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Technology prospects and the cross-section of stock returns☆

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ABSTRACT

In an economy with time-varying investment opportunities, the changes in technology prospects affect aggregate consumption and individual firm's future dividends, and lead to systematic technology risk. We construct a technology factor to track the changes in technology prospects measured by U.S. patent shocks, and find that this factor explains the growth of aggregate consumption, helps to price important stock portfolios, and carries significant risk premium. Our empirical results suggest the existence of technology risk in the cross-section of stock returns.

1. Introduction

The idea that technological innovations can explain stock returns is occupying an increasingly important role in the asset pricing literature. Some recent studies focus on the role of aggregate, permanent technology shocks in macroeconomic dynamics and stock returns[1], while other studies inspect the effects of various technologies on the cross-sectional variation of stock returns[2]. No study, however, has analyzed how investors' expectation of aggregate technology level ("technology prospects," hereafter) affects stock returns. In this paper, we aim to examine if technology prospects help to explain stock returns and if the market grants technology risk premium. This research question is important because the stock prices are determined not only by current technology state but also by the investors' anticipation of future technological progress.

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[1] Lettau (2003), Panageas and Yu (2006), and Kaltenbrunner and Lochstoer (2008) model the effect of technology shocks on market returns and premia. Hsu (2009) finds that technology shocks, measured by patent data and R&D data, have strong predictive power for market returns and premia. Other relevant studies include Papanikolaou (2008) and Pástor and Veronesi (2008).

[2] A partial list of studies on the adjustment costs in production functions includes Gomes et al. (2003), Zhang (2005), and Gala (2006). On the other hand, Pakes (1985) finds that firms' patents and R&D expenses have positive impacts on their stock returns using a micro data set composed of 120 firms over an 8-year period. Apedjinou and Vassalou (2004) find that corporate innovations can explain expected stock returns, especially the momentum phenomenon.

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In an intertemporal economy, time-variant technology prospects affect periodic optimal consumption and thus enter into the pricing kernel. Based on the permanent income hypothesis (Friedman, 1957) and aggregate budget constraint (Campbell, 1993), investors' current consumption depends not only on their current wealth but also on expected future income. Since aggregate technological growth drives up productivity (Solow, 1957) and has persistent or even permanent effect on future output, technology prospects should be positively related with aggregate consumption. According to Merton's (1973) intertemporal capital asset pricing model (ICAPM), all economic variables related to consumption growth may act as systematic risk factors in the stochastic discount factor (SDF) and affect expected asset returns[3]. On the other hand, when technology prospects change, different firms' expected productivity and cash flows rise to different extents, which could give birth to the cross-sectional variation of stock returns.

We empirically test if the changes in technology prospects work as a systematic risk factor in the SDF and whether this factor is priced. We use U.S. patent shocks constructed by Hsu (2009) as a proxy for aggregate technological innovations. Then, we use the tracking portfolio method proposed in Lamont (2001) to construct a technology factor that measures the changes in technology prospects[4]. We project future technological innovations on current excess returns of base assets and control variables. The coefficient-weighted returns of these base assets constitute a return-based technology factor that tracks the changes in technology prospects. We find that the proposed technology factor is independent of common risk factors as well as recession indicators, and is able to explain contemporaneous consumption growth. Our findings are consistent with the consumption-based motivation and suggest that the technology factor works as a distinct factor.

We follow Cochrane (1996, 2001) to examine the risk loading of the technology factor in the SDF and the price of technology risk in the sample period 1981Q4–2007Q3. We find that the technology factor carries significantly negative loading and significantly positive premium, suggesting that the technology factor helps to price assets and itself is also priced. The ICAPM with the technology factor is able to explain over 30% of the cross-sectional variation of Fama and French's (1993) 25 portfolios, 10 momentum portfolios, and 10 R&D intensity portfolios[5]. When we implement a conditional test, the ICAPM is able to explain over 50% of the variation. Even at the presence of size, book-to-market, and momentum factors, the technology factor still significantly helps to price these testing assets. The statistic and economic significance of the technology factor is not superseded by other consumption risk factors such as consumption growth and *cay*. These findings survive several robustness checks, including a test with a longer sample period back to 1963.

We would like to clarify that the technology factor proposed in this study is distinct from the Solow residual (1957) from several perspectives: First, the technology factor measures the changes in investor's expectation of *future* technological progress, while the Solow residual is about *realized* productivity shocks. The Solow residual includes all shocks unexplained by labor and capital, but those shocks could be temporary and irrelevant to technological development. Basu and Fernald (2002) argue that productivity shocks and technology shocks are distinct concepts and perform empirical differences.

This study may contribute to the asset pricing literature from the following perspectives. We show that technological innovations can affect the asset prices through expectation, in addition to realization. Moreover, we use a patent data set that allows us to better measure technological innovations and understand their effect in the cross-section of stock returns. Lastly, we find that technology risk explains a part of the return spread driven by momentum, R&D intensity, and investment intensity. Our findings therefore hint at a technology-based explanation for the cross-section of stock returns, yet further investigation is called to show *why* the technology factor covariates with stock returns.

The rest of the paper is organized as follows. We motivate technology risk within an ICAPM framework in Section 2 and construct the technology factor in Section 3. Section 4 includes the testing strategy and main empirical results, and Section 5 describes relevant robustness checks. Section 6 concludes this paper.

2. Motivation

Solow (1957) suggests that aggregate technology level should play an important role other than labor and capital in aggregate production function, which can be characterized as

$$Y_t = A_t F(n_t, k_t), \tag{1}$$

where the total output Y_t at time t is determined by aggregate technology level (A_t), labor input (n_t), and capital input (k_t). The main implication of his model is that, even with fixed labor and capital input, an economy can still grow and fluctuate due to variant technology condition. When this argument is connected to the long-term budget constraint as well as permanent income hypothesis, the investors' optimal consumption should take account of the expectation of future technology level. When there happens good news to technology prospects, investors would anticipate a persistent increase in future output, thanks to technological progress. As a result, investors will have less restricted long-term budget constraints, which raise the consumption today (e.g. Campbell, 1993, 1994) because, unlike most other productivity shocks, technology shocks tend to have more persistent real effects on the economy.

[3] Motivated by the ICAPM, Chen et al. (1986) and Chen (1991) inspect if the production growth, default premium, term premium, short-term interest rate, inflation, and market dividend yield can explain stock returns as they all affect consumption growth. Recent ICAPM-based studies consider aggregate productivity shocks (Balvers and Huang, 2007a), real money growth (Balvers and Huang, 2007b), and size premium as well as value premium (Petkova, 2006; Guo et al., 2007).

[4] This approach has been widely used in the construction of risk factors such as news about future GDP growth (Vassalou, 2003) and expected volatility (Ang et al., 2006).

[5] Since Jegadeesh and Titman (1993), it has been well documented that stocks with higher returns in the past (i.e. high-momentum stocks) outperform stocks with lower returns in the past. On the other hand, recent empirical studies indicate that firms' R&D activities increase subsequent stock returns (e.g. Lev and Sougiannis, 1996; Chan et al., 2001; Eberhart et al., 2004; Li, 2007).