



Asset prices and economic fluctuations: The implications of stochastic volatility[☆]



Junping Chen^a, Xiong Xiong^{b,d,*}, Jie Zhu^{c,e}, Xiaoneng Zhu^{a,f}

^a School of Finance, Shanghai University of Finance and Economics, China

^b College of Management and Economics, Tianjin University, China

^c SHU-UTS SILC Business School, Shanghai University, China

^d China Center for Social Computing and Analytics, Tianjin University, Tianjin, China

^e University of Technology Sydney, Australia

^f Shanghai Key Laboratory of Financial Information Technology, China

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ABSTRACT

This paper investigates whether the multi-factor stochastic volatility of stock returns is related to economic fluctuations and affects asset prices. We address these issues in a dynamic Fama-French three-factor volatility model framework. Consistent with the ICAPM with stochastic volatility (Campbell et al., 2017), we find that the conditional volatility of the size and value factors is significantly related to economic uncertainty. These volatilities are also significant pricing factors. The out-of-sample forecasting analysis further reveals that the conditional volatility can predict stock returns and deliver economic gain in asset allocation. Our analysis sharpens the understanding on the link between the stock market and economic fundamentals.

1. Introduction

Voluminous studies demonstrate that asset prices and returns can predict economic activity. The intuition behind these studies is simple and straightforward: since investors' expectations about future states of the economy largely determines what they are willing to pay for assets today, asset prices naturally reveal the information about future business cycles. Since the Fama-French three factors (1993, FF3 hereafter) are perhaps the most influential measures of asset prices, it is not surprising that these factors are found to have predictive power for economic fluctuations.¹ On the theoretical side, the preeminent work of Zhang (2005), in the neoclassical framework with rational expectations, demonstrates that costly reversibility and countercyclical price of risk can explain the premia of the FF3 factors, theoretically linking the FF3 factors to the business cycle.

Given the empirical and theoretical evidence that the FF3 factors

are proxy variables of states of the economy, the important work of Campbell et al. (2017) suggests that the variance of the FF3 factors should also be proxy variables of future states of the economy. Because investment opportunities could deteriorate due to either the decline in expected stock returns or the increase in volatility of stock returns, Campbell et al. (2017) extend the intertemporal capital asset pricing model (ICAPM hereafter) of Merton (1973) by incorporating the stochastic volatility of state variables into the ICAPM. They show that the volatility of state variables should also be related to future business cycles. Along this line of reasoning, it implies that volatility of market, size and value factors is related to systematic macroeconomic risks and economic activity. Rather surprisingly, few studies, if any, have investigated the links between volatility of size and value factors and economic activity.² This paper attempts to take the challenge and addresses two empirical questions. First, does volatility of the size and value factors link to macroeconomic activity? And second, if that is the

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* Corresponding author at: College of Management and Economics, Tianjin University, China.

E-mail addresses: mogu0922@sina.com (J. Chen), xxpeter@tju.edu.cn (X. Xiong), zhu_jie@t.shu.edu.cn (J. Zhu), xiaonengz@gmail.com (X. Zhu).

¹ For reference, see Vassalou (2003), Petkova and Zhang (2005), Hahn and Lee (2006), and Petkova (2006).

² There exists a strand of empirical literature on risk-return relation, including Ang et al. (2006), Christensen et al. (2010, 2015), and Kanas (2012). Yet most of these studies only explore the relation between return and volatility of the market factor. In addition, a few studies (e.g., Vassalou, 2003; Petkova and Zhang, 2005; and Petkova, 2006) investigate the relation between size and value factors and economic activity, but they do not examine whether volatility of these factors is related to macroeconomic risk.

case, is volatility of the size and value factors priced in the stock market?

In the spirit of Fama and French (2012), we examine five international stock markets: Asia-Pacific (excluding Japan), Europe, Japan, North America, and the global market. It aims to provide insights on the importance of the variance of FF3 factors in asset pricing. As addressed by Fama and French (2012), the data include all size groups. This distinguishes from previous international studies which focus on large stocks. Because small stocks tend to generate anomalous results, this feature is likely to sharpen our understanding on the fluctuations of stock returns. By concentrating on the regional markets, we test asset pricing implications in the broadest region in which asset prices tend to be integrated. In doing so, our empirical approach should have strong testing power.

We use a dynamic multi-factor volatility model (DMFVM) to capture volatility dynamics of FF3 factors. Since economic theory suggests that volatility of FF3 factors should be related to economic fundamentals, we link the conditional variance of FF3 factors to macroeconomic uncertainty and industrial production growth. Our analysis indicates that volatility of FF3 factors is related to systematic macroeconomic risks. Chabi-Yo (2009) builds a model to show that volatility of FF3 factors is related to variance risk premia and should be priced in stock returns, which is consistent with Bollerslev et al. (2009). Along this line, we also empirically test the relation between volatility of FF3 factors and variance risk premia. We find that volatility of FF3 factors is significantly related to variance risk premium, which is predicted by our model.

Having established the relation between volatility of FF3 factors and economic activity, we next test asset pricing implications. The in-sample test suggests that volatility of FF3 factors generally carry significant and positive risk premia in international stock markets, rendering the DMFVM with a superior performance in asset pricing than other competitive models in terms of smaller sum of squared errors, larger adjusted R-square, and smaller pricing error statistics. These results hold up well in a set of robustness tests. Furthermore, the out-of-sample forecasting analysis indicates that the DMFVM significantly beats other models in terms of forecasting accuracy. Notably, the asset allocation results imply that variance of FF3 factors delivers economic value.

We contribute to the literature in two aspects. First, our empirical analysis sharpens understanding on financial anomalies. While FF3 factors are usually employed as benchmark pricing factors in the asset pricing literature, how volatility of these factors relating to systematic macroeconomic risks is, to our best knowledge, unexamined. Our study takes one step in this direction by linking the variance of size and value anomalies to systematic macroeconomic risks. Second, we extend the analysis of He et al. (2015a) and Chabi-Yo (2009) by offering international evidence on relevance of volatility of size and value factors in asset pricing.

The rest of the paper is organized as follows. Section 2 presents the DMFVM model. Section 3 discusses data issues and estimates the model. Section 4 relates the variance of FF3 factors to economic uncertainty and economic activity. Section 5 conducts the in-sample asset pricing test. Section 6 conducts exercises on out of sample forecasting. Section 7 concludes.

2. The dynamic multi-factor volatility model

One of the key issues in asset pricing is to find pricing factors explaining variations in stock returns. The FF3 model is frequently applied in empirical studies. However, the model is essentially static, which means that FF3 factors are constructed separately at each period. The lack of the dynamic feature leads the model fragile in explaining asset pricing anomalies. Keeping this in mind, He et al. (2010) consider a dynamic asset pricing model (DFPM) which includes the dynamic feature of FF3 factors. They show that dynamic factors are

informative and the proposed model has performed better than benchmark models in in-sample and out-of-sample tests. Another strand of related literature on intertemporal models indicates that stock returns are not only determined by FF3 factors, but also by volatility of these factors. He et al. (2015a) utilize the econometric technique that helps to extract dynamic factors and their volatility simultaneously. The incorporation of both dynamic factors and their volatility into return generating process improves the explanation power for differences in expected returns in cross section, and also obtains significant improvements in forecasts and asset allocation. The result confirms that both dynamic factors and their volatility are informative for pricing assets. In this paper, we generalize the analysis to international stock markets.

The model specification is similar to the one introduced in He et al. (2010) and He et al. (2015a). Following the literature, we denote the 2×3 portfolios sorted on size and book-to-market (BTM) ratio as SL, SM, SH, BL, BM, and BH, where S and B stand for small and big, and L, M, and H stand for low, medium, and high. Let $R_t = [R_{SL,t} R_{SM,t} R_{SH,t} R_{BL,t} R_{BM,t} R_{BH,t}]'$ be a 6×1 vector of excess returns over riskfree rates on 6 portfolios at t . We demean the R_t series by subtracting each observation from its mean. The latent MKT, SIZE, and BTM dynamic factors are given by $D_t = [D_{MKT,t} D_{SIZE,t} D_{BTM,t}]'$. The model with dynamic factors is represented in a state-space form, with 6 observation equations given by:

$$\begin{bmatrix} R_{SL,t} \\ R_{SM,t} \\ R_{SH,t} \\ R_{BL,t} \\ R_{BM,t} \\ R_{BH,t} \end{bmatrix} = \begin{bmatrix} \mu_{SL} & \mu_S & \mu_L \\ \mu_{SM} & \mu_S & \mu_M \\ \mu_{SH} & \mu_S & \mu_H \\ \mu_{BL} & \mu_B & \mu_L \\ \mu_{BM} & \mu_B & \mu_M \\ \mu_{BH} & \mu_B & \mu_H \end{bmatrix} \begin{bmatrix} D_{MKT,t} \\ D_{SIZE,t} \\ D_{BTM,t} \end{bmatrix} + \begin{bmatrix} e_{SL,t} \\ e_{SM,t} \\ e_{SH,t} \\ e_{BL,t} \\ e_{BM,t} \\ e_{BH,t} \end{bmatrix}, \quad (1)$$

where μ_S are the factor loadings and $e_t = [e_{SL,t} e_{SM,t} e_{SH,t} e_{BL,t} e_{BM,t} e_{BH,t}]'$ is the 6×1 vector of error terms. Note in order to let these extracted factors have a predetermined interpretation, the factor loading matrix, μ , has to impose some restrictions.

The dynamic market factor, $D_{MKT,t}$, is identified from the first column of μ . Its value varies in rows so that price dynamics in different portfolios can be captured. The dynamic size factor, $D_{SIZE,t}$, is designed to capture the variation related with size in returns that is not captured by $D_{MKT,t}$. By construction, the portfolios SL, SM, SH are within the small size group, while the portfolios BL, BM, and BH are within the big size group. Thus the first three coefficients in the second column of μ are all equal to μ_S , while the last three coefficients are equal to μ_B . Similarly, $D_{BTM,t}$ can be identified by putting restrictions on the third column of μ . We need three different coefficients in that column to reflect the fact that there are three groups in BTM-sorting portfolios.

We assume each dynamic factor follows an AR(1) process:

$$\begin{bmatrix} D_{MKT,t} \\ D_{SIZE,t} \\ D_{BTM,t} \end{bmatrix} = \begin{bmatrix} \phi_{MKT} & 0 & 0 \\ 0 & \phi_{SIZE} & 0 \\ 0 & 0 & \phi_{BTM} \end{bmatrix} \begin{bmatrix} D_{MKT,t-1} \\ D_{SIZE,t-1} \\ D_{BTM,t-1} \end{bmatrix} + \begin{bmatrix} v_{MKT,t} \\ v_{SIZE,t} \\ v_{BTM,t} \end{bmatrix}, \quad (2)$$

where ϕ_S are the autoregressive coefficients. Eqs. (1) and (2) present the dynamic factor model in a state space form. We further assume that e_t is normally distributed, and e_t is uncorrelated with v_t .

In addition, to allow time-varying conditional variance of dynamic factors, we assume the vector of factor innovations, $v_t = [v_{MKT,t} v_{SIZE,t} v_{BTM,t}]'$, follows a GARCH (1,1) process for each of its component. In a succinct form:

$$h_{t|t-1} = \omega + A v_{t-1}^2 + \Gamma h_{t-1}, \quad (3)$$

where $h_{t|t-1}$ is the vector of conditional variance at t based on information set I_{t-1} ; $\omega = [\omega_{MKT} \omega_{SIZE} \omega_{BTM}]'$ is the 3×1 vector of constants; and A and Γ are diagonal coefficient matrices, $A = \text{diag}(\alpha_{MKT} \alpha_{SIZE} \alpha_{BTM})$ and $\Gamma = \text{diag}(\gamma_{MKT} \gamma_{SIZE} \gamma_{BTM})$. With these assumptions, Eqs. (1), (2), and (3) constitute the DMFVM. Since v_t is unobservable, following Kim and

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