Time-varying exposure to permanent and short-term risk and stock price momentum

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Abstract

This paper provides an explanation for the documented link between earnings and stock price momentum. A simple dynamic model that accounts for firms' exposures to both short-term and long-term earnings shocks produces momentum-like effects. Price sensitivities to the two types of shocks vary in the cross-section depending on firm fundamentals and change over time depending on firm financial health. The combined effects of short-term and long-term earnings shocks lead to a positive relationship between cumulative past and expected returns of winner and loser momentum portfolios. The model predicts greater profitability of momentum strategies in the subset of companies that are more sensitive to short-term shocks and temporarily financially constrained. Empirical tests support the model predictions.

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I. Introduction

Momentum investment strategies go long the stocks with the highest recent price performance and short the ones with the lowest. The profitability of these so called momentum portfolios was first documented by Jegadeesh and Titman (1993) for the US stock market. A large body of literature has since shown the presence of momentum in other markets around the world. [1]

A theory of the momentum premium should be able to not only justify the magnitude of the strategy's profits but also the reversal in returns for holding periods beyond a year. Both sentiment and rational theories have been proposed in the literature. [2] Explanations based on sentiment rely on biases in the way investors process information. Barberis, Schleifer and Vishny (1998) argue that a conservatism bias, which implies that investors are slow in updating their beliefs in the face of new information, leads to under-reaction in the short term. Daniel, Hirschleifer and Subrahmanyam (1998) present a model where overconfident traders overweight past information deemed to be correct, neglecting future information. Both models can generate price continuations and reversals but they cannot explain the magnitude and the specific formation and holding periods over which momentum strategies are profitable. Rational explanations argue that returns to momentum strategies are a compensation for risk. This can be the case if there is a dispersion in unconditional drifts in returns (Conrad and Kaul, 1998), or if betas are time-varying but persistent.[3] While rational models can provide quantitative predictions regarding the magnitude and performance patterns of momentum strategies, they are not successful in replicating both simultaneously.

A relatively more recent empirical literature (Chordia and Shivakumar (2006), Novy Marx (2012)) shows that the abnormal returns to momentum portfolios disappear after controlling for measures of earnings surprises. Motivated by this evidence, this paper proposes a micro-founded model that generates earnings momentum and price momentum. The key feature of the model is that earnings are subject to both temporary *and* permanent shocks. I show that the combination of the two shocks matches the short-to-intermediate term nature of momentum profits.

This paper examines the pricing implications of a firm's cash policy response to the two types earnings shocks, which, to the best of my knowledge, is an unexplored channel for the purposes of studying momentum. Since profits to momentum strategies are relatively short lived, the link between earnings and price momentum is more likely to emerge through the cash policy of a firm

[1] Rouwenhorst (1998) shows that there is persistence in returns over the medium-term horizon not only in the US, but also in international equity markets. Moskowitz and Grinblatt (1999) show that there is a strong momentum effect in industry portfolios. Chan, Hameed and Tong (2000) show that there is momentum also in international stock market indices. Jagageesh and Titman (2001a) show that the profits to the momentum anomaly have not disappeared after its initial discovery (at the time the paper was published). Avramov et al. (2007) show that momentum profits arise mainly due to low rated firms, while there is no momentum present among high rated firms. Asness, Moskowitz and Pedersen (2013) document the presence of momentum across eight different markets and asset classes.

[2] Data mining has also been proposed as a possible reason for the existence of momentum returns. However, the pervasive evidence on the profitability of momentum strategies in out-of-sample tests, both before and after the seminal Jegadeesh and Titman (1993) study, addresses any such concerns.

[3] Johnson (2002) links momentum to the growth rate in dividends, which follows a mean-reverting process. He shows that sensitivity to dividend growth rate risk increases with growth rates, justifying the higher expected returns to the winner leg of the momentum portfolio. Berk, Green and Naik (1999) model betas as being dependent on the collection of projects the firm has invested in, a collection which changes slowly over time

rather than investment or capital structure policies which have a more long-term nature and do not adjust as frequently. Bolton, Chen and Wang (2011) show that cash policy is indeed important for firm valuation. Decamps et al. (2016) build a similar model but incorporate both temporary and permanent shocks to earnings and show that their combination has different implications on cash policy and valuation. The setting in this paper is thus similar to Decamps et al. (2016), with the addition of a stochastic discount factor that prices both temporary and permanent systematic shocks.

Profitability-scaled cash holdings, which depends on both types of earnings shocks, drives the dynamics of the model. Exposure to transitory shocks can lead to losses, motivating the firm to maintain cash reserves. Holding cash is costly and there is an optimal or target level of cash that balances the precautionary benefits with the carry costs (Bolton, Chen and Wang, 2011). Whenever cash exceeds the optimal level, the firm distributes the excess as a dividend. When cash holdings fall below target, transitory shocks can potentially drive the firm out of business, regardless of its long term prospects. As a result, the firm becomes increasingly sensitive to transitory shocks. The sensitivity to permanent shocks, on the other hand, does not change significantly and becomes less important compared to the transitory one. Based on this analysis, the firms experiencing the largest price responses to cash-flow shocks are the ones where cash is below target. A sorting by past performance over the previous year will therefore contain a large proportion of this subset of companies.

At the time of portfolio formation, the firms that have had the largest price increases (the winners) will have reached a level of productivity-scaled cash holdings that is close enough to target so that they are less likely to be liquidated. The losers on the other hand, are the surviving companies among the most constrained ones that have received negative earnings shocks. The model intuition is that momentum strategies are bets that the prices of winners will continue to rise due to them being closer to target, while the prices of the losers will continue to decline due to them being farther from target. Sorting on performance over the past year provides an indication as to how far from their respective targets these companies are. The closer to (farther from) the target, the more likely it is that price increases (declines) will continue.

The first prediction of the model is therefore that momentum returns are attributable to those companies where scaled cash holdings are below target. A simple test in the data confirms this. A conditional double sort on momentum and a proxy for the distance from target cash shows that momentum portfolios yield statistically significant alphas only in the lowest quintile for the distance from target cash holdings. This result links momentum to financial distress, which is consistent with the finding in Avramov (2005) that momentum is concentrated in companies that have the lowest credit ratings. These represent a very small proportion of the universe of stocks, and so do companies whose scaled cash holdings are below target.

Computing the correlation between realized cumulative excess returns and expected excess returns in model simulations allows for comparative statics exercises. These shed light on how firm fundamentals relate to the correlation in returns, therefore allowing to identify the companies with the highest correlation. As argued by Sagi and Seasholes (2009), a higher autocorrelation in returns can provide enhanced momentum strategies since the winners (losers) with the highest autocorrelation will be more persistent. The model predicts that the correlation between realized and expected returns should be highest on those stocks that have: (1) the highest volatility of short-term shocks, (2) the lowest volatilities of permanent shocks, (3) positively correlated permanent and short-term earnings shocks, (4) the lowest growth rates in productivity and (5) the lowest growth rates in productivity-scaled earnings.

The higher the volatility of short-term shocks and the lower the volatility of productivity shocks, the more likely it is that the short-term beta of the company will be high. This provides a testable hypothesis in terms of momentum profits being higher for companies where the ratio of the volatilities of short-term and permanent shocks is higher. I use sales as a proxy for productivity, which serves to compute the volatility of permanent shocks. The volatility of the earnings proxies for the volatility of short-term shocks in the model. I then form portfolios by double sorting on past performance over the previous year and the ratio of the shock volatilities. The returns to momentum strategies along the quintiles with the highest volatility ratios produce higher returns compared to unrestricted momentum strategies.

Returns to momentum portfolios formed on simulated model data with parameters set at the baseline levels close to those in Decamps et al. (2016), are positive and statistically significant. They average at 2% per month, with a test statistic greater than 4.5. In different sets of simulations, one of the key parameters of the model is changed in order to observe the effect on momentum portfolio returns. The results of these simulations are generally in line with those of the comparative statics exercises.

Since the dynamics of the model are driven by earnings shocks, which in reality the firm receives on earnings announcement dates, the model links earnings announcements to price momentum. Constructing Standardized Unexpected Earnigns (SUE) based on the model, where earnings changes are linked to the level of productivity, yields a measure that, on its own, is able to reduce the power of momentum in cross-sectional Fama-MacBeth regressions. Accounting for profitability is therefore important for explaining the effect of past performance on expected returns. This provides additional support for the mechanism for momentum that is implied by this model.

Another widely used measure of earnings surprises in the literature is Cumulative Abnormal Returns (CAR) on the earnings announcement day. According to the model, the price responses of liquidity constrained firms on the announcement day will be large due to the higher short-term beta. Therefore, these higher returns will not necessarily be abnormal, but a compensation for the higher liquidation risk. Independent double sorts on CAR and the proxy for the distance from target cash show that CAR strategy returns are higher in the quantile where firms are most constrained.

This paper puts together various strands of the literature related to momentum, linking it simultaneously to time-variation in expected returns, earnings momentum and financial distress. Conrad and Kaul (1998) argue that differences in unconditionally expected returns yield momentum effects, since a sort on past performance would be a sort on these unconditional expected returns.

Jegadeesh and Titman (2001) criticise this conjecture stating that their model would imply that momentum profits would persist indefinitely, which is inconsistent with the evidence of the disappearing profitability of the strategy for holding periods beyond a year. Time-variation in expected returns makes the model here not subject to the same critique. Chordia and Shivakumar (2002) also link momentum to time-series variation in conditionally expected returns. These can be predicted by a set of macroeconomic variables, which are mainly related to credit market conditions. This is in line with Avramov (2005) linking momentum to financial distress. The paper is, however, mainly descriptive in the sense that it documents where momentum returns are highest but it does not explain why this occurs. The model presented here can provide a link between earnings momentum and price momentum that arises from financial distress, which could also explain the findings of Avramov (2005).

Accounting for exposures to both permanent and short-term shocks is instrumental for the model being able to explain momentum strategy profits. Gorbenko and Strebulaev (2010) and Decamps et al. (2016) among others, stress the importance of both types of shocks in shaping firms' financial policies. This paper is similar in spirit with Palazzo (2011), in terms of considering the effects of corporate cash holdings on equity risk premia based on a model where target cash holdings and risk depend on the correlation between cash flows and a pricing kernel.

This paper is also related to Johnson (2002), where momentum effects arise from stochastic expected growth rates to dividends. Expected excess returns are also time-varying in this setting and, under certain assumptions, positively correlated with cumulative excess returns. Once generalized to account for both long-term and short-term shocks to the dividend growth rate, the model is much better capable of reproducing momentum effects, although of a much smaller magnitude than those observed in the data. Jegadeesh and Titman (1993) also recognize that there might be a link between news on short-term and long-term prospects of the company and the profitability of momentum strategies. They relate these to investor over/under-reaction. The analysis presented here provides an alternative explanation that is based on the company's time-varying exposures to systematic long-term and short-term risk. These two types of explanations need not necessarily be mutually exclusive.

The rest of the paper is organised as follows. Section 2 presents the model setup and the beta pricing implications. Section 3 provides the results of the comparative statics exercises and model simulations, along with the testable predictions. Section 4 describes the data and identification procedure. Some preliminary results are presented in Section 5. Section 6 concludes.

II. The Model

A. Model setup

The setup of the model is that of Décamps et al. (2016). Markets are complete and arbitrage-free. Time is continuous and the risk-free rate is constant at $r > 0$.

The firm considered in this model is an all equity-firm, whose cash-flows are exposed to both permanent and transitory shocks. Shocks of a permanent nature affect the productivity of the firm's assets in place. This productivity is denoted by A_t and is assumed to follow a geometric Brownian motion:

$$dA_t = \mu A_t dt + \sigma_P A_t dW_t^P$$

where μ and $\sigma_P > 0$ are constant and W^P is a standard Brownian motion under the physical measure, $\mathbb{P}$. The parameter μ represents the expected growth rate in the firm's productivity, while σ_P is the volatility of the productivity process. The cash flow that is generated every period, denoted by dX_t, is uncertain and depends on the level of productivity in the previous period:

$$dX_t = \alpha A_t dt + \sigma_T A_t dW_t^T$$

where α and σ_T are positive constants and W^T is a standard Brownian motion under the physical measure, $\mathbb{P}$. The parameter α represents the expected growth rate in productivity-scaled cash flows, while σ_T is the volatility of the productivity-scaled cash-flow process. W^T represents the short-term shock to scaled cash-flows, and it is correlated with W^P with an instantaneous correlation coefficient of $\rho \in [-1, 1]$:

$$dW_t^T dW_t^P = \rho dt$$

Given this correlation, it is possible to decompose the short-term shocks to cash flows into permanent and transitory components:

$$dW_t^T = \rho dW_t^P + \sqrt{1-\rho^2} dW_t^Z$$

where W^Z is another Brownian motion which is uncorrelated to W^P. This means that short-term shocks to cash flows (dW_t^T) consist of a combination of shocks to the productivity level which have a permanent nature (given that productivity follows a GBM) and shocks of a transitory nature that do not necessarily affect productivity. The cash flow process can then be expressed as:

$$dX_t = \alpha A_t dt + \sigma_T A_t \rho dW_t^P + \sigma_T A_t \sqrt{1-\rho^2} dW_t^Z$$

If the firm is not exposed to short-term shocks ($\sigma_T = 0$), cash-flows cannot be negative. This is because in this case they would be given by $\alpha A_t dt$ and both α and A_t are positive. The presence of short-term shocks ($\sigma_T > 0$) means that cash-flows can become negative. The firm is therefore exposed to potential losses, and has a precautionary motive for retaining earnings as cash reserves. The firm's cash holdings are denoted as M_t, and there is a carry cost of liquidity denoted as λ where $\lambda \in (0, r]$. Cash reserves have the following $\mathbb{P}$-dynamics:

$$dM_t = (r - \lambda) M_t dt + dX_t - dD_t$$

where D_t is the cumulative dividend paid to shareholders up to time t.

The firm is liquidated at time τ if the cash buffer reaches zero following a series of negative shocks. The firm value will then be a function of productivity and cash reserves, $V(a,m)$, and it will be given by:

$$V(a,m) = \max_{(D_t)_t,\tau} \mathbb{E}^{\mathbb{Q}}_{a,m}\left[\int_0^{\tau} e^{-rt}dD_t + e^{-r\tau}\left(\frac{\omega\hat{\alpha}A_\tau}{r-\hat{\mu}} + M_\tau\right)\right]$$

where ω is the fraction of the unconstrained value of the assets that is recovered in the liquidation event, $\hat{\alpha}$ and $\hat{\mu}$ are the risk-adjusted growth rated in cash flows and productivity respectively. The objective of the shareholders is to choose the dividend and liquidation policies that maximize firm value.

B. *Model solution*

In the region where it is optimal to retain earnings, $M \in (0, \bar{M})$, the equity value function $V(a,m)$ will satisfy the following ODE:

$$rV = \hat{\mu}aV_a + (\hat{\alpha}a + (r-\lambda)m)V_m + \frac{1}{2}a^2\left(\sigma_P^2V_{aa} + 2\rho\sigma_P\sigma_T V_{a,m} + \sigma_T^2V_{mm}\right)$$

The LHS of the above equation represents the required return on the equity of the firm. The first two terms on the RHS represent the effects of changes in profitability μa and cash savings $\alpha a + (r-\lambda)m$. The last term represents the effects of the volatilities in profitability and cash flows. $V_{a,m} \neq 0$ in this model, meaning that changes in productivity affect firm value as well as cash reserves.

The equity value is homogenous of degree one in A and M, therefore:

$$V(a,m) = aV(1, \frac{m}{a}) \equiv aF(c)$$

where $c = \frac{m}{a}$ represents the productivity scaled cash holdings. The first and second order derivatives of the equity value with respect to productivity and cash holdings can be expressed as: $V_a = F(c) - cF'(c)$, $V_{aa} = \frac{c^2}{a}F''(c)$, $V_m = F'(c)$, $V_{mm} = \frac{1}{a}F''(c)$ and $V_{am} = -\frac{c}{a}F''(c)$. The above ODE can then be re-written as:

$$(r-\mu)F(c) = (\hat{\alpha} + (r-\lambda-\hat{\mu})c)F'(c) + \frac{1}{2}\left(\sigma_P^2c^2 - 2\rho\sigma_P\sigma_T c + \sigma_T^2\right)F''(c) \tag{1}$$

subject to boundary conditions

$$F(0) = \frac{\omega\,\hat{\alpha}}{r-\hat{\mu}},$$

$$F'(c*) = 1, F''(c*) = 0,$$

$$F(c) = F(c*) + c - c*,\ \ for\ c > c*$$

.

C. *Expected returns and risk premia*

In order to analyse expected returns and risk premia under this setting, a representative agent is assumed to have a marginal utility process Λ_t, whose dynamics are given by:

$$\frac{d\Lambda_t}{\Lambda_t} = -rdt - \eta_T dZ_t^T - \eta_P dZ_t^P$$

where Z_t^T and Z_t^P are standard Brownian motions independent of one another. Z_t^T is correlated with the source of short-term risk to the firm's cash-flows, W_t^T, with a correlation coefficient of χ_T. Z_t^P is correlated with the source of permanent risk to the firm's cash-flows, W_t^P, with a correlation coefficient of χ_P. η_T and η_P are the market prices of short-term and permanent cash-flow risks, respectively. This specification of the stochastic discount factor implies that the systematic components of both short-term and permanent sources of risks are priced.

In order to derive the conditional risk premium on the equity, coefficients in the ODE in Equation (**??**) can be compared to the coefficients of the HJB equation for $F(c)$ under the physical measure. It can be shown that the conditional expected excess return on the equity, denoted as EER_t, is given by:

$$EER_t(c) = \chi_T \sigma_T \eta_T \frac{F'(c)}{F(c)} + \chi_P \sigma_P \eta_P (1 - \frac{cF'(c)}{F(c)}) \tag{2}$$

The above expression shows that the equity's conditional risk premium is given by the sum of the risk premiums associated with exposures to permanent and short-term systematic risks. The short-term shock premium is given by the first term on the right-hand side of Equation (**??**). It is determined by the market price of short-term cash-flow risk, η_T, and the firm's exposure to this risk. The latter is given by the product of the correlation of the firm's cash-flows to systematic short-term cash-flow shocks, χ_T, the volatility of the firm's scaled cash-flows, σ_T, and the semi-elasticity of $F(c)$ with respect to c, $\frac{F'(c)}{F(c)}$.

The permanent shock premium is given by the second term in Equation (**??**). It is determined by the market price of permanent risk, η_P, and the firm's exposure to this risk. The exposure to permanent shock risk is given by the product of the correlation of the firm's cash-flows with permanent shocks to the pricing kernel, χ_P, the volatility of the productivity process, σ_P, and 1 minus the semi-elasticity of $F(c)$ with respect to c, $1 - \frac{cF'(c)}{F(c)}$. This specification implies that conditional expected returns are time-varying and depend on the level of productivity-scaled cash holdings.

D. *Expected returns and cumulative realized returns*

For the purposes of studying momentum, it is interesting to see the conditions under which the covariance between expected excess returns (EER_t) and cumulative excess returns (denoted as

CER_t) is positive.

The instantaneous cumulative excess return will be given by:

$$
\begin{aligned}
dCER_t(c) \equiv \frac{dV}{V} - rdt = \{\hat{\mu}(1 - \frac{cF'(c)}{F(c)}) + (\hat{\alpha} + (r-\lambda)c)\frac{F'(c)}{F(c)} \\
+ \frac{1}{2}\left[\sigma_P^2 c^2 - 2\rho\sigma_P\sigma_T c + \sigma_T^2\right]\frac{F''(c)}{F(c)} - r\}dt \\
+ (1 - \frac{cF'(c)}{F(c)})\sigma_P dW_t^P + \frac{F'(c)}{F(c)}\sigma_T dW_t^T
\end{aligned}
\tag{3}
$$

The instantaneous covariance between realized and expected returns is given by:

$$
\mathbb{E}_t\left[(CER_{t+dt} - \mathbb{E}_t(CER_{t+dt}))\cdot(EER_{t+dt} - \mathbb{E}_t(EER_{t+dt}))\right] \tag{4}
$$

The overall sign of the covariance will depend on the signs of the correlations between transitory and permanent cash flow shocks with transitory and permanent shocks to the pricing kernel. Looking at the instantaneous correlation coefficient between cumulative and expected returns (denoted as $\Upsilon(c)$) is, however, more informative as many terms simplify and it becomes easier to determine conditions under which the expression would be expected to be positive. Denoting $f_1(c) = \frac{F'(c)}{F(c)}$, it can be shown that the instantaneous correlation between cumulative and expected returns is given by:

$$
\Upsilon(c) = \frac{1}{\sigma_c}\frac{f_1(c)\sigma_c^2 - C_t\sigma_P^2 + \sigma_P\sigma_T\rho}{\sqrt{[f_1(c)]^2\sigma_T^2 + (1 - c\,f_1(c))^2\sigma_P^2 + 2f_1(c)(1 - c\,f_1(c))\sigma_P\sigma_T\rho}} \tag{5}
$$

The sign of $\Upsilon(c)$ is determined by the sign of the numerator in (5). Depending on the correlation coefficient between permanent and transitory shocks:

- For $\rho > 0$, $\Upsilon(c) > 0$ if $f_1(c) > \frac{1}{\sigma_c^2}\left(C_t\sigma_P^2 - \sigma_P\sigma_T|\rho|\right)$.
- For $\rho < 0$, $\Upsilon(c) > 0$ if $f_1(c) > \frac{1}{\sigma_c^2}\left(C_t\sigma_P^2 + \sigma_P\sigma_T|\rho|\right)$.

In both cases, the instantaneous correlation between cumulative past and expected returns would be positive when the term $f_1(c)$ is sufficiently large. This would imply that positive correlation in returns would be expected when $f_1(c)$ is large. As will be shown in the comparative statics exercises in the next section, the correlation between cumulative excess returns and expected excess returns is higher for firms where the correlation between permanent and transitory shocks is positive. In this case, the effects of permanent shocks will be amplified by the positively correlated transitory shocks (when the firm is constrained) and this will be more so for firms where their short-term beta is higher.

E. Momentum mechanism

A beta pricing model can be derived from this setting assuming that there is a traded asset (such as the market) whose returns follow a Brownian motion with a drift. It can be shown that the short-term beta can be expressed as:

$$\beta_t^T(c) = \frac{\chi_T \sigma_T}{\sigma_M^T} \frac{F'(c)}{F(c)}$$

The permanent-shocks beta can be expressed as:

$$\beta_t^P(c) = \frac{\chi_P \sigma_P}{\sigma_M^P} \left(1 - \frac{cF'(c)}{F(c)}\right)$$

Both betas vary over time and depend on the level of productivity-scaled cash holdings. $\frac{F'(c)}{F(c)}$ leads to time-variation in the short-term shock beta. The ratio is positive and decreasing (proof provided in Appendix **??**). As a result, the transitory beta rises with the negative of the distance of scaled cash holdings from the target level. $\frac{cF'(c)}{F(c)}$ leads to time-variation in the permanent shocks beta. The sign of $\frac{cF'(c)}{F(c)}$ and the sign of its derivative are, on the other hand, unconstrained (proofs provided in Appendix **??**).

$\frac{F'(c)}{F(c)}$ also represents the semi-elasticity of firm value with respect to scaled cash holdings in the region $(o, c*)$. Similarly to the transitory beta, the sensitivity of firm value to cash rises with the distance of cash holdings to target. This sensitivity is greater than exponential. As argued by Johnson (2002), extreme sensitivity of firm value with respect to a risk factor may cause prices to behave in a fashion that seems bubble-like but is in fact rational.

Figure **??** illustrates the behaviour of the transitory and permanent betas. The left panel shows how the permanent and transitory betas change with scaled cash holdings (when below target) for a firm that approaches liquidation. The right panel shows the corresponding change in expected excess returns and the instantaneous correlation between cumulative and expected returns. The parameters are set at the baseline levels of Decamps et al. (2016). The volatilities of short-term and permanent shocks of the market are set to: $\sigma_M^T = 0.09$ and $\sigma_P^T = 0.25$ and the correlations of the firm's cash flows to short-term and permanent shocks to the pricing kernel are both set to be equal to 0.8. This is so as to be able to compare the two betas, β_t^T and β_t^P, only along their respective sensitivities to productivity scaled cash holdings. The number of months used in the simulation is 600.

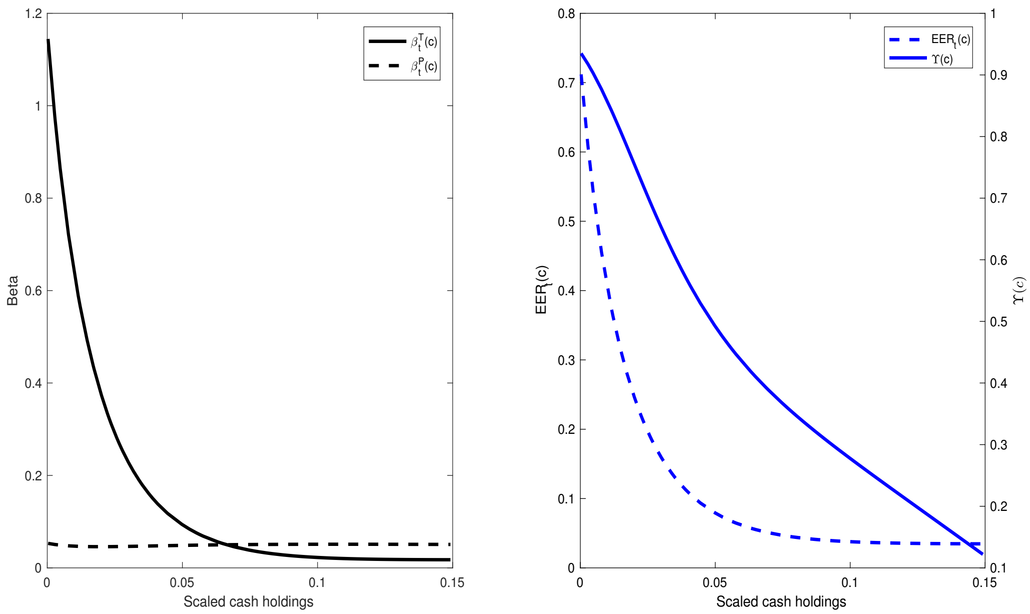

Figure 1. The figure plots the permanent and transitory betas as a function of productivity-scaled cash-holdings. The parameter values are at the baseline level of Decamps (2016), where:$\alpha = 0.18$, $\mu = 0.01$,$\sigma_P = 0.25$, $\sigma_T = 0.09$, $\rho = 0.5$, $r = 0.06$ and $\lambda = 0.02$. The market parameter values are set to: $\sigma_M^T = 0.09$ and $\sigma_P^T = 0.25$. The correlations between long-term and short-term shocks to the pricing kernel and long-term and short-term shocks to cash flows, denoted as χ_P and χ_T respectively, are both set to 0.8 in both cases.

The left panel in Figure **??** shows that the permanent shock beta is more important at higher levels of scaled cash holdings. The short-term shock beta, on the other hand, increases at an increasing rate with the distance from target and becomes much larger than the permanent shocks beta. When cash reaches very low levels, transitory shocks have a larger effect on scaled cash holdings. In this case, the cash balance is low relative to productivity. A transitory shock (either positive or negative) affects only the numerator of the scaled cash holdings ratio, while a permanent shock affects both numerator and denominator. At a low level of the numerator, transitory shocks affect the ratio of cash to profitability more. If the cash balance was already high, the effects of transitory shocks would be much smaller. Intuitively, firms that are close to liquidation are extremely sensitive to transitory cash-flow shocks as these could potentially lead to immediate liquidation, regardless of the long-term prospects of the company.

The right panel in Figure **??** shows expected returns rising with the (negative of) the distance of profitability scaled cash holdings from their target level. Similarly, the correlation between cumulative excess returns and expected excess returns (plotted on the right vertical axis) increases with the distance from target cash. The correlation is positive in all instances, implying that high (low) expected excess returns follow high (low) cumulative realized excess returns for this firm. In the region where the short-term beta exceeds the permanent one, the correlation plot steepens. The result in Equation (**??**) highlights the need for a sufficiently large transitory beta for a positive instantaneous correlation between cumulative and expected returns. The plots in Figure **??**

generally conform with the implication of Equation (**??**). The figure also shows that when cash holdings approach the target, the correlation between expected and past returns reaches a low level. Because empirically most firms maintain cash holdings at the target level, the model simulations imply a low correlation coefficient for most firms. In other words, a significant positive correlation between cumulative and expected returns would be expected only for the most constrained firms.

As mentioned earlier, the normalized transitory shock beta also represents the semi-elasticity of firm value with respect to scaled cash holdings. Both are convex. The semi-elasticity of firm value with respect to cash represents the return as a response to changes in cash. The convexity of this semi-elasticity, essentially representing the sensitivity of returns to changes in cash, implies increasingly larger returns in absolute terms as the firm becomes more constrained. The largest recent price moves (highest returns in absolute terms) will therefore occur in those firms where the distance of their scaled cash holdings from their target has been highest.

Based on the above analysis, momentum would be expected to be concentrated on the most constrained, high short-term beta firms. Among these, because the firm value function F(c) is increasing in c, the firms with positive cumulative returns (i.e. the winners) are the ones where scaled cash holdings have increased. Avramov (2002) documents positive sales growth for the winners in the year prior to portfolio formation. Interpreting sales as a profitability indicator, large positive permanent (profitability) shocks most likely drive the increase in the scaled cash holdings of the winners. The effects of permanent shocks can be analysed looking at the dynamics of scaled cash holdings:

$$\begin{aligned} dC_t = {} & [\alpha - \sigma_P \sigma_T \rho + (r - \lambda - \mu) C_t] dt \\ & + \sigma_T \sqrt{1-\rho^2} dW_t^Z + (\rho \sigma_T - C_t \sigma_P) dW_t^P - \frac{dD_t}{A_t} \end{aligned} \tag{6}$$

A positive permanent shock leads to an increase in scaled cash holdings when the correlation between permanent and short term shocks is positive and scaled cash holdings are at a low level (which is the case in the analysis here). Hence the winner firms are more likely to have a positive correlation between permanent and transitory shocks. At the time of portfolio formation, a momentum sort will go long the stocks that have had the largest price increases, which are likely to be the most constrained firms that have had the largest increases in scaled cash holdings. These will most likely be firms that have positively correlated short-term and permanent shocks. Intuitively, the largest increase in scaled cash holdings will occur when these positive realizations of permanent shocks have coincided with positive transitory shocks. At the time of portfolio formation, since all shocks are IID, the firm is equally likely to receive either positive or negative shocks of a transitory or permanent nature. Considering the fact that the winners in the past year are constrained firms that have received the largest positive shocks of both types, their level of productivity is most likely to have increased to a high enough level where there isn't much convexity in the short-term beta. From Equation (**??**), when C_t is high enough, the change in scaled cash holdings for these firms is more likely to be positive than negative. Scaled cash holdings will most likely increase regardless of the sign of the shock of either type that the firm receives. Some of the winner firms, however, may not have reached this level of productivity. In this case, the price decrease from a decline in scaled cash holdings will be larger in absolute terms than the price increase from an increase in scaled cash holdings (due to the convexity). A decrease in scaled cash holdings will increase the transitory beta and correspondingly the expected return on the stock (instantaneous or for a given holding period). On average, most winners will be expected to have reached a high enough productivity level whereby it is more likely that scaled cash holdings increase and hence firm value increases. This occurs in the region where the short-term beta function becomes flat. Because some of the past winners may not have reached such a level, however, and experience reversal as a result, the overall expected return on the winner portfolio increases. Considering the past winners that reversed at time t, half of them will have a decline in price while the other half an increase. As a result, the prices of most winners in the portfolio will continue to increase over the holding period. Intuitively, since the past winners are most likely constrained firms that have received positive permanent shocks, the winner leg of a momentum portfolio would be a bet that the prospects of these firms, on average, will continue to improve.

On the other hand, firms with negative cumulative returns (i.e. the losers) would most likely be those that have recently received large negative productivity shocks and have a positive correlation between permanent and transitory shocks. This is consistent with Avramov (2005) documenting negative sales growth for the loser firms in the year prior to portfolio formation. If the correlation were negative, because of the low level of scaled cash holdings, permanent and transitory shocks of opposite signs would offset each other and thus scaled cash holdings would not change much. A positive correlation makes it likely that negative productivity shocks are associated with negative transitory shocks, leading to a larger decrease in scaled cash holdings. At the time of portfolio formation the level of scaled cash holdings of the losers will be quite low. Due to the very high convexity at such low levels of scaled cash holdings, decreases in the cash ratio will lead to larger price declines in absolute terms than the price increases from a rise in scaled cash holdings. Large enough shocks at this point are very likely to lead to liquidation. In this setting, due to the convexity of the beta (and the firm's semi-elasticity with respect to scaled cash holdings) firms that are liquidated in any given period are the past losers. At the time of portfolio formation, the biggest losers of the past year will have gone out of business and the survivors will be the ones that have had a recent increase in scaled cash holdings (short-term reversal). This means that the expected return on the companies that have survived up to time t will be lower. Due to the convexity in the beta, however, on average the price of the portfolio of losers will continue to decline. In this case there is also a positive relationship between realized cumulative returns over the previous year (skipping the most recent month) and expected excess return on the company. Going short these companies then is essentially a bet that despite the recent positive liquidity shock, the firm is not a good investment over the long term.

The main takeaway from the above analysis is the concentration of momentum sorts on liquidity constrained firms. The model proposes a mechanism for the emergence of momentum that is based on distress risk, in accordance with Fama and French (1992) relating cross-sectional anomalies in returns to financial distress. The analysis also supports the finding in Avramov (2005) that momentum is concentrated among firms with the highest credit risk. The model does not incorporate debt, but a large corporate finance literature considers cash holdings as negative debt. A decline in the level of cash, therefore, would be equivalent to an increase in the level of debt (from target). The most constrained firms would be the riskiest ones, and would therefore be the ones with the lowest credit ratings. This is consistent with Acharaya and Davydenko (2012) who show that, over the short term, there is a negative correlation between cash holdings and credit risk. Given the empirical evidence that most firms are close to their target level of cash holdings, a small proportion of firms would therefore be at levels very much below target. This is also consistent with Avramov (2005), who finds that it is only a small number of stocks that accounts for most of the momentum effects.

III. Simulations

A. Comparative statics

Because the correlation between past and expected returns depends on the parameters governing the cash flow process, which also affect the state variable in the shareholders' optimization problem, comparative statics would be instructive. Namely, it is useful to examine how changing some of the key model parameters affects the correlation in returns. These exercises allow for the identification of those firms where the correlation in returns is highest. As argued by Sagi and Seasholes (2007), restricting a momentum strategy to these firms would yield even higher momentum returns than those identified by Jegadeesh and Titman (1993). The returns to such strategies would be higher because there would be more persistence in both winners and losers.

The baseline parametrization in Décamps et al. (2016) serves as the baseline in the simulations presented here as well. In each of the comparative statics exercises presented in Figure **??** one of the key parameters varies over a range of plausible values presented on the horizontal axis (expressed in annual terms). The choices of the supports for the parameter values generally rely on the estimation results from Gryglewicz et al. (2017). In each simulation, solving the model at every point in time allows for the computation of the correlation between past and expected returns (at every point in time). So as to control for the different paths that the productivity-scaled cash holdings can take, the simulation is repeated 100 times for a given parameter set. The plots report the average over each of the 100 simulations of the time-series averages of the correlation in returns.

The first panel in Figure **??** shows how the instantaneous correlation between expected and cumulative past returns changes with the correlation between permanent and short-term shocks. The black line represents the baseline case, where the correlation between cash-flow shocks is set to 0.2. The average correlation coefficient between expected and past returns increases with the

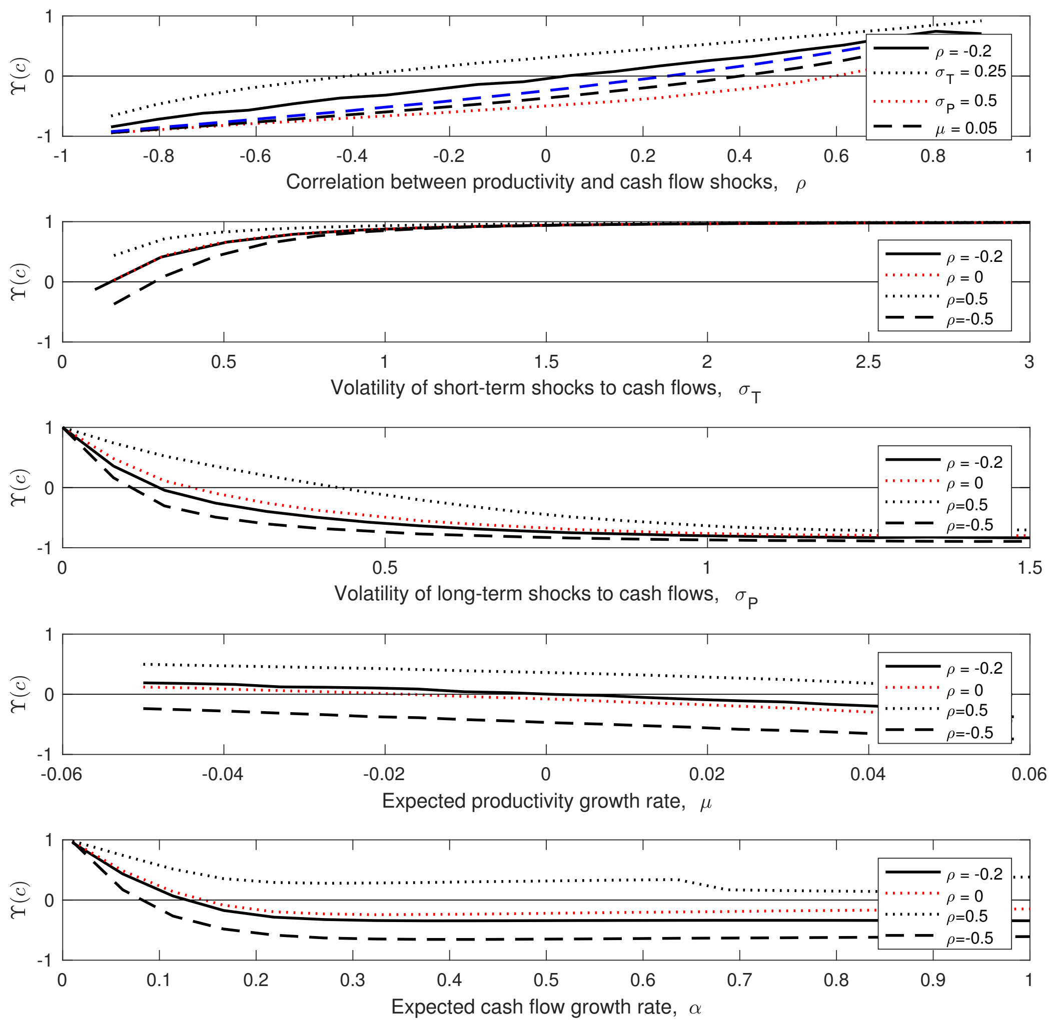

Figure 2. **Comparative statics: Changes in correlation between cumulative past and expected returns with respect to model parameters.** The figure shows the average instantaneous correlation between cumulative excess returns and expected excess returns using simulated data. The correlation coefficient is plotted as a function of the volatilities of long-term and short-term cash flow shocks, the expected cash flow and productivity growth rates and the correlation coefficient between temporary and permanent shocks. The baseline parametrisation in each plot is similar to Décamps et al. (2016), where $r = 0.06$, $\alpha = 0.18$, $\mu = 0.01$, $\sigma_P = 0.25$, $\sigma_T = 0.18$, $\rho = -0.2$, $\lambda = 0.02$ and $\omega = 0.55$. The correlations between long-term and short-term shocks to the pricing kernel and long-term and short-term shocks to cash flows, denoted as χ_P and χ_T respectively, are both set to 0.5 in all the simulations.

correlation between temporary and permanent shocks to cash flows. In expectation, returns reverse when the correlation between the cash flow shocks is negative and continue when the correlation is positive (Appendix **??** provides analytical expressions for the correlation in returns in corner cases and when the correlation between the shocks is zero). Uncorrelated cash flow shocks are associated with an average correlation in returns close to zero. Gryglewicz et al. (2017) estimate the correlation coefficient between permanent and transitory shocks at an average value of -0.07. One would, therefore, expect a low correlation between cumulative and past returns for the average firm. As argued in the previous section, a positive correlation between permanent and short-term shocks makes it more likely that the largest winners (losers) continue to win (lose) due to the dynamics of scaled cash holdings shown in Equation (**??**). Positively correlated shocks ensure that, at a high enough level of scaled cash holdings, price increases continue and that, at a low enough level of scaled cash holdings, price decreases continue.

The dotted black line in the first panel corresponds to the case where the volatility of short-term shocks is at a higher level (0.25) compared to its value in the baseline case. A relatively small increase in the short-term shock volatility leads to an upward parallel shift of the line. For any given level of correlation between cash-flow shocks, a higher volatility of short-term shocks makes it more likely that the correlation in returns is positive.

When increasing the other parameters, namely σ_P, α and μ, the line shifts downwards. This would imply that the volatility of permanent shocks and the growth rates of the productivity and scaled cash-flow processes have a negative effect on the correlation in returns for any given level of correlation between cash-flow shocks. The effects of each of these parameters are shown separately in the other four panels in Figure **??**.

The second panel in Figure 1 shows how the average correlation in past and expected returns changes with respect to the volatilities of short-term shocks, while the third panel shows how the average correlation in past and expected returns changes with respect to the volatilities of permanent shocks. The effects of the two are opposite. The higher the volatility of short-term cash-flow shocks, the higher the instantaneous correlation between cumulative and expected returns. Intuitively, firms with a higher volatility of short-term shocks would have a higher short-term beta, all else equal. This would make them more susceptible to transitory shocks in case their scaled cash holdings fall below target. The short-term beta of these firms would then become even larger. As argued in the previous section, there is a positive relationship between the correlation in returns and the short-term beta of the firm.

The plot in the third panel shows a different picture. Expected returns follow cumulative returns less closely for firms with more volatile productivity shocks. As argued above, winners and losers in a momentum sort most likely have positively correlated cash-flow shocks. For firms with positively correlated cash flow shocks, target scaled cash holdings decrease with the volatility of permanent shocks. In this case, a low volatility of permanent shocks increases the target. Because a higher target denotes a riskier firm, the riskiest firms in a momentum sort have low volatilities of permanent shocks. Since the permanent shock volatility is low, the permanent shock beta is likely to be low. As a result, the short-term shock beta will most likely have a larger weight in the firm's overall beta. As argued above, a sufficiently high short-term beta allows for positively correlated cumulative past and expected returns. This correlation in returns is increasingly positive the larger the short-term beta becomes with respect to the permanent one.

The red line in the same plot presents the case corresponding to uncorrelated cash-flow shocks. This line is above the one representing the baseline case (where $\rho = -0.2$), consistent with the predictions in the first panel of the figure. The dotted black line represents the case where the correlation in the cash-flow shocks is even higher (set at $\rho = 0.5$), and correspondingly the line shifts upward. The dashed black line represents the case where the correlation in -0.5 and as a result the correlation between cumulative past and expected returns is positive only when the volatility of permanent shocks is lowest. Appendix **??** shows the analytical expressions for the correlation in returns in the extreme cases for the volatilities of permanent and short-term shocks.

The fourth panel in Figure **??** shows how the correlation in expected and cumulative excess returns changes depending on the expected growth rate in productivity. Returns persist less at higher levels of the productivity growth rate. A similar relationship holds between the expected growth rate in cash flows (fifth panel in Figure **??**) and the correlation in returns. Firms with the highest growth rates in productivity and earnings would be perceived as less risky, implying lower expected returns. This means that, in both cases, low expected excess returns follow high cumulative returns. These firms are also more likely to be close to their respective target levels of scaled cash holdings, where the correlation in returns is generally low.

B. Model simulation

Table 1 shows the performance of momentum strategies constructed on simulated panel data. For each parameter set, I simulate 100 panels and report the average returns and average test statistics of the 100 momentum portfolios. The chosen number of simulations for each parameter set ensures that the average value of the momentum mean portfolio returns falls within a 95% confidence interval. Each panel consists of the returns of 2000 firms simulated over 600 months, dropping the first 200 months to ensure that a steady state distribution is reached. Fama and French (1992) use a dataset of similar size for their empirical investigations.

Simulating a panel dataset requires firms differing in some characteristic. I draw the correlation coefficients of firms' cash-flows to permanent and short-term shocks to the pricing kernel from beta distributions. For each firm, the correlation between permanent cash-flow shocks and permanent shocks to the pricing kernel and the correlation between transitory cash-flow shocks and transitory shocks to the pricing kernel are drawn independently. 90% of each type of correlation (permanent or transitory) are drawn from a beta distribution with shape parameters: $\alpha^{\chi} = 3$ and $\beta^{\chi} = 5$. 10% of each type of correlation (permanent or transitory) are drawn from the negative of a beta distribution with shape parameters: $\alpha^{\chi} = 1$ and $\beta^{\chi} = 3$. For each type of correlation, the resulting distribution of all the observations, although defined over the interval [-1,1], resembles a normal.

Table I. This table reports the average mean returns and average test statistics of momentum portfolios constructed on 100 simulated panels for each scenario. Scenario 3 draws the volatilities of transitory cash-flow shocks from a uniform distribution with support [0.05, 0.25]. The fourth scenario draws the volatilities of the permanent cash-flow shocks from an exponential distribution where the rate parameter is given by the inverse of the difference between an assumed mean of 1 (close to the estimate from Gryglewiz et al., 2017) and a lower limit of 0.1. Scenario 5 draws the volatilities of the permanent cash-flow shocks from a uniform distribution with support [0.01, 2].

Scenario	σ_T	σ_P	ρ	μ	α	m	t-stat	Winner return	Loser return
1	0.09	0.25	0.1	0.01	0.18	1.88	4.76	0.41	-1.48
2	0.2	0.25	0.1	0.01	0.18	1.96	4.97	0.38	-1.58
3	U(0.05, 0.25)	0.25	-0.1	0.01	0.18	0.19	3.94	0.51	0.31
4	0.09	exp(1.11)	-0.1	0.01	0.18	0.78	0.64	0.57	-0.21
5	0.09	U(0.01,2)	-0.1	0.01	0.18	0.56	0.54	0.56	0.00
6	0.09	0.25	-0.1	0.05	0.40	0.02	0.90	0.58	0.56

The results reported in Table **??** are in line with the intuition gained from the comparative statics exercises. The first and second scenarios yield statistically significant momentum returns on average. Profits to momentum strategies average close to 2% per month with a t-stat > 4.5 in both cases. A higher volatility of short-term shocks in the second scenario yields higher average returns and higher test statistics on average than the first scenario. Although still significant, momentum strategies in the third scenario have lower average returns. Two main reasons lead to lower momentum returns. First, drawing the transitory cash-flow shock volatility from a uniform distribution with support [0.05, 0.25] leads to the ratio of the transitory shock volatility to permanent shock volatility being lower for most firms. The lower volatility ratio diminishes the importance of the transitory shock beta. In this case, the convexity necessary to generate momentum effects has a lesser impact. The second reason for the lower returns relates to the negative correlation between transitory and permanent cash-flow shocks. As argued in the section on the mechanism for momentum, a positive correlation between the shocks ensures continuation of returns for winners and losers. The negative correlation affects the loser leg of the portfolio more. The loser leg drives most of the momentum returns in the first two scenarios while in the third the returns for the losers turn from negative to positive.

The fourth and fifth scenarios incorporate a higher permanent shock volatility, resulting in insignificant average momentum strategy returns. A higher permanent shock volatility also lowers the relative importance of the transitory shock beta. The last scenario examines the effects of the expected growth rates in productivity and cash-flows. When set at higher levels, momentum returns diminish further.

Although some of the scenarios produce significant momentum effects, I do not make any claims regarding these simulations truly being representative of what happens in reality as it is generally quite difficult to model the full covariance structure of returns. Namely, the assumptions on the distributions of the correlation coefficients of firm cash flows to the pricing kernel are rather strong. They are based on evidence of CAPM-betas having a similar distribution, which could, on the other hand, also be influenced by the distribution of the volatilities of the shocks. Making the firms differ along more dimensions would require even stronger assumptions on the unknown distributions of the other model parameters. Nevertheless, there is some confidence in these results since they seem to be in line with empirical evidence and with the comparative statics exercises presented in the previous section.

C. Testable predictions

Hypothesis 1: Momentum is concentrated among firms with productivity-scaled cash below target. Based on the model, because momentum effects can be traced to firms' exposures to short-term shocks and the convexity of firms' short-term betas, the first prediction would be that momentum portfolios are likely to contain companies whose scaled cash holdings are below target. This is the case when the short-term shock beta is likely to be high. Since this corresponds to the semi-elasticity of the firm value with respect to changes in scaled cash holdings, this is where the largest price changes are most likely to occur.

Hypothesis 2: The level of productivity in the previous period is an important driver for the mechanism for momentum. Price changes will be even more pronounced if the most constrained firms receive very large realizations of permanent and transitory shocks to scaled cash-flows. This can be linked to standardized unexpected earnings, a measure widely used in the literature which, along with Cumulative Abnormal Returns (CAR) over the days surrounding the earnings annoucement, has been shown to subsume the power of momentum in explaining expected returns. In this setting however, the shocks correspond to productivity scaled earnings as opposed to earnings on their own. Constructing a measure that accounts for productivity, which is also important in determining how constrained a firm is, would probably allow for a better measure related to earnings shocks that could have a higher power in explaining momentum in the cross-section.

Hypothesis 3: CAR around earnings announcement dates reflect the convexity in the short-term beta. The high returns (in absolute terms) over the earnings announcement dates, as measured by CAR, could be attributable to the higher short-term beta of the constrained firms. Therefore, CAR would not necessarily be an "abnormal" reaction to news, but simply a compensation for the higher risk entailed by liquidity constraints. Because the convexity should be higher for the loser stocks, CAR would be expected to the larger (in absolute terms) for these stocks.

Hypothesis 4: Enhanced momentum strategies can be constructed by focusing on the firms expected to have higher autocorrelation in returns. The comparative statics exercises and the model simulations in the previous section provide some insights regarding where momentum strategies would be expected to be highest. Based on these, there would be greater correlation between cumulative past and expected returns and higher momentum profits when the volatility of short-term shocks is high relative to the volatility of permanent shocks and when growth rates in productivity and scaled earnings are low. The correlation in returns would also be expected to be higher for firms where the correlation between permanent and short-term shocks is positive.

IV. Data and Identification

A. Sample and control variables

Constructing the variables used in the empirical analysis requires the merger of data from the daily and monthly stock files from the Center for Research in Security Prices (CRSP) with quarterly as well as annual accounting fundamentals from Compustat. Data on Fama-French factors, NYSE breakpoints and industry SIC codes is obtained from Kenneth French's website. The sample, starting in 1962 and ending in 2016, excludes financial firms (SIC codes 6010- 6799).

To ensure that the accounting data is available before the time period over which returns are measured, I use the methodology employed in Fama and French (1992, 1993). Namely, the returns from July in year t to June in year $t+1$ are matched with the values of the accounting data in the fiscal year end in year $t-1$. Size is calculated as the absolute value of the product of market value, PRC, in June of year t, with shares outstanding, SHROUT, in June of year t (divided by 1000 since the SHROUT field in CRSP is recorded in thousands). The market value of equity at the end of December of year $t-1$ is used to compute the book-to-market variable. Book equity, BE, is given by shareholder's equity, SEQ in Compustat, adjusted for tax effects by adding deferred taxes, TXDB, and investment tax credits, ITCB, and subtracting the book value of preferred stock. For the latter, its redemption value is used, PSTKRV, if available, or else its liquidating value, PSTKL, or else its par value, PSTK. Book equity is not calculated if SEQ or TXDB are unavailable. It is taken to be zero if there is no available value for preferred stock or investment tax credit. All independent variables are trimmed at the 1% and 99% levels. Table **??** presents summary statistics (equal-weighted) for the variables used later in the analysis. These statistics are time-series averages of their respective cross-sectional values in each month.

The table also presents information on two proxies widely used in the literature to measure earnings surprises: cumulative abnormal returns over the three days surrounding the announcement (CAR) and standardised unexpected earnings (SUE). Earnings announcement dates are from Compustat's RDQ field. CAR is the cumulative abnormal return over that of the market over three days surrounding the announcement, starting from the day before RDQ and ending the day after. For the calculation of SUE I use earnings per share excluding extraordinary items, EPSPXQ field from Compustat. Following Berndard and Thomas (1990), I use a model for earnings based on a seasonal random walk with drift. The drift $\alpha_{i,q}$ for firm i in quarter q is measured as the average value of year-on-year changes in earnings over the previous eight quarters:

$$\alpha_{i,q} = \frac{\sum_{n=1}^{8} (EPS_{i,q-n} - EPS_{i,q-n-4})}{8}$$

The earnings forecast, $\mathbb{E}(EPS_{i,q})$, consists of the previous year's earnings per share plus the drift:

$$\mathbb{E}(EPS_{i,q}) = EPS_{i-4,q} + \alpha_{i,q}$$

Subtracting this forecast from the earnings announced for the quarter provides a measure of the earnings surprise. This measure is standardized by dividing by the standard deviation of the earnings surprises over the past eight quarters.

$$SUE_{i,q} = \frac{EPS_{i,q} - \mathbb{E}\left(EPS_{i,q}\right)}{\sigma_{i,q}}$$

The table also reports statistics for a proxy I constructed to measure the distance of productivity-scaled cash holdings from target, denoted as DTC (Distance from Target Cash). The choice of the proxy is motivated by the following. In the model, the firm pays out dividends whenever cash exceeds the target level. As a result, productivity scaled cash holdings fall back to target on dividend payment dates. Following Coles et al. (2012), I use sales as a proxy for productivity. I estimate target cash holdings based on the level of the cash-to-sales ratio, denoted as c here, on the most recent dividend payment date that coincided with an earnings announcement date. For the measure of cash, I use Compustat's cash and cash equivalents, CHE, when available or whenever they are higher than cash, CH. When CHE is missing or whenever it is lower than CH, I use the latter. Denoting the target level of scaled cash holdings as $\bar{c}$, I refer to the percentage change with respect to the target , $(c - \bar{c})/\bar{c}$, as a measure of how constrained a firm is on the day when earnings announcements are made. I use the relative rather than the absolute distance from target to account for the variation of target cash levels between firms. Based on the model predictions, momentum should be concentrated on firms that have been constrained over the previous year. As a result, I use the average of this measure over the previous twelve months. DTC^{-} is the value of DTC when scaled cash holdings are below target.

The average value of the proxy for the relative distance from target cash, at around 366 per cent per month, reflects the sharp increase in firms' cash holdings over the past two decades. The DTC measure varies substantially among firms, with a standard deviation of 15,117 per cent The positive skew of the distribution of DTC also reflects the rising trend in cash holdings for most firms. To measure how constrained a firm is in terms of its cash, a better proxy could account for both growth rates in cash and sales. Because the current measure is still able to identify the most constrained firms in the cross-section, however, the intuition should not differ significantly.

Table II. Summary Statistics

This table presents summary statistics for independent variables used in Fama-MacBeth regressions, measured in the period from January 1975 to December 2015. The sample includes U.S.-based common stocks in the merged CRSP and Compustat database, excluding financials. For each month, the mean, standard deviation, skewness, kurtosis, minimum, median and maximum value of each of the variables are calculated. The table provides the time-series average for each cross-sectional value of the respective statistic. The last column labelled n shows the average number of stocks for which the variable is available. *Size* is the natural logarithm of the market capitalization of the stock calculated at the end of June in the previous year. *BM* is the ratio of the book value of equity to the market value of equity. *GP/A* represents profitability, calculated as the ratio of gross profits to total assets of the company. $r_{1,0}$ is the short-term reversal, which is the stock return during month t. $r_{12,2}$ represents the stock's momentum, measured as the cumulative return of the stock during the 11-month period starting from 12 months before the measurement date and ending a month before the measurement date. DTC represents the percentage change in cash holdings scaled by sales from the proxy for the target, which is estimated as the most recent previous value of Cash/ Sales on a dividend payment date coinciding with an earnings announcement. CAR is cumulative abnormal returns over the three days surrounding the earnings announcement, SUE is standardized unexpected earnings. The statistics on the return variables are expressed in percentage terms.

	Mean	Standard deviation	Skewness	Kurtosis	Min	Max	Median	n
$r_{12,2}$	14.04	57.64	4.10	63.83	-84.73	994.794	5.32	3391
CAR	-0.17	6.95	-0.07	1.55	-25.23	23.19	-0.12	991
SUE	-0.08	1.44	-0.86	4.74	-7.49	4.41	0.01	758
DTC	366.71	15,117	28.32	980.42	-4.63	631,880	0.0012	1325
ln(ME)	4.80	1.88	0.30	-0.13	-1.13	11.53	4.68	4541
ln(B/M)	-0.40	0.93	0.67	5.44	-4.67	6.19	-0.39	3213
GP/A	0.36	0.63	7.35	530.14	-3.99	24.48	0.32	3415
$r_{1,0}$	1.17	14.87	2.87	56.77	-60.63	238.56	0.09	3695

B. *Statistics of momentum portfolios*

Table **??** shows average time-series statistics on portfolios sorted on past performance and size. I used 5 portfolios on past performance as opposed to 3 as in the Fama-French momentum factor so as to see more clearly how the characteristics change. The momentum portfolio return is given by the difference of the average of small and large winner returns with the average of the small and large loser returns. This portfolio has a correlation of 90% with the Fama-French momentum factor (using 3 portfolios, the correlation is 94%).

I use sales (S) as a proxy for productivity as Compustat's SALEQ and compute the productivity parameters assuming it follows a GBM. Based on this, the estimate for productivity growth for firm i in quarter q (on the earnings announcement date) is the average percentage change in sales over the previous eight quarters:

$$\mu_{i,q} = \frac{1}{8}\sum_{n=1}^{8} \frac{S_{i,q-n} - S_{i,q-n-4}}{S_{i,q-n-4}}$$

The unexpected component of sales is given by the difference between the sales in quarter q and their expected value. The sales surprises are standardized using standard deviation of the innovations over the previous 8 quarters. The standardized unexpected sales ($SUS_{i,q}$) are thus given by:

$$SUS_{i,q} = \frac{S_{i,q} - S_{i,q-4}\left(1 + \mu_{i,q}\right)}{\sigma^P_{i,q}}$$

I use Compustat's IBQ for earnings, and compute the earnings growth ($\alpha_{i,q}$) and volatility parameter ($\sigma^T_{i,q}$) assuming that earnings changes scaled by sales follow a random walk with drift. The average growth in scaled earnings is thus given by:

$$\alpha_{i,q} = \frac{1}{8}\sum_{n=1}^{8} \frac{IBQ_{i,q-n} - IBQ_{i,q-n-4}}{S_{i,q-n-4}}$$

The standardized unexpected productivity scaled earnings are given by:

$$SUIBQ^M_{i,q} = \frac{IBQ_{i,q} - IBQ_{i,q-4} - \alpha_{i,q} S_{i,q-4}}{\sigma^T_{i,q}}$$

where $\sigma^T_{i,q}$ is the standard deviation on the surprises in scaled earnings over the past 8 quarters.

Table **??** shows time-series averages of the ratio of the volatilities of the sales and earnings surprises, the distance from target cash, the proxy for the target, CAR, SUE, market capitalization and number of firms within each portfolio.

Table III. This table presents time-series averages of value-weighted statistics of momentum portfolios constructed on double sorts on past performance (5 portfolios) and size based on NYSE breakpoints (2 portfolios). Statistics are presented for each size portfolio separately. These include the average distance from the proxy for target scaled cash holdings, DTC, the average ratio of earnings and productivity shocks, $\frac{\sigma_T}{\sigma_P}$, Cumulative Abnormal Returns (CAR) over the three days surrounding the earnings announcement (shown in basis points), Standardized Unexpected Earnings (SUE), average firm size per portfolio, ME, and average number of stocks in the portfolio, n. The sample includes the period from January 1975 to December 2016, dates determined by the necessary information to construct the sales and earnings statistics.

Panel B: Portfolio characteristics from sorts on past performance of large firms

	DTC	$\frac{\sigma_T}{\sigma_P}$	$\bar{c}$	CAR	SUE	ME	n
Low	1.02	0.38	0.77	-7	-0.13	7766	80
2	1.01	0.25	0.45	-6	-0.07	9543	145
3	0.90	0.23	0.35	2	-0.03	1023	192
4	0.98	0.31	0.36	3	0.01	9879	193
High	1.37	0.26	0.52	4	0.03	8270	109

Panel A: Portfolio characteristics from sorts on past performance of small firms

	DTC	$\frac{\sigma_T}{\sigma_P}$	$\bar{c}$	CAR	SUE	ME	n
Low	9.71	0.42	0.9	-24	-0.09	433	623
2	46.07	0.37	1.10	-4	-0.06	494	576
3	16.12	0.25	0.50	1	-0.02	530	537
4	5.91	0.23	0.49	3	0.001	532	535
High	2.43	0.27	0.57	5	0.02	474	603

Panel C: Portfolio returns

	Average portfolio excess returns			Alphas and FF5 factor loadings for average			
	Small stocks	Large stocks	Average	α	HML	RMW	CMA
Low	0.41	0.34	0.37	-0.31	0.44	-0.73	-0.63
	[0.99]	[0.78]	[0.91]	[-1.16]	[3.65]	[-6.10]	[-3.42]
2	0.61	0.57	0.59	-0.21	0.33	-0.12	-0.25
	[2.21]	[2.08]	[2.20]	[-1.64]	[5.67]	[-2.07]	[-2.78]
3	0.85	0.67	0.76	-0.08	0.21	0.11	-0.03
	[3.54]	[3.09]	[3.41]	[-1.34]	[6.88]	[3.65]	[-0.61]
4	1.00	0.73	0.87	0.01	0.01	0.19	0.15
	[4.24]	[3.55]	[4.02]	[0.21]	[0.36]	[8.24]	[4.27]
High	1.31	1.06	1.18	0.42	-0.30	-0.03	0.17
	[4.47]	[4.16]	[4.41]	[4.07]	[-6.27]	[-0.55]	[2.39]
H - L	0.90	0.73	0.81	0.73	-0.74	0.71	0.81
	[2.92]	[1.95]	[2.49]	[2.22]	[-4.91]	[4.73]	[3.51]

The table shows no significant variation in the average DTC over the past year for large firms.

When looking at small firms, however, the spread is large with the value-weighted average DTC being lowest in the extreme quintiles. The value of the constraint measure is larger on average for small firms, reflecting the significant spread of this metric within this subsample. Another reason for DTC being larger for small firms could be related to them not paying out dividends as often. DTC is calculated based on the change in cash holdings from the most recent dividend payment date. Infrequent dividend payments could be spaced wide apart in time. Due to the positive trend in cash the large positive value of DTC for small firms could be more a reflection of the trend rather than high cash holdings.

Nevertheless, the high and low quintiles for small firms having lower levels of DTC compared to the other small firm portfolios is in line with Hypothesis 1. On a relative basis, these would be the most constrained firms. This result is also in accordance with previous evidence that most of the momentum returns are attributable to small firms, which is also evident from Panel C in the table.

The proxy for the target productivity-scaled cash holdings for both small and large firms is generally higher for the extreme quintiles, although the spread is not very large. The value-weighted averages of CAR and SUE are largest in absolute terms in the highest and lowest past performance portfolios, in line with the evidence linking price momentum to earnings momentum. Notably, CAR is much larger in absolute terms for the loser leg of the momentum portfolio constructed in the subsample of small firms. This is in line with Hypothesis 3, whereby the large negative response to negative earnings shocks derives from the higher short-term beta which in turn is due to the convexity.

The change in the ratio of the proxies for the volatilities of permanent and transitory cash-flow shocks over the momentum quintiles provides a rough preliminary test of the model prediction that this ratio should be highest in the extreme portfolios (Hypothesis 4). For both small and large stocks the ratio is highest for the loser portfolios. In the small firm subsample, it decreases then increases for the winner leg. There is, therefore, some indication of the volatilities ratio being higher for momentum stocks. A more formal test for the fourth hypothesis, which is based on double sorted portfolios, is presented in Section **??**.

V. Results

A. Fama-MacBeth regressions

Table **??** reports the results of Fama-MacBeth regressions of stock returns on past performance over twelve to two months, $r_{12,2}$, using different sets of control variables. The sample covers the period from January 1975 to December 2016. The availability of sufficient data on earnings and sales to construct the related variables determines the starting period for the regressions. All specifications contain controls that include size (log(ME)), book-to-market (log(B/M)), gross profitability (GP/A) and the previous month's return, $r_{1,0}$.

The first specification contains the baseline case showing that price momentum is an important predictor of future returns. The second specification confirms the result in Novy-Marx (2012). Including two standard measures of earnings surprises, SUE and CAR, subsumes the power of past performance in explaining future returns. The measure for the relative distance from target cash, DTC, is included in the third specification. DTC does not have any power in terms of return predictability. When the negative part of this variable, DTC^{-}, is used instead (shown in the fourth specification) the distance from target cash becomes significant. This would imply that liquidation risk is important and it is priced when cash holdings are below target. In unreported results, when the positive part of DTC is used in these regressions, the variable is insignificant.

The fifth specification includes SUE and DTC^{-} as controls. The power of momentum is reduced just as much as when CAR is included in the regression, as in the second specification. Although the t-statistic on DTC^{-} becomes insignificant, this result could provide a link between CAR and the distance from cash. For reasons explained in detail in subsection C, the relationship between CAR and the distance from target cash holdings may not be linear. Therefore, portfolio analysis would be much more instructive since it does not make any assumption about the nature of the relationship between the variables of interest. The results of these portfolio sorts are presented in Subsection C.

Specification six includes the ratio of the proxies for the volatilities of permanent shocks and transitory shocks as a control. The variable itself is insignificant, but when included in the regressions it substantially reduces the power of momentum. A possible reason for the variable being insignificant is the fact that it is predicted to be high for both high past performance and low past performance firms. These regressions show that the volatilities ratio and momentum could be related, but are unable to make this relationship clear. Independent double sorts on momentum and the ratio of volatilities, presented in the next subsection, confirm the intuition of a positive relationship between the two.

The analysis in this paper draws a direct link between earnings momentum and price momentum. Based on the model, the equivalent variable for SUE would be the following:

$$
\begin{aligned}
SUE_{i,q}^{M} &= \frac{X_i - \mathbf{E}\left(X_i\right)}{\sigma_T} \\
&= \frac{A_{i-1}\left(\alpha dt + \sigma_T dW_i^T\right) - A_{i-1}\alpha dt}{\sigma_T} \\
&= \frac{A_{i-1}\sigma_T dW_i^T}{\sigma_T} \\
&= A_{i-1} dW_i^T
\end{aligned}
$$

where dt in this case is a quarter. I constructed a variable based on this, using sales as a proxy for productivity and IBQ for earnings. The last line in the expression above represents the innovation to earnings over the past quarter, when using a model where earnings changes are scaled by sales (productivity). In line with the argument presented in the section on the mechanism for momentum, the impact of earnings shocks depends on the level of productivity in the previous period. In the tables below, I denote this variable as $SUE_{i,q}^{M}$, indicating that this is the standardized unexpected earnings measure based on the theoretical model. The seventh specification shows that the model-based measure of standardized unexpected earnings on its own subsumes the power of momentum. The t-stat on $SUE_{i,q}^{M}$, however, is not as large as those of SUE and CAR. Nevertheless, it does provide an indication that a proxy for productivity-scaled earnings contains significant information regarding momentum.

Table IV. This table reports the Fama and MacBeth regressions of monthly expected excess stock returns on earnings surprises measured based on standardized unexpected earnings (SUE), its permanent component (SUE_{perm}) as well as its temporary component SUE_{temp} and past performance which is measured as the cumulative return over the previous year skipping the most recent month to avoid the effect of short-term reversal. Controls include size (ln(ME)), book-to-market (ln(B/M)), profitability (GP/A) and short-term return reversal ($r_{1,0}$). Gross profit (GP), is measured as revenues (REVT) minus cost of goods sold (COGS), to total assets (AT). The sample covers the period from January 1975 to December 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$r_{12,2}$	0.79	-0.07	0.81	0.84	-0.01	0.12	0.05
	[4.56]	[-0.37]	[4.15]	[4.00]	[-0.54]	[0.55]	[0.22]
SUE^{M}							0.0002
							[2.31]
σ_T/σ_P						0.01	
						[0.29]	
DTC			0.004				
			[1.29]				
DTC^{-}				0.21	0.01		
				[2.47]	[0.07]		
SUE		0.27			0.29		
		[12.65]			[7.42]		
CAR		9.82					
		[16.98]					
ln(ME)	-0.07	-0.06	-0.04	-0.04	-0.04	-0.09	-0.06
	[-1.76]	[-1.51]	[-1.38]	[-1.21]	[-0.99]	[-1.86]	[-1.30]
ln(B/M)	0.23	0.20	0.19	0.18	0.16	0.25	0.18
	[4.64]	[3.03]	[4.19]	[3.42]	[1.84]	[3.37]	[2.39]
GP/A	0.72	0.75	0.56	0.52	0.49	0.67	0.56
	[5.76]	[5.00]	[5.01]	[3.87]	[2.15]	[4.06]	[3.09]
$r_{1,0}$	-4.17	-5.72	-4.25	-4.32	-2.24	-2.16	-2.24
	[-10.02]	[-11.58]	[-9.66]	[-9.16]	[-3.64]	[-4.44]	[-4.34]

B. *Portfolio analysis*

While Fama-MacBeth regressions allow for the examination of the relationship between returns and a variable of interest using a large set of controls, it assumes that all relationships considered are linear. Portfolio analysis is a non-parametric technique that does not impose any assumptions on the relations between the variables. The following two subsections present results of portfolio analyses for the purposes of testing some of the model predictions and gaining further insights on some of the relationships examined previously in the Fama-MacBeth regressions.

B.1. Momentum and liquidity constraints

Double sorts provide another way to test the prediction that momentum profits are attributable to cash constrained firms. I constructed double sorted portfolios on the proxy for the distance from target and past performance. These are conditional double sorts, meaning five portfolios are first constructed sorting on the control variable, which in this case is the proxy for the distance from target cash. Within each of these portfolios, five other portfolios are formed based on past performance. These sorts provide a link between returns and momentum, conditional on how constrained the firm is (according to the chosen proxy). The results are presented in Table **??**.

Table V. This table reports the average returns and regression results on the Fama-French five factor model of portfolios formed by dependent double sorts on the relative distance to target scaled cash holdings over the past year and momentum. The control variable is the proxy for the distance from target cash. Newey-West t-statistics reported in parentheses.

	Alphas and factor loadings				
Portfolio	r^e	α	HML	RMW	CMA
Low	1.11	1.98	-0.55	- 0.18	-0.15
	[2.17]	[3.99]	[-1.71]	[-0.55]	[-0.35]
2	0.19	-0.25	-0.15	1.53	0.22
	[0.43]	[-0.46]	[-0.62]	[3.55]	[0.45]
3	0.26	0.56	-0.83	0.10	0.39
	[0.71]	[1.36]	[-2.5]	[0.39]	[0.85]
4	0.12	0.56	-0.83	0.10	0.39
	[0.30]	[0.80]	[-3.93]	[0.12]	[-0.31]
High	1.27	1.30	-1.38	0.03	1.57
	[2.10]	[1.60]	[-3.14]	[0.06]	[1.80]

The table shows that average excess returns to momentum strategies are high and most significant in the lowest DTC quintile. Although the average excess return on the high average DTC quintile is slightly higher, it is less significant. The low DTC quintile represents the only portfolio that yields a positive alpha. The alpha of this portfolio is around 1.98% per month and with a t-stat of 3.99. The results reported here support the prediction that momentum returns are concentrated among the firms facing the highest liquidity constraints.

Table **??** presents the performance of portfolios formed on independent double sorts on momentum and the ratio of the volatilities of the proxies for short-term and permanent shocks, namely the standard deviation of shocks to earnings and the standard deviation of shocks to sales. Momentum strategies have a positive and significant alpha only along the high volatility quintiles. The average excess returns and alpha of the momentum portfolios along the first and second volatility ratio quintiles are slightly larger than those of momentum portfolios constructed based on all stocks. This supports the prediction of higher momentum among stocks where earnings are more volatile relative to sales (Hypothesis 4). These firms will be more even more sensitive to transitory shocks in case their cash holdings fall below target.

Table VI. This table reports the performance of the 25 portfolios constructed based on double sorts on price momentum and the ratio of volatilities of the proxies for short-term and permanent shocks, the excess returns on the high-low portfolios formed for each type of sort as well as the results of the regressions of the excess returns on the latter on the Fama-French five factors and momentum.

	Vol quintiles					Vol strategies							
	Low	2	3	4	High	r^e	α	β_{mkt}	β_{smb}	β_{hml}	β_{rmw}	β_{cma}	β_{mom}
Past performance quintiles													
Low	0.47	0.57	0.56	0.42	0.32	-0.38	-0.78	0.03	-0.01	-0.14	-0.09	0.10	0.04
						(-0.83)	(-1.60)	(0.21)	(-0.03)	(-0.59)	(-0.37)	(0.28)	(0.34)
2	0.84	0.68	1.04	0.97	0.86	-0.03	-0.44	-0.09	0.23	0.05	0.06	-0.14	0.04
						(-0.11)	(-1.47)	(-1.23)	(2.07)	(0.38)	(0.43)	(-0.67)	(0.52)
3	0.86	0.88	0.85	1.30	1.67	0.79	0.24	0.10	0.03	0.03	0.09	-0.05	0.09
						(2.67)	(0.77)	(1.33)	(0.26)	(0.23)	(0.65)	(-0.23)	(1.27)
4	1.38	1.16	0.88	1.58	1.38	0.11	-0.17	-0.04	0.06	0.01	-0.28	-0.06	-0.02
						(0.42)	(-0.60)	(-0.57)	(0.62)	(0.11)	(-2.16)	(-0.29)	(-0.29)
High	1.50	1.40	1.24	0.88	0.95	-0.44	-0.73	0.09	-0.28	-0.18	-0.11	0.21	-0.05
						(-1.50)	(-2.33)	(1.24)	(-2.47)	(-1.19)	(-0.76)	(0.95)	(-0.63)
Past performance strategies													
r^e	0.83	0.80	0.66	1.45	1.09								
	(1.99)	(1.87)	(1.43)	(3.37)	(2.46)								
α	0.65	0.72	0.48	1.17	0.96								
	(1.49)	(1.58)	(0.97)	(2.54)	(2.07)								
β_{mkt}	-0.43	-0.26	-0.32	-0.23	-0.37								
	(-3.99)	(-2.37)	(-2.74)	(-2.15)	(-3.29)								
β_{smb}	0.25	-0.06	-0.00	-0.09	0.01								
	(1.58)	(-0.35)	(-0.01)	(-0.51)	(0.05)								
β_{hml}	0.08	0.11	-0.06	-0.11	0.04								
	(0.38)	(0.51)	(-0.24)	(-0.48)	(0.18)								
β_{rmw}	-0.33	-0.42	-0.25	-0.33	-0.29								
	(-1.62)	(-2.01)	(-1.05)	(-1.50)	(-1.26)								
β_{cma}	-0.24	-0.20	0.12	0.04	-0.25								
	(-0.75)	(-0.61)	(0.35)	(0.11)	(-0.74)								
β_{mom}	0.17	0.03	0.10	0.19	0.11								
	(1.72)	(0.28)	(0.87)	(1.69)	(0.98)								

B.2. CAR and liquidity constraints

The correlation between CAR and DTC and DTC^{-} (Table **??** in Appendix 3) is rather low and around 0.01 in both cases. This could be because it would be more relevant to measure the correlation between the absolute value of CAR and DTC, since the model predicts that both very high values of CAR and very low values of CAR should be in the low DTC range. The correlation between the absolute value of CAR and DTC is -0.01, whereas the correlation between the absolute value of CAR and DTC^{-} is -0.05. This shows that the largest responses to earnings news would tend to be among those firms whose scaled cash holdings are at a large distance below target.

Tables 7-9 present the performance of independently double sorted portfolios on CAR and three different measures of DTC. Table **??** reports the results using the average value of DTC over the previous year, Table **??** reports the results using the contemporaneous measure of DTC and Table **??** shows the results of using the value of DTC the month prior to the earnings announcement. The results generally confirm the intuition that CAR is highest among the most constrained firms in terms of liquidity (cash holdings). In all three cases, the average excess returns on the CAR portfolios in the lowest quantile of the respective measure of DTC are positive and statistically significant. The alphas of these portfolios are positive in all three cases and higher than those of the other CAR portfolios. The alpha of the portfolio constructed using the DTC measure of the month before the earnings announcement is around 2% and statistically significant, with a t-stat of 2.38. A possible interpretation of this is that recent information on how constrained a firm is has more predictive power regarding CAR. In other words, the response to earnings news is highest among the most constrained firms, whereby more recent information on DTC seems to be more relevant.

Table VII. This table reports the performance of the 25 portfolios constructed based on double sorts on CAR and the average of the relative distance from target scaled cash holdings over the past year, the excess returns on the high-low portfolios formed for each type of sort as well as the results of the regressions of the excess returns on the latter on the Fama-French five factors and momentum.

	Cash quintiles					Cash strategies							
	Low	2	3	4	High	r^e	α	β_{mkt}	β_{smb}	β_{hml}	β_{rmw}	β_{cma}	β_{mom}
CAR quintiles													
Low	0.11	1.12	0.65	0.91	1.03	1.31	1.05	-0.07	0.33	0.12	0.05	-0.69	-0.03
						(2.97)	(2.22)	(-0.63)	(1.95)	(0.54)	(0.22)	(-2.09)	(-0.24)
2	0.72	0.97	1.02	0.97	1.03	0.33	-0.09	-0.02	0.03	-0.00	-0.26	0.13	0.14
						(1.16)	(-0.29)	(-0.27)	(0.25)	(-0.00)	(-1.86)	(0.58)	(1.95)
3	0.91	0.88	1.00	1.19	1.13	0.16	-0.40	0.03	0.03	0.10	0.32	0.12	0.00
						(0.57)	(-1.33)	(0.47)	(0.24)	(0.72)	(2.29)	(0.58)	(0.06)
4	1.39	1.33	1.38	1.19	1.20	-0.21	-0.66	0.04	-0.12	0.33	-0.04	-0.35	0.14
						(-0.73)	(-2.16)	(0.50)	(-1.08)	(2.30)	(-0.30)	(-1.63)	(2.00)
High	1.43	1.29	1.35	1.64	1.31	-0.03	-0.52	0.16	-0.40	-0.19	-0.20	0.38	0.18
						(-0.07)	(-1.33)	(1.73)	(-2.73)	(-1.03)	(-1.09)	(1.36)	(2.06)
CAR strategies													
r^e	1.32	0.14	0.88	0.30	0.24								
	(2.54)	(0.43)	(2.76)	(0.74)	(0.63)								
α	0.94	-0.20	0.39	-0.15	-0.26								
	(1.69)	(-0.56)	(1.14)	(-0.36)	(-0.62)								
β_{mkt}	-0.16	-0.08	-0.07	-0.15	0.09								
	(-1.20)	(-0.93)	(-0.82)	(-1.48)	(0.92)								
β_{smb}	0.59	0.09	0.31	-0.05	-0.14								
	(2.86)	(0.70)	(2.51)	(-0.31)	(-0.94)								
β_{hml}	-0.18	-0.31	-0.11	0.24	-0.22								
	(-0.66)	(-1.84)	(-0.68)	(1.16)	(-1.10)								
β_{rmw}	0.28	-0.04	0.28	0.38	-0.11								
	(1.08)	(-0.24)	(1.77)	(1.92)	(-0.57)								
β_{cma}	-0.26	0.26	0.09	-0.07	0.44								
	(-0.67)	(1.04)	(0.35)	(-0.24)	(1.51)								
β_{mom}	0.00	0.03	0.00	-0.00	0.11								
	(0.03)	(0.36)	(0.00)	(-0.01)	(1.13)								

Table VIII. This table reports the performance of the 25 portfolios constructed based on double sorts on CAR and the relative distance from target scaled cash holdings, the excess returns on the high-low portfolios formed for each type of sort as well as the results of the regressions of the excess returns on the latter on the Fama-French five factors and momentum.

	Cash quintiles					Cash strategies							
	Low	2	3	4	High	r^e	α	β_{mkt}	β_{smb}	β_{hml}	β_{rmw}	β_{cma}	β_{mom}
CAR quintiles													
Low	0.18	0.76	0.63	0.72	1.27	1.55	1.42	0.01	0.15	-0.19	0.05	-0.41	-0.21
						(3.89)	(3.36)	(0.08)	(1.00)	(-0.91)	(0.25)	(-1.37)	(-2.18)
2	0.84	0.78	1.01	1.23	1.33	0.51	0.11	-0.05	0.09	0.13	-0.12	-0.37	0.19
						(1.41)	(0.29)	(-0.53)	(0.63)	(0.72)	(-0.68)	(-1.35)	(2.14)
3	1.00	0.77	0.92	0.93	1.25	0.23	-0.12	-0.00	-0.15	0.01	-0.02	0.03	-0.01
						(0.79)	(-0.38)	(-0.06)	(-1.39)	(0.07)	(-0.11)	(0.12)	(-0.10)
4	1.35	1.48	1.23	1.03	1.34	0.00	-0.61	0.14	-0.06	-0.08	0.08	0.31	0.08
						(0.01)	(-1.89)	(1.82)	(-0.52)	(-0.54)	(0.53)	(1.36)	(1.09)
High	1.35	1.39	1.28	1.54	1.39	0.06	-0.45	0.09	-0.17	-0.09	-0.19	0.35	0.15
						(0.18)	(-1.25)	(1.09)	(-1.30)	(-0.49)	(-1.13)	(1.37)	(1.80)
CAR strategies													
r^e	1.24	0.55	0.66	0.27	0.10								
	(2.63)	(1.54)	(2.18)	(0.80)	(0.24)								
α	0.83	0.19	0.28	-0.16	-0.53								
	(1.64)	(0.48)	(0.87)	(-0.44)	(-1.24)								
β_{mkt}	-0.04	-0.16	-0.06	-0.06	0.06								
	(-0.36)	(-1.71)	(-0.72)	(-0.69)	(0.61)								
β_{smb}	0.24	0.16	0.08	-0.08	-0.08								
	(1.33)	(1.18)	(0.70)	(-0.67)	(-0.54)								
β_{hml}	-0.39	-0.07	-0.05	0.15	-0.00								
	(-1.61)	(-0.36)	(-0.29)	(0.89)	(-0.01)								
β_{rmw}	0.26	-0.06	-0.12	-0.03	-0.10								
	(1.09)	(-0.36)	(-0.77)	(-0.18)	(-0.51)								
β_{cma}	0.20	-0.00	0.09	0.01	0.52								
	(0.55)	(-0.00)	(0.40)	(0.04)	(1.71)								
β_{mom}	-0.03	0.16	0.05	0.09	0.17								
	(-0.27)	(1.82)	(0.61)	(1.13)	(1.74)								

Table IX. This table reports the performance of the 25 portfolios constructed based on double sorts on CAR and the relative distance from target scaled cash holdings, two months before portfolio formation, the excess returns on the high-low portfolios formed for each type of sort as well as the results of the regressions of the excess returns on the latter on the Fama-French five factors and momentum.

	Cash quintiles					Cash strategies							
	Low	2	3	4	High	r^e	α	β_{mkt}	β_{smb}	β_{hml}	β_{rmw}	β_{cma}	β_{mom}
CAR quintiles													
Low	-0.13	1.26	-0.00	0.57	1.04	1.08	0.57	-0.06	0.27	-0.49	0.64	0.64	-0.25
						(1.22)	(0.61)	(-0.26)	(0.82)	(-1.09)	(1.48)	(0.99)	(-1.21)
2	1.06	0.49	-0.05	1.00	1.20	0.09	-0.95	0.33	-0.10	0.22	0.34	0.84	0.04
						(0.14)	(-1.40)	(2.12)	(-0.42)	(0.70)	(1.06)	(1.83)	(0.30)
3	1.14	1.11	1.39	1.30	1.34	0.16	-0.01	0.02	-0.14	0.52	-0.50	-0.63	0.13
						(0.25)	(-0.02)	(0.11)	(-0.59)	(1.58)	(-1.61)	(-1.34)	(0.83)
4	1.51	1.17	1.28	0.85	1.38	0.04	-0.16	-0.23	-0.22	-0.16	-0.02	-0.63	0.30
						(0.06)	(-0.24)	(-1.43)	(-0.94)	(-0.53)	(-0.05)	(-1.38)	(1.97)
High	2.44	2.44	2.01	1.94	2.17	-0.69	-1.14	-0.25	0.94	0.46	0.46	-1.05	0.15
						(-0.87)	(-1.37)	(-1.27)	(3.34)	(1.19)	(1.27)	(-1.81)	(0.84)
CAR strategies													
r^e	2.53	1.04	1.71	0.28	0.53								
	(3.20)	(1.36)	(2.40)	(0.44)	(0.62)								
α	1.99	0.32	1.49	-0.16	0.01								
	(2.38)	(0.40)	(1.99)	(-0.25)	(0.01)								
β_{mkt}	-0.19	0.21	-0.16	-0.26	0.06								
	(-0.93)	(1.11)	(-0.92)	(-1.67)	(0.29)								
β_{smb}	0.39	-0.14	0.24	0.51	0.44								
	(1.36)	(-0.49)	(0.95)	(2.15)	(1.40)								
β_{hml}	-0.92	-0.85	-0.48	-1.20	0.28								
	(-2.41)	(-2.14)	(-1.35)	(-3.77)	(0.66)								
β_{rmw}	0.49	-0.12	-0.09	0.13	-0.05								
	(1.28)	(-0.35)	(-0.25)	(0.43)	(-0.12)								
β_{cma}	1.58	1.64	0.38	1.50	-0.05								
	(2.71)	(2.80)	(0.67)	(3.24)	(-0.08)								
β_{mom}	-0.25	-0.12	0.30	0.08	0.06								
	(-1.34)	(-0.69)	(1.75)	(0.54)	(0.32)								

VI. Conclusion

A dynamic model of corporate financial policies that accounts for exposure to both short-term and permanent shocks to earnings, augmented by a stochastic discount factor that prices both sources of risk, provides a possible mechanism that explains how price momentum is linked to earnings momentum in the cross-section of stock returns. Expected returns in the model are time-varying and this time variation comes from changes in productivity-scaled cash holdings. These changes are driven by earnings shocks, which are related to both short-term and permanent aggregate sources of risk. The sensitivity to short-term risk is convex with respect to changes in scaled cash holdings when the firm is cash constrained. The effects of the two types of earnings shocks also differ depending on the distance from target cash holdings. Momentum arises from the combined effect of the convexity of the short-term beta and the dynamics of scaled-cash holdings of constrained firms. Momentum strategies constructed on simulated data based on the model yield returns that average 2% per month with test statistics greater than 4.5.

The model predictions are generally supported by empirical tests. These show that momentum is concentrated among stocks whose cash holdings are below target. Momentum strategies also yield significant alphas only among the quintiles where the ratio of the volatilities of short-term shocks and permanent shocks is highest. All else equal, firms where this ratio of volatilities is higher will have larger responses to short-term shocks when scaled cash holdings fall below target.

Due to the convexity of the short-term beta when the firm becomes constrained, responses to earnings shocks will be large. This is intuitive, since when a firm is close to liquidation short-term shocks could drive it out of business regardless of its long-term prospects. The combined effect of this convexity with the dependence of the dynamics of productivity-scaled cash holdings on the level of cash holdings when below target, could explain the high cumulative abnormal returns surrounding earnings announcement dates. For instance, CAR could (partly) be a compensation for the higher liquidation risk of the constrained firms. In other words, CAR may not necessarily be related to news, but rather to the short-term beta of the constrained companies. Double sorts on CAR strategies and the relative distance from target cash generally support this intuition.

The implications of the theoretical model and the results of the empirical tests are in line with the finding of Avramov (2005) that momentum is concentrated in high credit risk stocks. Deteriorating credit market conditions would be associated with lower cash holdings (in the short term), as shown by Acharaya and Davydenko (2012). This in turn increases the short-term liquidation risk of the company and the impact would be expected to be highest among the companies with the lowest credit ratings.

The evidence supporting the model predictions highlights the role of firm's financial policies in explaining stock risk premia. These models can provide new insights with regards to predictability of stock returns. Linking liquidation risk to both earnings momentum and price momentum supports the Fama and French (1992) conjecture that cross-sectional regularities in stock returns are related to financial distress.

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VII. Appendix 1

Proofs: Given that $F'(c) > 1$ when $c \in (o, c*)$ and $F(c) > 0$, their ratio $\frac{F'(c)}{F(c)} > 0$. This is equivalent to short-term risk exposure having a positive price. To see that this is a decreasing function, one can look at the sign of the first derivative of the transitory beta:

$$\left(\frac{F'(c)}{F(c)}\right)' = \frac{F(c)F''(c) - [F'(c)]^2}{[F(c)]^2}$$

Since $F(c)$ is increasing and concave, $F''(c)$ will be negative, making the above ratio negative as well. The sign of the permanent beta is not constrained, although it is most likely to be positive (since the average level of scaled cash holdings is typically below 0.2, and the short term beta is unlikely to be greater than 5, thus making the permanent beta more likely to be positive but less than 1. The sign of its first derivative with respect to scaled cash holdings is also unconstrained.

VIII. Appendix 2

A. *Covariance in cumulative and expected excess returns*

Since the expected value will be given by the drift terms of the respective processes ($dCER_t$ and $dEER_t$), the remaining terms from the differences in the expression for the covariance will include only the random terms of each. Hence,

$$CER_{t+dt} - \mathbb{E}_t(CER_{t+dt}) = f_1(c)\sigma_T dW_t^T + (1 - c\, f_1(c))\sigma_P dW_t^P \tag{1}$$

To compute $EER_{t+dt} - \mathbb{E}_t(EER_{t+dt})$ we need the dynamics of $dEER_t$ which can be found by Ito's lemma. The random part of the $dEER_t(c)$ process will be given by:

$$\left[\chi_P\sigma_P\eta_P f_1(c) - (\chi_T\sigma_T\eta_T - C_t\chi_P\sigma_P\eta_P)f_1'(c)\right]\left(C_t\sigma_P dW_t^P - \sigma_T dW_t^T\right)$$

The instantaneous variance of the EER_t process will then be given by:

$$\left[\chi_P\sigma_P\eta_P f_1(c) - (\chi_T\sigma_T\eta_T - C_t\chi_P\sigma_P\eta_P)f_1'(c)\right]^2\left(C_t^2\sigma_P^2 + \sigma_T^2 - 2\rho\sigma_P\sigma_T C_t\right)$$

Based on the above expression, the variance of expected excess returns would be higher, all else equal, for firms whose permanent and transitory shocks to cash flows are negatively correlated. This is consistent with the fact that the variance of scaled cash holdings is higher for such firms.

The instantaneous covariance in (2) will be given by:

$$\begin{aligned}\Gamma(c) = &\left[\chi_P\sigma_P\eta_P\left[f_1(c) + C_t f_1'(c)\right] - \chi_T\sigma_T\eta_T f_1'(c)\right] \\ &\cdot\left[f_1(c)\left(2C_t\sigma_P\sigma_T\rho - \sigma_T^2 - C_t^2\sigma_P^2\right) + C_t\sigma_P^2 - \sigma_P\sigma_T\rho\right]\end{aligned} \tag{2}$$

The term $2C_t\sigma_P\sigma_T\rho - \sigma_T^2 - C_t^2\sigma_P^2$ in the above expression is equal to the negative of the instantaneous variance of the scaled cash holdings, which can be denoted as σ_c^2. Hence, it is possible to re-write (4) as:

$$\begin{aligned}\Gamma(c) = &\left[\chi_P\sigma_P\eta_P\left[f_1(c) + C_t f_1^{'}(c)\right] - \chi_T\sigma_T\eta_T f_1^{'}(c)\right]\\ &\cdot\left[-f_1(c)\sigma_c^2 + C_t\sigma_P^2 - \sigma_P\sigma_T\rho\right]\end{aligned} \tag{3}$$

1. $f_1(c) = \frac{F'(c)}{F(c)}$ will always be positive since $F'(c) \geqslant 1$ and $F(c) > 0$.
2. $f_1'(c) = \frac{F(c)F''(c)-[F'(c)]^2}{[F(c)]^2} < 0$, since $F(c) > 0$ and, because the function $F(c)$ is concave, $F''(c) < 0$.

The expression in (5) can be re-arranged as:

$$\begin{aligned}\chi_T\eta_T\Bigg\{&\frac{\chi_P\eta_P}{\chi_T\eta_T}\left[\sigma_P^3 f_1(c)C_t - \sigma_P\sigma_c^2 C_t f_1(c) f_1'(c)\right] - f_1'(c)\sigma_T\sigma_P^2 C_t\\ &+ \frac{\chi_P\eta_P}{\chi_T\eta_T}\left[-\sigma_P\sigma_c^2[f_1(c)]^2 + \sigma_P^3 C_t^2 f_1'(c)\right] + f_1'(c)f_1(c)\sigma_T\sigma_c^2\\ &+ \frac{\chi_P\eta_P}{\chi_T\eta_T}\left[-f_1(c)\sigma_T\sigma_P^2\rho - \sigma_P^2 C_t f_1'(c)\sigma_T\rho\right] + f_1'(c)\sigma_T^2\sigma_P\rho\Bigg\}\end{aligned} \tag{4}$$

The sign of the first term in equation (7) in the text is most likely equal to -1. This can be seen by examining the expression in the numerator:

$$\begin{aligned}&\chi_P\sigma_P\eta_P\left[f_1(c) + C_t f_1^{'}(c)\right] - \chi_T\sigma_T\eta_T f_1^{'}(c)\\ &= \chi_P\sigma_P\eta_P f_1(c) + \left[\chi_P\sigma_P\eta_P C_t - \chi_T\sigma_T\eta_T\right] f_1^{'}(c)\end{aligned}$$

The first term should normally be negative since χ_P would usually be expected to be negative [4], while $f_1(c)$ is always positive (as shown above). The second term is also more likely to be negative since $f_1^{'}(c)$ is always negative while the expression in the brackets would normally be expected to be positive. The latter would be due to the fact that scaled cash holdings, C_t, would usually be below 1, making the first term, which would normally be negative, more likely to be smaller in absolute value than the second term in the bracket (also more likely to be negative). The difference of the two would thus be expected to be positive. The product of this difference with $f_1^{'}(c)$ would therefore normally be expected to be negative. As a result, the whole expression above would be expected to be negative in most cases. This would, therefore, lead to the first term on the right hand side of (7) in the first line being more likely to be equal to -1.

[4] This is assuming positive market prices of short-term and long-term risks. η_T and η_P can be interpreted as the volatilities of short-term and long-term shocks to the pricing kernel, respectively.

B. Corner cases for the correlation between cash-flow shocks

Some intuition can be gained about the effect of the correlation in cash flow shocks by looking at extreme cases. When the cash-flow shocks are perfectly positively correlated, it is very likely that past cumulative and expected returns are also perfectly positively correlated. The variance of profitability-scaled cash holdings in this case is given by:

$$\begin{aligned}
\sigma_c^2 &= C_t^2\sigma_P^2 + \sigma_T^2 - 2C_t\sigma_P\sigma_T\rho \\
&= C_t^2\sigma_P^2 + \sigma_T^2 - 2C_t\sigma_P\sigma_T \\
&= (C_t\sigma_P - \sigma_T)^2
\end{aligned}$$

Substituting the above in Equation (??), the correlation between cumulative and expected excess returns will be given by:

$$\begin{aligned}
\Upsilon(c) &= \frac{f_1(c)\,(C_t\sigma_P - \sigma_T)^2 - C_t\sigma_P^2 + \sigma_P\sigma_T}{\sqrt{(C_t\sigma_P - \sigma_T)^2\,(f_1(c)\sigma_T + (1 - c\,f_1(c))\sigma_P)^2}} \\
&= \frac{f_1(c)\,(C_t\sigma_P - \sigma_T)^2 - C_t\sigma_P^2 + \sigma_P\sigma_T}{|\,(C_t\sigma_P - \sigma_T)\,(f_1(c)\sigma_T + (1 - c\,f_1(c))\sigma_P)\,|} \\
&= \frac{f_1(c)\,(C_t\sigma_P - \sigma_T)^2 - C_t\sigma_P^2 + \sigma_P\sigma_T}{|f_1(c)C_t\sigma_T\sigma_P + C_t\sigma_P^2 - f_1(c)C_t^2\sigma_P^2 - f_1(c)\sigma_T^2 - \sigma_T\sigma_P + f_1(c)C_t\sigma_T\sigma_P|} \\
&= \frac{f_1(c)\,(C_t\sigma_P - \sigma_T)^2 - C_t\sigma_P^2 + \sigma_P\sigma_T}{|f_1(c)\left(2C_t\sigma_T\sigma_P - C_t^2\sigma_P^2 - \sigma_T^2\right) + C_t\sigma_P^2 - \sigma_P\sigma_T|} \\
&= \frac{f_1(c)\,(C_t\sigma_P - \sigma_T)^2 - C_t\sigma_P^2 + \sigma_P\sigma_T}{|-f_1(c)\,(C_t\sigma_P - \sigma_T)^2 + C_t\sigma_P^2 - \sigma_P\sigma_T|} \\
&= \frac{f_1(c)\,(C_t\sigma_P - \sigma_T)^2 - C_t\sigma_P^2 + \sigma_P\sigma_T}{|f_1(c)\,(C_t\sigma_P - \sigma_T)^2 - C_t\sigma_P^2 + \sigma_P\sigma_T|}
\end{aligned}$$

The above expression is most likely to be positive and hence equal to one. However, there could be certain parameter combinations where it may be negative and therefore equal to -1. This is possibly the reason why the average correlation in returns does not always increase when the correlation in shocks is highest (correlations in returns with opposite signs will cancel out). The likelihood of the expression in the numerator being positive is larger for smaller values of the volatility of productivity shocks as well as smaller values of expected growth rates in productivity and cash flows and for larger values of the volatility of transitory shocks.

When the cash-flow shocks are perfectly negatively correlated, the correlation in returns will be given by:

$$\Upsilon(c) = \frac{f_1(c)\,(C_t\sigma_P + \sigma_T)^2 - C_t\sigma_P^2 - \sigma_P\sigma_T}{|f_1(c)\,(C_t\sigma_P + \sigma_T)^2 - C_t\sigma_P^2 - \sigma_P\sigma_T|}$$

The sign of the above expression could vary from $+1$ to -1 depending on the sign of the expression in the numerator. Simulations show that the latter is most likely to be negative. Different parameter combinations, however, especially those that lead to higher correlations in returns, will lead to the ratio being equal to one. This means that perfectly correlated cash flow shocks are associated with perfectly correlated cumulative and expected returns, although the signs of the correlations are not strictly determined.

When the correlation between the cash flow shocks is equal to zero, the correlation in returns is given by:

$$\begin{aligned}
\Upsilon(c) &= \frac{f_1(c)\left(C_t^2\sigma_P^2+\sigma_T^2\right)-C_t\sigma_P^2}{\sqrt{\left(C_t^2\sigma_P^2+\sigma_T^2\right)\left(f_1(c)^2\sigma_T^2+(1-C_tf_1(c))^2\sigma_P^2\right)}} \\
&= \frac{f_1(c)\left(C_t^2\sigma_P^2+\sigma_T^2\right)-C_t\sigma_P^2}{\sqrt{\left(C_t^2\sigma_P^2+\sigma_T^2\right)\left(f_1(c)^2\sigma_T^2+\sigma_P^2-2C_tf_1(c)\sigma_P^2+C_t^2f_1(c)^2\sigma_P^2\right)}} \\
&= \frac{f_1(c)\left(C_t^2\sigma_P^2+\sigma_T^2\right)-C_t\sigma_P^2}{\sqrt{\left(C_t^2\sigma_P^2+\sigma_T^2\right)\left(f_1(c)^2(\sigma_T^2+C_t^2\sigma_P^2)+\sigma_P^2-2C_tf_1(c)\sigma_P^2\right)}} \\
&= \frac{f_1(c)\left(C_t^2\sigma_P^2+\sigma_T^2\right)-C_t\sigma_P^2}{\sqrt{\left(f_1(c)^2(\sigma_T^2+C_t^2\sigma_P^2)^2+\sigma_P^2\left(C_t^2\sigma_P^2+\sigma_T^2\right)-2C_tf_1(c)\sigma_P^2\left(C_t^2\sigma_P^2+\sigma_T^2\right)\right)}} \\
&= \frac{f_1(c)\left(C_t^2\sigma_P^2+\sigma_T^2\right)-C_t\sigma_P^2}{\sqrt{\left(f_1(c)^2(\sigma_T^2+C_t^2\sigma_P^2)^2+C_t^2\sigma_P^4+\sigma_T^2\sigma_P^2-2C_tf_1(c)\sigma_P^2\left(C_t^2\sigma_P^2+\sigma_T^2\right)\right)}} \\
&= \frac{f_1(c)\left(C_t^2\sigma_P^2+\sigma_T^2\right)-C_t\sigma_P^2}{\sqrt{\left(f_1(c)\left(C_t^2\sigma_P^2+\sigma_T^2\right)-C_t\sigma_P^2\right)^2+\sigma_T^2\sigma_P^2}}
\end{aligned}$$

The value of this correlation coefficient can vary anywhere in between $]-1,1[$, and the sign will depend on the combination of the other model parameters.

C. Corner cases for the volatilities of permanent and short-term shocks

$\sigma_P = 0$: In this case the instantaneous correlation between cumulative and expected excess returns will be equal to 1. Because $\sigma_c^2 = \sigma_T^2$:

$$\Upsilon(c) = \frac{f_1(c)\sigma_T^2}{\sqrt{\sigma_T^2([f_1(c)]^2\sigma_T^2)}} = 1$$

$\sigma_T = 0$: In this case the instantaneous correlation between cumulative and expected excess returns will be equal to -1. Because $\sigma_c^2 = C_t^2\sigma_P^2$:

$$\begin{aligned}\Upsilon(c) &= \frac{f_1(c)C_t^2\sigma_P^2 - C_t\sigma_P^2}{\sqrt{C_t^2\sigma_P^2([1 - C_t f_1(c)]^2\sigma_P^2)}} \\ &= \frac{f_1(c)C_t^2\sigma_P^2 - C_t\sigma_P^2}{|C_t\sigma_P^2(1 - C_t f_1(c))|} \\ &= \frac{f_1(c)C_t^2\sigma_P^2 - C_t\sigma_P^2}{|f_1(c)C_t^2\sigma_P^2 - C_t\sigma_P^2|} \\ &= -1\end{aligned}$$

The expression in the numerator is more likely to be negative and hence the ratio more likely to be equal to -1, since both $f(c)$ and C_t are usually less than 0.5.

IX. Appendix 3

Table X. Spearman rank correlation coefficients between independent variables. This table presents the time-series averages of cross-sectional Spearman rank correlations between pairs of the variables. The sample covers the period from January 1975 to December 2016.

	SUE	CAR	DTC	DTC^-	GP/A	ME	B/M	$r_{1,0}$	$r_{12,2}$
SUE		0.18	0.01	-0.01	-0.05	0.00	0.05	0.15	0.14
CAR			0.01	0.01	0.02	0.02	0.01	0.43	0.05
DTC				1	0.00	0.00	-0.003	0.01	0.04
DTC^-					0.05	0.07	-0.02	0.02	0.07
GP/A						-0.04	-0.16	0.03	0.07
ME							-0.27	0.05	0.07
B/M								0.02	0.03
$r_{1,0}$									0.04