during January.

$R_{UScma,t}$ is the return on the USCMA. All returns and zero beta rate are US dollar denominated.

While it has been argued that the size effect has disappeared, the right test to conduct is whether we can drop the SMB from the pricing factors. Intuitively, if the other factors are enough to price the SMB, those factors will price any assets that the SMB prices, and the SMB can be dropped from the Fama-French five-factor model. The proper test to drop the SMB from the Fama-French five-three factor model can be stated as follows.²

$$R_{USsmb,t} = \alpha + \beta_{US}(R_{USrm,t} - R_{USrf,t}) + h_{US}(R_{UShml,t}) + r_{US}(R_{USrmw,t}) + c_{US}(R_{UScma,t}) + \varepsilon_{USsmb,t} \quad (2.2)$$

If $\alpha = 0$, the size premium is explained by other Fama-French factors and the SMB factor can be dropped unconditionally from the Fama-French five-factor model.

2.2.2 United Kingdom

For the UK data, two versions of Fama-French models are used as benchmark unconditional asset pricing models. First, Griffin (2002) argues that regressions for the UK portfolios and individual stocks indicate that the UK Fama-French three-factor model explains much more time-series variation in returns and generally have lower pricing errors than the global Fama-French three-factor model. Based on this argument, the first model³ is specified by

²Many practitioners mistakenly think that the SMB can be dropped if the average SMB is equal to zero (or the factor is not priced). However, this is not the proper test unless the factor is orthogonalized. See Fama and French (2015) for more details.

³While it would be more consistent to use the Fama-French five-factor model as the benchmark local model, the profitability and investment factors are not available for the UK stock market. Because of the data availability, the Fama-French three-factor model is employed as the benchmark domestic asset pricing model. For the hybrid model with partial integration, however, five US Fama-French factors are added as proxies for the global factors. See ? and Fama and French (2017) and the references therein for the discussions on the local/global/hybrid models.

$$R_{UKsmb,t} = \alpha + \beta_{UK}(R_{UKrm,t} - R_{UKrf,t}) + h_{UK}(R_{UKhml,t}) + \varepsilon_{UKsmb,t} \quad (2.3)$$

where $R_{UKrm,t} - R_{UKrf,t}$ is the UK market portfolio excess return, $R_{UKsmb,t}$ is the return to the UKSMB, and $R_{UKhml,t}$ is the return on the UKHML. All returns and risk-free rate are UK pound denominated (or hedged US dollar returns and risk-free rate).

However, many articles (see for instance, Baele (2005) and Bekaert, Hodrick, and Zhang (2009)) have noted that the process towards market integration may not be smooth, and a more general asset pricing model with the exposures to both global and local asset pricing factors is necessary. This general model is consistent with partial world market integration. The second model, the hybrid (world-local) Fama-French model incorporates the US factors as proxies for the global factors in addition to the UK factors, with returns determined by

$$\begin{aligned} R_{UKsmb,t} = & \alpha + \beta_{UK}(R_{UKrm,t} - R_{UKrf,t}) + h_{UK}(R_{UKhml,t}) + \beta_{US}(R_{USrm,t} - R_{USrf,t}) \\ & + h_{US}(R_{UShml,t}) + s_{US}(R_{USsmb,t}) + r_{US}(R_{USrmw,t}) + c_{US}(R_{UScma,t}) + \varepsilon_{UKsmb,t} \end{aligned} \quad (2.4)$$

As before, if $\alpha = 0$ from the above two models for the UK data, the size premium is explained by other local or five global Fama-French factors and the SMB factor can be dropped unconditionally from the corresponding Fama-French model.

2.3 Conditional Asset Pricing Tests with Great Moderation

2.3.1 United States

The following two testable hypotheses are proposed to determine if the US SMB factor can be dropped from the Fama-French model conditionally. First Equations (2.1) and (2.2) are combined to form a conditional asset pricing model. Because the factor loadings can be also regime-dependent, the first US model is specified with regime switching volatility betas. If switching betas are not utilized, the estimated SMB alpha could just reflect the omission of regime-dependent factor loadings.

US-Hypothesis I: the US SMB is a priced factor during the high volatility regimes with the January effect.

$$\begin{aligned}
 R_{USsmb,t} = & \phi_L I(V_L) + \phi_H I(V_H) + (\beta_{US1} + \beta_{US2} I(V_H))(R_{USrm,t} - R_{USrf,t}) + (h_{US1} \\
 & + h_{US2} I(V_H))(R_{UShml,t}) + (r_{US1} + r_{US2} I(V_H))(R_{USrmw,t}) + (c_{US1} \\
 & + c_{US2} I(V_H))(R_{UScma,t}) + (\psi_L I(V_L) + \psi_H I(V_H))JAN + \varepsilon_{USsmb,t} \\
 \Delta y_t = & \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t)), \varepsilon_{USsmb,t} \sim N(0, \sigma^2)
 \end{aligned} \tag{2.5}$$

where $I(V_H)$ is the indicator function having the value 1 for high-vol regimes and the value 0 for other regimes, $I(V_L)$ is the indicator function having the value 1 for low-vol regimes and the value 0 for other regimes, JAN is the indicator function having the value 1 for January and the value 0 for other months. As in the univariate regime switching model for the industrial production growth, I assume that the probability of changing mean regimes is independent of the probability of changing volatility regimes. If $\phi_H \neq 0$ and $\phi_L = 0$, the size premium is a priced factor only during the high volatility regimes. The expected sign of the ϕ_H is positive if investors ask the size premium as the compensation for the volatility risk. The coefficients for the January dummy variable

(*JAN*) are also regime-dependent⁴ and added to investigate whether this new stylized fact can be explained away by the January effect because Keim (1983) documents that the size premium is mostly attributable to large abnormal returns during January.

As in Perez-Quiros and Timmermann (2000), the SMB can be a priced factor during the recession regimes rather than the high volatility regimes. Specifically, Perez-Quiros and Timmermann (2000) find that the size premium would be present only in a recession regime by estimating the conditional distribution of stock returns using several financial or macro variables with two regime specifications, which they interpret as business cycle regimes. Because two regimes are primarily identified based on stock returns, the estimated regimes sometimes can mix high volatility regimes in the stock market (e.g. 1987 stock market crash) with a recession regime. Instead, this paper uses joint distribution of the growth rate of industrial production and the SMB factor to estimate independent mean and volatility regimes. This new identification scheme can produce a sharper interpretation on Perez-Quiros and Timmermann (2000)'s results and a possible explanation on the real economic effect behind the macroeconomic volatility factor and the size premium.

US-Hypothesis II: the US SMB is a priced factor during the recession regimes with the January effect.

$$\begin{aligned}
R_{USsmb,t} = & \lambda_H I(S_H) + \lambda_L I(S_L) + (\beta_{US1} + \beta_{US2} I(S_L))(R_{USrm,t} - R_{USrf,t}) + (h_{US1} \\
& + h_{US2} I(S_L))(R_{UShml,t}) + (r_{US1} + r_{US2} I(S_L))(R_{USrmw,t}) + (c_{US1} \\
& + c_{US2} I(S_L))(R_{UScma,t}) + (\psi_L I(S_L) + \psi_H I(S_H))JAN + \varepsilon_{USsmb,t} \\
\Delta y_t = & \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t)), \varepsilon_{smb,t} \sim N(0, \sigma^2)
\end{aligned} \tag{2.6}$$

where $I(S_L)$ is the indicator function having the value 1 for low-mean (recession) regimes

⁴I thank an anonymous referee for suggesting the regime-dependent specification for the January effect.

and the value 0 for other regimes. $I(S_H)$ is the indicator function having the value 1 for high-mean (boom) regimes and the value 0 for other regimes. As before, I assume that the probability of changing mean regimes is independent of the probability of changing volatility regimes. For example, if $\lambda_L \neq 0$ and $\lambda_H = 0$, the size premium is a priced factor only during the recession regimes.

2.3.2 United Kingdom

Theoretically the UK size premium can be a compensation for the exposures to global or local macroeconomic factors because of the market integration issue. However the empirical findings in the next section indicate that the UK size premium is a compensation for the global macroeconomic volatility regimes proxied by the US volatility regimes.⁵ Therefore, only the corresponding local and hybrid Fama-French models with global macroeconomic volatility regimes are presented. Specifically, two testable hypotheses are proposed to determine if the size factor can be dropped from the local or hybrid Fama-French model conditionally.

UK-Hypothesis I: the UK SMB is a priced factor with the UK Fama-French model during the global high volatility regimes with the January effect.

A conditional UK Fama-French model with Equations (2.1) and (2.3) is developed to test if this hypothesis holds.

⁵Equivalent models are also estimated with the UK industrial production growth. The results with the UK industrial production growth are available upon request.

$$\begin{aligned}
R_{UKsmb,t} &= \phi_L I(V_L) + \phi_H I(V_H) + (\beta_{UK1} + \beta_{UK2} I(V_H))(R_{UKrm,t} - R_{UKrf,t}) \\
&\quad + (h_{UK1} + h_{UK2} I(V_H))(R_{UKhml,t}) + (\psi_L I(V_L) + \psi_H I(V_H))JAN + \varepsilon_{UKsmb,t} \quad (2.7) \\
\Delta y_t &= \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t)), \varepsilon_{UKsmb,t} \sim N(0, \sigma^2)
\end{aligned}$$

UK-Hypothesis II: the UK SMB is a priced factor with the hybrid Fama-French model during the global high volatility regimes with the January effect.

To test this hypothesis, a conditional hybrid Fama-French model is proposed by combining Equations (2.1) and (2.4).

$$\begin{aligned}
R_{UKsmb,t} &= \phi_L I(V_L) + \phi_H I(V_H) + (\beta_{UK1} + \beta_{UK2} I(V_H))(R_{UKrm,t} - R_{UKrf,t}) \\
&\quad + (h_{UK1} + h_{UK2} I(V_H))(R_{UKhml,t}) + (\beta_{US1} + \beta_{US2} I(V_H))(R_{USrm,t} - R_{USrf,t}) \\
&\quad + (s_{US1} + s_{US2} I(V_H))(R_{USsmb,t}) + (h_{US1} + h_{US2} I(V_H))(R_{UShml,t}) \quad (2.8) \\
&\quad + (r_{US1} + r_{US2} I(V_H))(R_{USrmw,t}) + (c_{US1} + c_{US2} I(V_H))(R_{UScma,t}) \\
&\quad + (\psi_L I(V_L) + \psi_H I(V_H))JAN + \varepsilon_{UKsmb,t} \\
\Delta y_t &= \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t)), \varepsilon_{UKsmb,t} \sim N(0, \sigma^2)
\end{aligned}$$

As before, for example, if $\phi_H \neq 0$ and $\phi_L = 0$, the size premium is a priced factor only during the global high volatility regimes. The expected sign of the ϕ_H is positive if investors ask the size premium as the compensation for the volatility risk.

3 Data

The US return data are from July 1963 to September 2018 (663 monthly observations). The monthly market excess returns (USRMRF), the value premium (USHML), the size

premium (USSMB), the profitability premium (USRMW), and the investment premium (USCMA) are downloaded from Kenneth French’s website.⁶ For the UK return data, two data sources are combined to produce longest possible data. First, the UK Fama-French three factors from July 1963 to September 1980 used in Dimson, Nagel, and Quigley (2003) are downloaded from Stephan Nagel’s website. And the equivalent three factors from October 1980 to December 2017 constructed annually as in Gregory, Tharyan, and Christidis (2013) are downloaded from their website in the University of Exeter.⁷ To verify the consistency of two data sources, the correlations of these factors for the common periods are computed. The correlations are high with 0.892 (UKSMB), 0.808 (UKHML), and 0.996 (UKRMRF). Finally, the index of US industry production (INDG, seasonally adjusted) is from the Federal Reserve Bank of St. Louis.

Table 1 reports summary statistics on the US Fama-French five factors and the US industrial production growth. All returns are US dollar denominated. The mean excess return on the US stock market portfolio is about 0.54% per month and is highly volatile (4.37% per month). The other US Fama-French five factors (USSMB, USHML, USRMW, USCMA) have lower mean returns around 0.3% per month with lower volatility (around 3% for USSMB and USHML and around 2% for USRMW and USCMA). The US industrial production growth is on average 2.47% and its volatility is 8.81% in annualized terms. Figure 1 shows time-series variation of these variables and indicates that there were notable reduction in the volatility of US output fluctuations in the early 1980’s.

Table 2 summarizes descriptive statistics on the UK Fama-French three factors (Panel A) and the correlations between US and UK Fama-French factors (Panel B). All UK factors are UK pound (or hedged US dollar) denominated. The mean excess return on the UK stock market portfolio is about 0.55% per month and is highly volatile (5.13%

⁶[http : //mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html](http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html)

⁷[http : //business-school.exeter.ac.uk/research/areas/centres/xfi/research/famafrench/files/](http://business-school.exeter.ac.uk/research/areas/centres/xfi/research/famafrench/files/).

per month). The UKSMB and the UKHML have mean returns, 0.16% and 0.40% per month with volatilities 3.29% and 2.76%, respectively. The correlations between US and UK factors are modest; the correlations between equivalent factors are 0.2 (SMB), 0.34 (HML), and 0.60 (RMRF). Finally, Figure 2 shows time-series variation of the UK Fama-French three factors.

4 Empirical Results

4.1 Preliminary Results

4.1.1 Great Moderation

This paper first estimates a univariate regime switching model (Equation (2.1)) for the US industrial production growth (Δy_t). Table 3 presents the estimation results for the whole sample (from July 1963 to September 2018). All parameters are estimated precisely with statistical significance. The regime represented by $\mu(S_t) = \mu_h$ has average growth equal to annualized 4.29% while the regime represented by $\mu(S_t) = \mu_l$, has an average growth rate of -4.71%. Thus, the high growth regime ($S_t = h$) is an expansion state and the low growth regime ($S_t = l$) is a recession state. These fluctuations in the regime switching mean growth rate of the industrial production capture business cycles in the economy. The volatility estimates provide the degree to which macroeconomic risk varies across regimes. The high volatility regime ($\sigma(V_t) = \sigma_h$) has residual variance of 15.85, whereas the low volatility regime ($\sigma(V_t) = \sigma_l$) has the much smaller variance 5.46.

The probability that high mean growth will be followed by another high mean growth regime is 0.98, implying that the high mean regime is expected to last on average about 50 months. The high volatility regimes are much less persistent than the mean regimes.

The probability that a high volatility regime will be followed by another high volatility regime is only 0.74. While it is often said that recessions coincides with the high volatility regimes, the correlation of two are quite small (e.g. around 0.2 since July 1963). Perhaps the recession would be officially near the end (or ended), whereas the economic uncertainty could be still high.

Figure 3 shows time-series plots of the smoothed posterior probabilities of being in a high volatility regime ($\sigma(V_t) = \sigma_h$) and the posterior probabilities of being in a low mean regime ($\mu(S_t) = \mu_l$). The estimated mean regimes are closely tracking business cycle patterns because they coincide almost with recession periods announced by the NBER. The volatility regimes pick up the so-called great moderation since 1984. Figure 3 shows that from 1984 to the recent period before 2008 financial crisis, the probabilities of being in high volatility regimes are essentially zero, except for the spikes in probability around 1999 and 2006.

4.1.2 Unconditional Asset Pricing Tests for US and UK

Unconditional asset pricing tests for the US size factor are conducted estimating various versions of Equation (2.2). Keim (1983) documents that the size effect exists only during January, and as a result the size premium is often regarded as the artifact of the investors' behavior rather than compensation for risk. Thus the January dummy variable (JAN) is added to investigate the robustness of the size effect. Table 4 first presents that the SMB alpha (α) with Newey-West standard errors, based on the Fama-French three-factor model. The SMB alpha is statistically insignificant while the January dummy is positive (1.57) with t-statistics 3.23. Fama and French (2015) show that the SMB alpha is positive and statistically significant by adding the profitability and investment anomalies based on the Fama-French five-factor model. Consistent with this result, the size effect is indeed positive (0.31) with t-statistics (2.37) using Equation (2.2). However,

once the January dummy is added to the specification, the SMB alpha is statistically insignificant with t-statistics 1.62. The results show that the size effect does not exist *unconditionally* in the US data, and the SMB factor can be dropped from various versions of the Fama-French model *unconditionally*, particularly with the January dummy.

Second, Equations (2.3) and (2.4) are estimated to test if the UK size factor is priced unconditionally with the UK or hybrid Fama-French model. Table 5 presents that the SMB alpha (α) with Newey-West standard errors in panel A for the UK Fama-French three-factor model and panel B for the hybrid model. First, the alpha for the UK model is only 0.15% with t-statistics 1.02. However, once the hybrid Fama-French model is employed, the alpha becomes slightly higher with 0.26% and marginally significant with t-statistics 1.87 while it seems less pronounced by adding the January dummy. The UK size premium is positively exposed to the USSMB (0.20) and negatively to the USRMW (-0.34) factors with t-statistics 4.53 and -5.30, respectively. The results may imply the importance of using the hybrid (global-local) asset pricing model since the UKSMB factor could be present albeit with marginal significance *unconditionally*.

4.2 Conditional Asset Pricing Tests with Macroeconomic Uncertainty

Several hypotheses are tested to determine if the US or UK size premium is a priced factor in the high macro volatility regimes.

4.2.1 United States

US-Hypothesis I: the SMB is a priced factor during the high volatility regimes with the January effect.

The empirical results in Table 6 clearly indicate that the US size premium is a priced factor in high macro volatility states. While ϕ_L is close to zero and insignificant, ϕ_H is positive and highly significant (0.83 with t-statistics 2.73). In particular, this new stylized fact is present with regime-dependent January effect. The January effect is also regime-dependent. The coefficient for the January dummy is negative in low macro volatility regimes while it is positive (2.66) with t-statistics 3.80 in high macro volatility regimes. Thus the size premium can't be simply regarded as the artifact of the investors' behavior. This table also shows that the HML betas are regime-dependent with opposite signs. Particularly, in high volatility regimes, the HML loading is significantly positive (0.39) while it is negative (-0.34) in low volatility regimes with statistical significance. The CMA betas are also regime-dependent but have decreasing loadings (-0.51) in high macro volatility states. Thus, while the high SMB alpha in the high volatility regimes are partly explained by the increase in the HML loadings, the SMB is a still priced factor in high volatility regimes. The estimated parameters for the industrial production growth in Table 6 and the mean and the volatility regimes of this model in Figure 4 are qualitatively similar to the corresponding estimates in Table 3 and the regimes identified in the univariate model.

US-Hypothesis II: the SMB is a priced factor during the recession regimes with the January effect.

As in Perez-Quiros and Timmermann (2000), the SMB can be a priced factor during the recession regimes rather than the high volatility regimes. This hypothesis is tested with Equation (2.6). Table 7 shows that the size effect (λ_L) is positive but insignificant with t-statistics 0.84 in the recession regimes. And contrary to the argument of Perez-Quiros and Timmermann (2000), the US size premium is present with marginally

significant t-statistics 1.81 in the high mean regimes. Thus the results indicate that the SMB factor is not priced in recession regimes and, judged by the degree of statistical significance and consistency with the underlying theory, volatility regimes seem more crucial to understand the size effect.

4.2.2 United Kingdom

UK-Hypothesis I: the SMB is a priced factor with the UK Fama-French model during the global high macro volatility regimes with the January effect.

The test results on this hypothesis are obtained by estimating Equation (2.7) from July 1963 to December 2017. Table 8 shows the evidence that the size premium is a priced factor only in global high macro volatility states. ϕ_L is close to zero and insignificant. However ϕ_H is positive (3.83) and highly significant with t-statistics 5.07. The January effect in U.K. stock markets doesn't seem to exist in the conditional model while it was present albeit weakly in the unconditional model in Table 5. The coefficient for the January dummy is negative (-4.00) with t-statistics -2.77 in high macro volatility regimes. As in the US case, this table shows that the HML and market betas are regime-dependent. However both loadings are negative and statistically significant only in high volatility regimes. In summary, the high SMB alpha in the high volatility regimes are not explained by the January effect and regime-dependent behavior in the factor loadings, and the UKSMB is a priced factor in global high macro volatility regimes.⁸

⁸The estimated mean and the volatility regimes of these models are close to those in Figure 4, and unreported to conserve the space.

UK-Hypothesis II: the SMB is a priced factor with the hybrid Fama-French model during the global high volatility regimes with the January effect.

Table 9 reports the estimation results of the hybrid Fama-French model (Equation (2.8)). Even with this general setup, the UK size premium is a priced factor only in global high macro volatility states. While ϕ_L is again close to zero and insignificant, ϕ_H is 2.82 with t-statistics 4.63. The January dummy coefficient is again negative (-5.06) with t-statistics -3.87 in high macro volatility regimes. This finding confirms that the UK SMB is indeed a priced factor in global high volatility regimes. The loadings for the UK Fama-French factors are similar to those in Table 8, and the loadings for several US Fama-French factors are regime-dependent and highly significant. Particularly, the loadings for the USCMA is increasing -0.30 with t-statistics -2.80 and 0.78 with t-statistics 1.97, respectively. Thus, the high UKSMB alpha in the high volatility regimes are partly explained by the increase in the USCMA loading. Other parameter estimates are similar to those from the model without the US five factors.

4.3 Economic Interpretations

The empirical results presented in the previous section support the hypothesis that the SMB factor earns a significant risk premium only in uncertain macroeconomic states. The result is robust across two countries (US and UK), with the January effect, and across several model specifications.

4.3.1 Risk Premia and Macro Volatility Risk

Interestingly a number of recent papers find evidence of the importance of macroeconomic volatility movements in determining risk premia. For example, Boguth and Kuehn (2013) show that time-variation in consumption volatility is a negatively priced source of risk for various test portfolios. Bansal, Kiku, Shaliastovich, and Yaron (2013) also argue that macro volatility movements (measured as realized variance of industrial production growth) have first-order implications for asset prices and are strongly correlated with discount-rate news. They show that volatility risks carry a separate risk premium, and their asset pricing model with volatility risks accounts for the cross-sectional difference in risk premia across book-to-market and size sorted portfolios. However, unfortunately, we do not have a good explanation of why aggregate macroeconomic volatility changes over time (e.g. the cause of great moderation). Both Boguth and Kuehn (2013) and Bansal, Kiku, Shaliastovich, and Yaron (2013) assume an exogenous time-varying volatility process. The next section discusses a plausible economic hypothesis based on the capital market imperfection from the observation that the worsening credit conditions due to the changing macroeconomic volatility has an important implication on the changing size premium.

4.3.2 The Size Premium and Credit Market Conditions

While it is unclear why the macro volatility risk is important for understanding risk premia, we have one good theoretical explanation on the size premium. Perez-Quiros and Timmermann (2000), based on the imperfect capital market theories, claim that small firms' collateral is likely to be very low during the recession, and with little collateral they do not have the same access to credit markets that are enjoyed by large firms. Investors would ask a compensation for small firms if those firms' risk should be disproportionately affected by tighter credit conditions. Thus, the high returns to small firms might be

compensation for taking this credit-related risk in a recession regime.⁹

The main reason to observe the capital market imperfections is the information asymmetry between borrowers and lenders (e.g. adverse selection and moral hazard problems). When the asymmetric information problems becomes severe between lenders and borrowers, the higher credit risk will be reflected as a higher external finance premia, a wedge between the external financing by issuing equity or debt and the internal financing by retaining earnings. There are many empirical results supporting the impact of capital market imperfections on firms' financing decisions across different economic environments. For example, Choe, Masulis, and Nanda (1993) present that firms' financing decisions are affected by business cycles. Ozkan and Ozkan (2004) find that small, non-rated firms with strong investment opportunities and volatile cash flow, i.e., with a high degree of information asymmetry, hold more cash as a safeguard against the worsening credit conditions.

4.3.3 Macro Volatility Risk and Credit Market Conditions

Perhaps, in well-developed US and UK financial markets, recession itself would not hamper raising capitals for the small firms unless it coincides with the high uncertainty. While the lack of the data makes it difficult to directly test what causes high macro volatility states and the relation between credit market conditions and macro volatility, there are some indirect evidence to support the importance of macro volatility risks on credit market conditions.

For example, using OECD data, Mendicino (2007) documents a negative and significant relation between credit market size and the volatility of output, consumption,

⁹There are also many papers on the relationship between company size and leverage or cost of debt. For example, Frank and Goyal (2009) examine the relationship between firm size and leverage using a sample of US firms for the period 1950 to 2003. They find that firm size is an important factor in explaining a company's leverage and that bigger firms are able to sustain higher levels of leverage without degrading their overall cost of capital.

investment, investment in residential properties and housing prices. Here table 1 can be interpreted as the indirect evidence showing that in a high macro volatility states, even in the developed markets, the size of credit market could be reduced to increase credit constraints. Tang and Yan (2010) also find that the credit risk proxied by average credit default swap (CDS) spreads is increasing in GDP growth volatility.

Baum, Caglayan, and Ozkan (2009) also report the potentially adverse effects of macroeconomic volatility on the allocation of banks' lending behavior. Based on a clear negative association between proxies of macroeconomic uncertainty and the cross-sectional variability of banks' loan-to-asset ratios, they argue that banks will behave more homogenously during the times of higher macroeconomic uncertainty. This adverse effects would affect small firms significantly. Gertler and Gilchrist (1994) suggest that small firms are more dependent on bank loans while large firms have better access to direct sources of credit such as commercial paper. Bernanke, Gertler, and Gilchrist (1996) also claim that a "flight-to-quality" in lending occurs as a decline in the share of credit flowing to small firms.

In summary, these empirical studies seem to support that only high macroeconomic volatility regimes would discourage the provision of credit by increasing uncertainty about prospective returns and exposing banks to potentially large losses. Therefore, investors would ask compensation for this systematic risk to credit-constrained small-size firms in high volatility regimes consistent with the empirical results shown in this paper.

5 Conclusion

Since Banz (1981) first reports that small-capitalization firms on the New York Stock Exchange (NYSE) earned higher average returns than is predicted by the CAPM from

1936 to 1975, the size effect has been subject to many theoretical and empirical scrutinies. van Dijk (2011) identifies two contradictory developments in research on the size effect since the late 1990s. Many theoretical models are developed to explain the size effect (e.g. Berk, Green, and Naik (1999)), but most of empirical studies report that the size effect has disappeared since the early 1980s (e.g. Horowitz, Loughran, and Savin (2000)).

The empirical results of this paper unequivocally show that the size factor (SMB) earns a significant risk premium only in uncertain macroeconomic states with various robustness checks across two countries (US and UK) and different model specifications and the January effect. Arguably the so-called “Great Moderation” coined by Ben Bernanke has been effectively masked the size effect until recently. Kim and Nelson (1999) and McConnell and Perez-Quiros (2000) show that US output volatility had declined substantially in the early 1980s. Interestingly, this period coincides with the initial publication of the size effect. However, the size effect has been resurrected since the recent financial crisis coupled with uncertain economic environment.

This paper is closely related to two strands of asset pricing literature. First, a number of recent papers (see, for instance, Boguth and Kuehn (2013) and Bansal, Kiku, Shaliastovich, and Yaron (2013)) find evidence that macroeconomic volatility risks determine risk premia. Second, the asset pricing studies with the capital market imperfection hypothesis (e.g. Perez-Quiros and Timmermann (2000)) argue that because of the imperfect capital market theories, the high returns to small firms might be compensation for taking the credit-related risk in a recession regime.

The empirical findings of this paper indicate that the size premium exist only in high volatility regimes rather than in recession regimes. While the lack of the data makes it difficult to test the relation directly, credit conditions look more closely related to changing volatility regimes than to recession regimes. For example, Baum, Caglayan, and Ozkan (2009) present evidence that the adverse effects of macroeconomic volatility

on the allocation of banks' lending behavior while the changes in banks' lending behavior have direct implications on the size premium (e.g., Gertler and Gilchrist (1994)). Perhaps, in well-developed US and UK financial markets, recession itself would not hamper raising capitals for the small firms unless it coincides with the high uncertainty. Only high macroeconomic volatility regimes would discourage the provision of credit by increasing uncertainty about prospective returns and exposing banks to potentially large losses. Investors would ask compensation for credit-constrained small-size firms in high volatility regimes to be consistent with the results of this paper.

References

- Baele, L., 2005, “Volatility Spillover Effects in European Equity Markets,” *Journal of Financial and Quantitative Analysis*, 40, 373–401.
- Bai, J., and P. Wang, 2011, “Conditional Markov chain and its application in economic time series analysis,” *Journal of Applied Econometrics*, 26, 715–734.
- Bansal, R., D. Kiku, I. Shaliastovich, and A. Yaron, 2013, “Volatility, the Macroeconomy and Asset Prices,” *Journal of Finance*, forthcoming.
- Banz, R. W., 1981, “The Relationship Between Return and Market Value of Common Stocks,” *Journal of Financial Economics*, 9, 3–18.
- Baum, C. F., M. Caglayan, and N. Ozkan, 2009, “The Second Moments Matter: The Impact of Macroeconomic Uncertainty on the Allocation of Loanable Funds,” *Economic Letters*, 102, 87–89.
- Bekaert, G., R. Hodrick, and X. Zhang, 2009, “International Stock Return Comovement,” *Journal of Finance*, 64, 2591–2626.
- Berk, J. B., R. C. Green, and V. Naik, 1999, “Optimal Investment, Growth Options, and Security Returns,” *Journal of Finance*, 54, 1553–1607.
- Bernanke, B., M. Gertler, and S. Gilchrist, 1996, “The Financial Accelerator and the Flight to Quality,” *The Review of Economics and Statistics*, 78, 1–15.
- Boguth, O., and L. Kuehn, 2013, “Consumption Volatility Risk,” *Journal of Finance*, forthcoming.
- Choe, H., R. W. Masulis, and V. K. Nanda, 1993, “Common Stock Offerings Across the Business Cycle: Theory and Evidence,” *Journal of Empirical Finance*, 1, 3–31.
- Dimson, E., and P. Marsh, 1999, “Murphy’s Law and Market Anomalies,” *Journal of Portfolio Management*, 25, 53–69.

- Dimson, E., S. Nagel, and G. Quigley, 2003, “Capturing the Value Premium in the United Kingdom,” *Financial Analysts Journal*, 59, 35–45.
- Fama, E., and K. French, 1993, “Common Risk Factors in the Returns on Stocks and Bonds,” *Journal of Financial Economics*, 33, 3–56.
- , 2012, “Size, Value, and Momentum in International Stock Returns,” *Journal of Financial Economics*, 105(3), 457–472.
- , 2015, “A Five-factor Asset Pricing Model,” *Journal of Financial Economics*, 116(1), 1–22.
- , 2017, “International Tests of a Five-factor Asset Pricing Model,” *Journal of Financial Economics*, 123(3), 441–463.
- Frank, M. Z., and V. K. Goyal, 2009, “Capital Structure Decisions: Which Factors are Reliably Important?,” *Financial Management*, 38, 1–37.
- Gertler, M., and S. Gilchrist, 1994, “Monetary policy, business cycles, and the behavior of small manufacturing firms,” *Quarterly Journal of Economics*, 109, 309–340.
- Gregory, A., R. Tharyan, and A. Christidis, 2013, “Constructing and Testing Alternative Versions of the Fama-French and Carhart Models in the UK,” *Journal of Business Finance and Accounting*, 40, 172–214.
- Griffin, J. M., 2002, “Are the Fama and French Factors Global or Country Specific?,” *Review of Financial Studies*, 15(3), 783–803.
- Hamilton, J. D., 1989, “A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle,” *Econometrica*, 57, 357–384.
- Holmstrom, B., and J. Tirole, 1997, “Financial Intermediation, Loanable Funds, and the Real Sector,” *Quarterly Journal of Economics*, 112, 663–691.
- Horowitz, J. L., T. Loughran, and N. E. Savin, 2000, “Three Analyses of the Firm Size Premium,” *Journal of Empirical Finance*, 7, 143–153.

- Hou, K., and M. A. van Dijk, 2010, “Profitability Shocks and the Size Effect in the Cross-section of Expected Stock Returns,” SSRN Working Paper Series.
- Keim, D. B., 1983, “Size-related Anomalies and Stock Return Seasonality : Further Empirical Evidence,” *Journal of Financial Economics*, 12, 13–32.
- Kim, C., and C. Nelson, 1999, “Has the U.S. Economy Become More Stable? A Bayesian Approach Based on a Markov-Switching Model of the Business Cycle,” *Review of Economics and Statistics*, 81, 1–10.
- Lettau, M., S. C. Ludvigson, and J. A. Wachter, 2008, “The Declining Equity Premium: What Role Does Macroeconomic Risk Play?,” *Review of Financial Studies*, 21, 1653–1687.
- McConnell, M. M., and G. Perez-Quiros, 2000, “Output Fluctuations in the United States: What Has Changed since the Early 1980’s?,” *American Economic Review*, 90(5), 1464–1476.
- Mendicino, C., 2007, “Credit Market and Macroeconomic Volatility,” ECB Working Paper, No. 743.
- Ozkan, A., and N. Ozkan, 2004, “Corporate Cash Holdings: An Empirical Investigation of UK companies,” *Journal of Banking and Finance*, 28, 2103–2134.
- Perez-Quiros, G., and A. Timmermann, 2000, “Firm Size and Cyclical Variations in Stock Returns,” *Journal of Finance*, 55, 1229–1262.
- Schwert, G. W., 2003, “Anomalies and Market Efficiency,” *Handbook of Economics of Finance*.
- Tang, Y., and H. Yan, 2010, “Market Conditions, Default Risk, and Credit Spreads,” *Journal of Banking and Finance*, 34, 724–734.
- van Dijk, M. A., 2011, “Is Size Dead? A Review of the Size Effect in Equity Returns,” *Journal of Banking and Finance*, 35, 3263–3274.

This figure shows the growth rates of US industrial production (% , annualized) and the US Fama-French five factors (% , USRMRF, USSMB, USHML, USRMW, and USCMA). The shaded lines in the plot correspond to NBER recession dates. The data are monthly and span the period from 1963:07 to 2018:09.

Figure 1: The Growth rates of US Industrial Production and the US Fama-French Three Factors

This figure shows the UK Fama-French three factors (% , UKRMRF, UKSMB, and UKHML). The shaded lines in the plot correspond to NBER recession dates. The data are monthly and span the period from 1963:07 to 2017:12.

Figure 2: The UK Fama-French Three Factors

This figure plots the time-series of smoothed state probabilities from a univariate regime switching model for the growth rates of US industrial production (% , annualized). Prob (High Volatility) is the unconditional probability of being in a high volatility regime, calculated by summing the probability of being in a high volatility regime and high mean regime, and the probability of being in a high volatility regime and low mean regime. Prob (Low Mean) is calculated analogously. The shaded lines in the plot correspond to NBER recession dates. The data are monthly and span the period from 1963:07 to 2018:09.

Figure 3: Smoothed State Probabilities of High Volatility and Recession regimes, Univariate Switching Model (1963:07 - 2018:09)

This figure plots the time-series of smoothed probabilities of high volatility and recession regimes from the bivariate models defined in Section 2.3.1. Prob (High Volatility) is the unconditional probability of being in a high volatility regime, calculated by summing the probability of being in a high volatility regime and high mean regime, and the probability of being in a high volatility regime and low mean regime. Prob (Low Mean) is calculated analogously. The shaded lines in the plot correspond to NBER recession dates. The data are monthly and span the period from 1963:07 to 2018:09.

Figure 4: Smoothed State Probabilities of High Volatility and Recession regimes, Bivariate Switching Model (1963:07 - 2018:09)

Table 1: Descriptive Statistics for U.S. data

Summary statistics for the US Fama-French five factors and the growth rates of the US industrial production (1963:07 - 2018:09). The Auto (1) give the first autocorrelation. Note: The US Fama-French five factors (% , USRMRF, USSMB, USHML, USRMW, USCMA) are from Kenneth French's website. I define the growth rate of industrial production (INDG, seasonally adjusted and annualized percentage) as log differenced series of the index of industry production from the Federal Reserve Bank of St. Louis.

	USRMRF	USSMB	USHML	USRMW	USCMA	INDG
Mean	0.54	0.25	0.32	0.25	0.28	2.47
Std. Dev.	4.37	3.02	2.80	2.16	2.00	8.81
Skewness	-0.54	0.38	0.09	-0.32	0.30	-1.00
Kurtosis	5.04	6.23	5.09	14.59	4.64	8.14
Auto(1)	0.07	0.06	0.17	0.16	0.12	0.32

Table 2: Descriptive Statistics for UK data and correlations between US and UK factors (1963:07 - 2017:12)

Summary statistics for the UK Fama-French three factors (Panel A) and their correlations with US five factors (Panel B). The Auto (1) give the first autocorrelation. Note: for the UK Fama-French three factors (% UKRMRF, UKSMB, UKHML), two data sources used in published papers are combined to produce longest possible data. First, the UK Fama-French three factors from July 1963 to September 1980 used in Dimson, Nagel, and Quigley (2003) are downloaded from Stephan Nagel's website. And the equivalent three factors from October 1980 to December 2017 constructed as in Gregory, Tharyan, and Christidis (2013) are downloaded from their website in the University of Exeter. Finally, the US Fama-French five factors (% USRMRF, USSMB, USHML, USRMW, USCMA) are from Kenneth French's website.

	UKRMRF	UKSMB	UKHML
Mean	0.55	0.16	0.40
Std. Dev.	5.13	3.29	2.76
Skewness	0.64	-0.64	-0.57
Kurtosis	14.33	7.81	11.06
Auto(1)	0.12	0.10	0.29

Panel B. Correlations between US and UK Fama-French factors

	USRMRF	USSMB	USHML	USRMW	USCMA	UKRMRF	UKSMB	UKHML
USRMRF	1.00							
USSMB	0.27	1.00						
USHML	-0.26	-0.07	1.00					
USRMW	-0.23	-0.35	0.06	1.00				
USCMA	-0.38	-0.10	0.70	-0.04	1.00			
UKRMRF	0.60	0.20	-0.08	-0.14	-0.18	1.00		
UKSMB	-0.07	0.20	0.06	-0.25	0.09	-0.27	1.00	
UKHML	-0.04	-0.11	0.34	0.18	0.20	0.02	-0.03	1.00

Table 3: A Markov Switching Model for the Growth Rate of US Industrial Production

This table reports the maximum likelihood estimates of the model (1963:07 - 2018:09):

$$\Delta y_t = \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t))$$

where Δy_t are monthly growth rates of the US industrial production (% , annualized). S_t and V_t are latent state variables for the regimes of mean and variance. I assume that the probability of changing mean regimes is independent of the probability of changing volatility regimes. It follows that there are two mean regimes, $\mu_t \equiv \mu(S_t) \in \{\mu_l, \mu_h\}$ and two volatility regimes, $\sigma_t \equiv \sigma(V_t) \in \{\sigma_l, \sigma_h\}$, where l denotes the low regime and h the high regime. I denote the transition probabilities of the Markov chains by

$$\begin{aligned} P(\mu_t = \mu_h | \mu_{t-1} = \mu_h) &= p_{hh}^\mu, P(\mu_t = \mu_l | \mu_{t-1} = \mu_l) = p_{ll}^\mu \\ P(\sigma_t = \sigma_h | \sigma_{t-1} = \sigma_h) &= p_{hh}^\sigma, P(\sigma_t = \sigma_l | \sigma_{t-1} = \sigma_l) = p_{ll}^\sigma \end{aligned}$$

	μ_h	μ_l	σ_h^2	σ_l^2	p_{hh}^μ	p_{ll}^μ	p_{hh}^σ	p_{ll}^σ
t-stat	4.29	-4.71	15.85	5.46	0.98	0.89	0.74	0.96
	12.94	-4.85	8.18	19.44	110.50	25.08	9.29	64.31

Table 4: Unconditional Asset Pricing Tests for the US Size Premium

This table reports unconditional asset pricing test results to investigate if the size premium in US (USSMB) is redundant given other US Fama-French factors (USRMRF, USHML, USRMW, USCMA) (1963:07 - 2018:09):

$$R_{USsmb,t} = \alpha + \beta_{US}(R_{USrm,t} - R_{USrf,t}) + h_{US}(R_{UShml,t}) + r_{US}(R_{USrmw,t}) + c_{US}(R_{UScma,t}) + \psi JAN + \varepsilon_{USsmb,t}$$

where $R_{USsmb,t}$ is the return to the USSMB, $R_{USrm,t} - R_{USrf,t}$ is the US market portfolio excess return (USRMRF), $R_{UShml,t}$ is the return on the USHML, $R_{USrmw,t}$ is the return on the USRMW, $R_{UScma,t}$ is the return on the USCMA. The US Fama-French five factors are from Kenneth French's website. I use Newey-West standard errors. If $\alpha = 0$, the size premium is explained by other Fama-French factors and the SMB factor can be dropped unconditionally from the Fama-French model.

	α	β_{US}	h_{US}	r_{US}	c_{US}	ψ
	0.15	0.19	0.00			
t-stat	1.20	5.28	0.02			
	0.03	0.18	-0.02			1.57
t-stat	0.23	5.16	-0.15			3.23
	0.31	0.13	0.06	-0.44	-0.12	
t-stat	2.37	3.05	0.50	-3.07	-0.87	
	0.22	0.13	0.04	-0.41	-0.11	1.03
t-stat	1.62	3.05	0.38	-2.83	-0.82	2.24

Table 5: Unconditional Asset Pricing Tests for the UK Size Premium

This table reports unconditional asset pricing test results to investigate if the size premium in UK (UKSMB) is redundant under the UK Fama-French model (UKRMRF, UKHML) or the hybrid Fama-French model:

The UK Fama-French Model (Panel A)

$$R_{UKsmb,t} = \alpha + \beta_{UK}(R_{UKrm,t} - R_{UKrf,t}) + h_{UK}(R_{UKhml,t}) + \varepsilon_{UKsmb,t}$$

where $R_{UKsmb,t}$ is the return to the UKSMB, $R_{UKrm,t} - R_{UKrf,t}$ is the UK market portfolio excess return (UKRMRF), $R_{UKhml,t}$ is the return on the UKHML. Note: two data sources are combined to produce longest possible UK Fama-French factors (1963:07 - 2017:12) as explained in Table 2.

The hybrid Fama-French Model (Panel B)

$$R_{UKsmb,t} = \alpha + \beta_{UK}(R_{UKrm,t} - R_{UKrf,t}) + h_{UK}(R_{UKhml,t}) + \beta_{US}(R_{USrm,t} - R_{USrf,t}) + h_{US}(R_{USHml,t}) + s_{US}(R_{USSmb,t}) + r_{US}(R_{USrmw,t}) + c_{US}(R_{UScma,t}) + \psi_{UK}JAN + \varepsilon_{UKsmb,t}$$

where $R_{USrm,t} - R_{USrf,t}$ is the US market portfolio excess return (USRMRF), $R_{USHml,t}$ is the return on the USHML, $R_{USSmb,t}$ is the return to the USSMB, $R_{USrmw,t}$ is the return on the USRMW, $R_{UScma,t}$ is the return on the USCMA. The US Fama-French five factors are from Kenneth French's website.

I use Newey-West standard errors for both panels. If $\alpha = 0$, the size premium is explained by other Fama-French factors and the SMB factor can be dropped unconditionally from the corresponding Fama-French model.

Panel A. the UK Fama-French model

	α	β_{UK}	h_{UK}	ψ_{UK}
	0.15	-0.18	-0.04	1.40
t-stat	1.02	-2.73	-0.35	2.77

Panel B. the hybrid Fama-French model

	α	β_{UK}	h_{UK}	β_{US}	h_{US}	s_{US}	r_{US}	c_{US}	ψ_{UK}
	0.26	-0.24	0.01	0.05	0.09	0.20	-0.34	0.00	
t-stat	1.87	-3.31	0.22	1.00	1.27	4.53	-5.30	0.01	
	0.22	-0.24	0.01	0.05	0.08	0.19	-0.33	0.01	0.58
t-stat	1.52	-3.32	0.19	1.05	1.15	4.38	-5.10	0.06	1.25

Table 6: the US size premium and Great Moderation with the January effect

This table reports conditional asset pricing test results to investigate if the US size premium (USSMB) is redundant given other US Fama-French factors (USRMRF, USHML, USRMW, USCMA) and the January effect dummy (*JAN*). The following bivariate regime switching model is estimated to test the hypothesis (1963:07 - 2018:09).

$$R_{USsmb,t} = \phi_L I(V_L) + \phi_H I(V_H) + (\beta_{US1} + \beta_{US2} I(V_H))(R_{USrm,t} - R_{USrf,t}) + (h_{US1} + h_{US2} I(V_H))(R_{UShml,t}) \\ + (r_{US1} + r_{US2} I(V_H))(R_{USrmw,t}) + (c_{US1} + c_{US2} I(V_H))(R_{UScma,t}) + (\psi_L I(V_L) + \psi_H I(V_H))JAN + \varepsilon_{USsmb,t} \\ \Delta y_t = \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t)), \varepsilon_{USsmb,t} \sim N(0, \sigma^2)$$

where $R_{USsmb,t}$ is the return to the USSMB, $R_{USrm,t} - R_{USrf,t}$ is the US market portfolio excess return (USRMRF), $R_{UShml,t}$ is the return on the USHML, $R_{USsmb,t}$ is the return to the USSMB, $R_{USrmw,t}$ is the return on the USRMW, $R_{UScma,t}$ is the return on the USCMA. $I(V_H)$ is the indicator function having the value 1 for high-vol regimes and the value 0 for other regimes. $I(V_L)$ is the indicator function having the value 1 for low-vol regimes and the value 1 for other regimes. Δy_t is the monthly growth rate of the industrial production (% , annualized) from the Federal Reserve Bank of St. Louis. S_t and V_t are latent state variables for the regimes of mean and variance. I assume that the probability of changing mean regimes is independent of the probability of changing volatility regimes. It follows that there are two mean regimes, $\mu_t \equiv \mu(S_t) \in \{\mu_l, \mu_h\}$ and two volatility regimes, $\sigma_t \equiv \sigma(V_t) \in \{\sigma_l, \sigma_h\}$, where l denotes the low regime and h the high regime. I denote the transition probabilities of the Markov chains by

$$P(\mu_t = \mu_h | \mu_{t-1} = \mu_h) = p_{hh}^\mu, P(\mu_t = \mu_l | \mu_{t-1} = \mu_l) = p_{ll}^\mu \\ P(\sigma_t = \sigma_h | \sigma_{t-1} = \sigma_h) = p_{hh}^\sigma, P(\sigma_t = \sigma_l | \sigma_{t-1} = \sigma_l) = p_{ll}^\sigma$$

If $\phi_H \neq 0$, the size premium is a priced factor during the high volatility regimes.

	ϕ_L	ϕ_H	ψ_L	ψ_H
	0.02	0.83	-0.45	2.66
t-stat	0.13	2.73	-0.97	3.80

	μ_h	μ_l	σ_h^2	σ_l^2	p_{hh}^μ	p_{ll}^μ	p_{hh}^σ	p_{ll}^σ
	4.26	-5.96	11.78	5.26	0.98	0.90	0.79	0.92
t-stat	14.70	-6.16	14.20	21.81	143.84	26.47	14.13	42.28

	β_{US1}	β_{US2}	h_{US1}	h_{US2}	r_{US1}	r_{US2}	c_{US1}	c_{US2}	σ
	0.13	0.07	-0.34	0.61	-0.58	-0.11	0.03	-0.51	2.36
t-stat	3.76	1.21	-4.55	6.08	-7.93	-1.15	0.24	-2.81	32.44

Table 7: the US size premium and Recession with the January effect

This table reports conditional asset pricing test results to investigate if the US size premium (USSMB) is redundant given other US Fama-French factors (USRMRF, USHML, UDRMW, USCMA). The following bivariate regime switching model is estimated to test the hypothesis (1963:07 - 2018:09).

$$R_{USsmb,t} = \lambda_H I(S_H) + \lambda_L I(S_L) + (\beta_{US1} + \beta_{US2} I(S_L))(R_{USrm,t} - R_{USrf,t}) + (h_{US1} + h_{US2} I(S_L))(R_{UShml,t}) \\ + (r_{US1} + r_{US2} I(S_L))(R_{USrmw,t}) + (c_{US1} + c_{US2} I(S_L))(R_{UScma,t}) + (\psi_L I(S_L) + \psi_H I(S_H))JAN + \varepsilon_{USsmb,t} \\ \Delta y_t = \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t)), \varepsilon_{smb,t} \sim N(0, \sigma^2)$$

where $R_{USsmb,t}$ is the return to the USSMB, $R_{USrm,t} - R_{USrf,t}$ is the US market portfolio excess return (USRMRF), $R_{UShml,t}$ is the return on the USHML, $R_{USsmb,t}$ is the return to the USSMB, $R_{USrmw,t}$ is the return on the USRMW, $R_{UScma,t}$ is the return on the USCMA. $I(S_L)$ is the indicator function having the value 1 for low-mean (recession) regimes and the value 0 for other regimes. $I(S_H)$ is the indicator function having the value 1 for high-mean (boom) regimes and the value 0 for other regimes. Δy_t is the monthly growth rate of the US industrial production (% , annualized) from the Federal Reserve Bank of St. Louis. S_t and V_t are latent state variables for the regimes of mean and variance. I assume that the probability of changing mean regimes is independent of the probability of changing volatility regimes. It follows that there are two mean regimes, $\mu_t \equiv \mu(S_t) \in \{\mu_l, \mu_h\}$ and two volatility regimes, $\sigma_t \equiv \sigma(V_t) \in \{\sigma_l, \sigma_h\}$, where l denotes the low regime and h the high regime. I denote the transition probabilities of the Markov chains by

$$P(\mu_t = \mu_h | \mu_{t-1} = \mu_h) = p_{hh}^\mu, P(\mu_t = \mu_l | \mu_{t-1} = \mu_l) = p_{ll}^\mu \\ P(\sigma_t = \sigma_h | \sigma_{t-1} = \sigma_h) = p_{hh}^\sigma, P(\sigma_t = \sigma_l | \sigma_{t-1} = \sigma_l) = p_{ll}^\sigma$$

If $\lambda_L \neq 0$, the size premium is a priced factor during the recession regimes.

	λ_L	λ_H	ψ_L	ψ_H
	0.21	0.26	2.30	0.15
t-stat	0.84	1.81	3.30	0.17

	μ_h	μ_l	σ_h^2	σ_l^2	p_{hh}^μ	p_{ll}^μ	p_{hh}^σ	p_{ll}^σ
	5.07	-1.21	18.41	5.78	0.96	0.90	0.73	0.97
t-stat	11.96	-1.57	8.49	24.40	54.46	24.23	9.82	87.82

	β_{US1}	β_{US2}	h_{US1}	h_{US2}	r_{US1}	r_{US2}	c_{US1}	c_{US2}	σ
	0.10	0.16	0.40	-0.17	-0.11	-0.75	-0.22	-0.24	2.48
t-stat	1.87	4.05	4.44	-2.17	-0.97	-10.07	-1.71	-1.92	32.37

Table 8: the UK size premium and US Great Moderation with the January effect, the UK Fama-French model

This table reports conditional asset pricing test results to investigate if the UK size premium (UKSMB) is redundant given other UK Fama-French factors (UKRMRF, UKHML) and the January effect dummy (*JAN*). The following bivariate regime switching model is estimated to test the hypothesis (1963:07 - 2017:12).

$$R_{UKsmb,t} = \phi_L I(V_L) + \phi_H I(V_H) + (\beta_{UK1} + \beta_{UK2} I(V_H))(R_{UKrm,t} - R_{UKrf,t}) \\ + (h_{UK1} + h_{UK2} I(V_H))(R_{UKhml,t}) + (\psi_L I(V_L) + \psi_H I(V_H))JAN + \varepsilon_{UKsmb,t} \\ \Delta y_t = \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t)), \varepsilon_{UKsmb,t} \sim N(0, \sigma^2)$$

where $R_{UKsmb,t}$ is the return to the UKSMB, $R_{UKrm,t} - R_{UKrf,t}$ is the UK market portfolio excess return (UKRMRF), $R_{UKhml,t}$ is the return on the UKHML. Note: two data sources are combined to produce longest possible UK Fama-French factors (1963:07 - 2017:12) as explained in Table 2. $I(V_H)$ is the indicator function having the value 1 for high-vol regimes and the value 0 for other regimes. $I(V_L)$ is the indicator function having the value 1 for low-vol regimes and the value 0 for other regimes. Δy_t is the monthly growth rate of the US industrial production (% , annualized) from the Federal Reserve Bank of St. Louis. S_t and V_t are latent state variables for the regimes of mean and variance. I assume that the probability of changing mean regimes is independent of the probability of changing volatility regimes. It follows that there are two mean regimes, $\mu_t \equiv \mu(S_t) \in \{\mu_l, \mu_h\}$ and two volatility regimes, $\sigma_t \equiv \sigma(V_t) \in \{\sigma_l, \sigma_h\}$, where l denotes the low regime and h the high regime. I denote the transition probabilities of the Markov chains by

$$P(\mu_t = \mu_h | \mu_{t-1} = \mu_h) = p_{hh}^\mu, P(\mu_t = \mu_l | \mu_{t-1} = \mu_l) = p_{ll}^\mu \\ P(\sigma_t = \sigma_h | \sigma_{t-1} = \sigma_h) = p_{hh}^\sigma, P(\sigma_t = \sigma_l | \sigma_{t-1} = \sigma_l) = p_{ll}^\sigma$$

If $\phi_H \neq 0$, the size premium is a priced factor during the high volatility regimes.

	ϕ_L	ϕ_H	ψ_L	ψ_H	β_{UK1}	β_{UK2}	h_{UK1}	h_{UK2}	σ
t-stat	0.20	3.83	0.31	-4.00	-0.04	-0.44	-0.05	-0.92	3.44
	1.26	5.07	0.54	-2.77	-0.97	-6.27	-1.37	-5.30	32.94

	μ_h	μ_l	σ_h^2	σ_l^2	p_{hh}^μ	p_{ll}^μ	p_{hh}^σ	p_{ll}^σ
t-stat	4.43	-5.83	16.65	5.89	0.98	0.89	0.49	0.94
	13.78	-6.09	8.64	24.16	110.74	23.69	4.27	54.40

Table 9: the UK size premium and US Great Moderation with the January effect, the hybrid Fama-French model

This table reports conditional asset pricing test results to investigate if the UK size premium (UKSMB) is redundant given other UK Fama-French factors (UKRMRF, UKHML), US Fama-French factors (USRMRF, USHML, USSMB, USRMW, USCMA) and the January effect dummy (JAN). The following bivariate regime switching model is estimated to test the hypothesis (1963:07 - 2017:12).

$$R_{UKsmb,t} = \phi_L I(V_L) + \phi_H I(V_H) + (\beta_{UK1} + \beta_{UK2} I(V_H))(R_{UKrm,t} - R_{UKrf,t}) + (h_{UK1} + h_{UK2} I(V_H))(R_{UKhml,t}) \\ + (\beta_{US1} + \beta_{US2} I(V_H))(R_{USrm,t} - R_{USrf,t}) + (s_{US1} + s_{US2} I(V_H))(R_{USsmb,t}) + (h_{US1} + h_{US2} I(V_H))(R_{UShml,t}) \\ + (r_{US1} + r_{US2} I(V_H))(R_{USrmw,t}) + (c_{US1} + c_{US2} I(V_H))(R_{UScma,t}) + (\psi_L I(V_L) + \psi_H I(V_H))JAN + \varepsilon_{UKsmb,t} \\ \Delta y_t = \mu(S_t) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2(V_t)), \varepsilon_{UKsmb,t} \sim N(0, \sigma^2)$$

where $R_{UKsmb,t}$ is the return to the UKSMB, $R_{UKrm,t} - R_{UKrf,t}$ is the UK market portfolio excess return (UKRMRF), $R_{UKhml,t}$ is the return on the UKHML, $R_{USrm,t} - R_{USrf,t}$ is the US market portfolio excess return (USRMRF), $R_{UShml,t}$ is the return on the US HML, $R_{USsmb,t}$ is the return to the USSMB, $R_{USrmw,t}$ is the return on the USRMW, $R_{UScma,t}$ is the return on the USCMA. Note: two data sources are combined to produce longest possible UK Fama-French factors (1963:07 - 2017:12) as explained in Table 2. The US Fama-French three factors are from Kenneth French's website. $I(V_H)$ is the indicator function having the value 1 for high-vol regimes and the value 0 for other regimes. $I(V_L)$ is the indicator function having the value 1 for low-vol regimes and the value 0 for other regimes. Δy_t is the monthly growth rate of the US industrial production (%), annualized) from the Federal Reserve Bank of St. Louis. S_t and V_t are latent state variables for the regimes of mean and variance. I assume that the probability of changing mean regimes is independent of the probability of changing volatility regimes. It follows that there are two mean regimes, $\mu_t \equiv \mu(S_t) \in \{\mu_l, \mu_h\}$ and two volatility regimes, $\sigma_t \equiv \sigma(V_t) \in \{\sigma_l, \sigma_h\}$, where l denotes the low regime and h the high regime. I denote the transition probabilities of the Markov chains by

$$P(\mu_t = \mu_h | \mu_{t-1} = \mu_h) = p_{hh}^\mu, P(\mu_t = \mu_l | \mu_{t-1} = \mu_l) = p_{ll}^\mu \\ P(\sigma_t = \sigma_h | \sigma_{t-1} = \sigma_h) = p_{hh}^\sigma, P(\sigma_t = \sigma_l | \sigma_{t-1} = \sigma_l) = p_{ll}^\sigma$$

If $\phi_H \neq 0$, the size premium is a priced factor during the high volatility regimes.

	ϕ_L	ϕ_H	ψ_L	ψ_H
	0.21	2.82	0.32	-5.06
t-stat	1.09	4.63	0.47	-3.87

	μ_h	μ_l	σ_h^2	σ_l^2	p_{hh}^μ	p_{ll}^μ	p_{hh}^σ	p_{ll}^σ
	4.40	-4.80	15.34	5.48	0.98	0.89	0.75	0.96
t-stat	13.48	-4.90	9.69	23.08	101.55	24.59	11.35	76.31

	β_{UK1}	β_{UK2}	h_{UK1}	h_{UK2}	β_{US1}	β_{US2}	h_{US1}	h_{US2}
	-0.03	-0.37	-0.09	-0.24	-0.01	0.03	0.23	-0.13
t-stat	-0.37	-5.58	-1.90	-3.62	-0.09	0.21	2.57	-0.95

	s_{US1}	s_{US2}	r_{US1}	r_{US2}	c_{US1}	c_{US2}	σ
	-0.02	0.09	0.02	-0.47	-0.30	0.78	3.54
t-stat	-0.50	1.33	0.11	-1.17	-2.80	4.72	34.53